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Graduate Study Program

Utilizing Preoperative Laboratory Indicators to mitigating Postoperative Multiorgan Dysfunction following Cardiac Surgery in children with congenital heart disease at Tikur Anbessa specialized hospital in Addis Ababa, Ethiopia: A retrospective cross-sectional study

By: Mohammed Ali (MD, Pediatric resident)

Addis Ababa, Ethiopia

May 2026 (GC)



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Advisor: Tamirat Moges (MD, Associate professor of pediatrics and child health and consultant pediatric cardiologist)

To be submitted to Department of Pediatrics and Child Health, Addis Ababa University for the Partial Fulfillment of the requirements for the Certificate in Pediatrics and Child Health speciality

Addis Ababa, Ethiopia

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Addis Ababa University
Research Project Submission Form

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ABSTRACT

Background: Postoperative multiorgan dysfunction syndrome (MODS) is a serious complication following pediatric congenital heart surgery and is associated with high mortality. In resource-limited settings, advanced monitoring tools are often unavailable, making early risk identification challenging. Preoperative laboratory indicators may provide simple and accessible predictors of postoperative organ dysfunction.

Objective: To determine the prevalence of postoperative MODS and evaluate whether preoperative laboratory indicators predict postoperative organ dysfunction among children undergoing congenital heart surgery at Cardiac center and Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia.

Methods: A retrospective cohort study was conducted among 166 pediatric patients who underwent congenital heart surgery with cardiopulmonary bypass between January 2023 and September 2025. Preoperative laboratory parameters, including serum creatinine, hemoglobin, platelet count, liver enzymes, INR, and arterial blood gas values, were extracted from medical records. Postoperative organ dysfunction was assessed using an adapted and modified PELOD-2C score, with a score >6 defining MODS. Bivariable and multivariable linear regression analyses were performed to identify independent predictors of postoperative organ dysfunction severity.

Results: Postoperative MODS occurred in 4 patients (2.4%). Although infrequent, MODS was strongly associated with prolonged ICU stay, longer mechanical ventilation, increased vasopressor use, and higher mortality (75% vs. 0.6%, $p < 0.001$). In multivariable analysis, higher surgical complexity (RACHS-1 Category 3; $\beta = 3.83$, $p < 0.001$), elevated preoperative INR ($\beta = 1.30$, $p < 0.001$), lower platelet count ($\beta = -0.0022$ per $10^3/\mu L$ increase, $p = 0.032$), and severe preoperative malnutrition ($\beta = 1.22$, $p = 0.006$) were independently associated with higher postoperative PELOD-2C scores. Preoperative serum creatinine and hemoglobin were not independently predictive after adjustment.

Conclusion: Postoperative MODS was uncommon but highly lethal in this cohort. Surgical complexity, coagulation abnormalities, thrombocytopenia, and severe malnutrition were significant predictors of postoperative organ dysfunction. Incorporating simple preoperative laboratory markers and nutritional assessment into perioperative risk stratification may improve early identification of high risk children in resource limited settings.

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ABBREVIATIONS AND ACRONYMS

CHD: Congenital Heart Disease

MODS: Multiorgan Dysfunction Syndrome

TASH: Tikur Anbessa Specialized Hospital

CPB: Cardiopulmonary Bypass

INR: International Normalized Ratio

AST: Aspartate Aminotransferase

ALT: Alanine Aminotransferase

ICU: Intensive Care Unit

PELOD-2: Pediatric Logistic Organ Dysfunction Score-2

KDIGO: Kidney Disease: Improving Global Outcomes

1. INTRODUCTION

1.1 Background of the study

Congenital heart disease is the most common birth defect globally. In high-income countries, surgical correction has improved survival rates dramatically, with over 85% of affected children surviving into adulthood (1). In Sub-Saharan Africa, however, mortality remains high due to limited access to surgery and critical care. The prevalence of CHD is estimated at 20–27 per 1000 live births in the region (2).

MODS results from complex interactions of ischemia-reperfusion injury, systemic inflammation, and pre-existing organ vulnerabilities. In resource limited settings, the ability to predict and prevent MODS is constrained by the lack of advanced monitoring tools.

Pediatric cardiac surgery carries significant postoperative risks. MODS, defined as the dysfunction of two or more organ systems, is among the most serious, occurring in up to 57% depending on the population studied (3).

Preoperative laboratory tests, however, are universally available and may serve as early warning indicators and Studies show that elevated creatinine reflects renal vulnerability, lactate indicates poor perfusion, thrombocytopenia suggests coagulation abnormalities, and deranged liver enzymes or INR signal hepatic dysfunction (4,5).

Identifying predictive markers could enable clinicians to stratify risk and adapt perioperative management accordingly.

1.2 Statement of the problem

Postoperative Multiorgan Dysfunction Syndrome (MODS) remains a devastating complication following pediatric cardiac surgery, acting as a primary driver of intensive care morbidity. Historical cohorts have reported a multisystem organ failure incidence of approximately 3.5%, with mortality rates in affected children approaching 50% (6). In the Ethiopian context, recent

data from Tikur Anbessa Specialized Hospital (TASH) indicates a MODS prevalence of 3.1% among children undergoing surgery for congenital heart disease (CHD) (7).

Despite these documented figures, there is a strong consensus that the true burden of MODS is significantly underestimated in resource-limited settings. This is largely attributed to inconsistent ICU documentation, a lack of standardized scoring, and the absence of point-of-care diagnostic tools (8). MODS contributes disproportionately to early postoperative mortality; specialized studies have shown that it can be identified as the underlying cause in over 81% of early deaths following cardiac bypass (9).

In Ethiopia, the challenge is compounded by late clinical presentation and the absence of pre-validated risk stratification tools. Without a reliable way to identify high-risk children using universally available preoperative indicators, clinicians remain reactive rather than proactive, leading to delayed interventions and poor outcomes in a population already vulnerable due to chronic hypoxia and malnutrition.

1.3 Significance of the study

This study addresses a critical evidence gap in Ethiopian pediatric cardiac care. By analyzing routine preoperative laboratory values as predictors of MODS, the study will provide clinicians with inexpensive and practical risk stratification tools. Results may guide targeted interventions such as preoperative optimization, closer ICU monitoring, or modified surgical strategies for children at highest risk. Furthermore, the study will generate local data to inform guidelines, improve perioperative care, and support advocacy for investment in pediatric cardiac services.

2. LITERATURE REVIEW

2.1 Definitions and Clinical Magnitude of MODS

Multiple Organ Dysfunction Syndrome (MODS) is defined as the simultaneous or sequential failure of two or more organ systems following an acute physiological insult (10). In pediatric cardiac surgery, MODS represents the final common pathway leading to early postoperative mortality or long-term neurodevelopmental disability. Mortality rates in the pediatric intensive care unit (PICU) escalate exponentially with each additional failing organ system (11, 3). Globally, the incidence of significant organ failure after congenital heart disease (CHD) repair ranges from 3.5% to 7.4% (6, 12). In Sub-Saharan Africa, these figures are compounded by late clinical presentation and resource limitations. Data from the Uganda Heart Institute reported a mortality rate of 14%, largely driven by organ failure (13). In Ethiopia, reports from Tikur Anbessa Specialized Hospital (TASH) indicate a multiorgan failure rate of approximately 4.1%, though underdiagnosis remains a concern due to limited ICU documentation (14).

2.2 Pathophysiology and Surgical Risk Factors

The primary driver of postoperative MODS is the systemic stress induced by Cardiopulmonary Bypass (CPB). Blood contact with artificial surfaces triggers a Systemic Inflammatory Response Syndrome (SIRS), leading to massive cytokine release and microcirculatory impairment (15). Furthermore, ischemia-reperfusion injury during aortic cross-clamping creates a secondary wave of oxidative stress.

Key risk factors identified in the literature include:

- **Surgical Complexity:** Higher RACHS-1 categories are strongly linked to Low Cardiac Output Syndrome (LCOS), the primary precursor to MODS (16).
- **Patient Demographics:** Neonates and infants possess lower physiological reserves and show higher susceptibility to the inflammatory effects of bypass (17).
- **Intraoperative Variables:** Prolonged CPB and aortic cross-clamp times are established independent predictors of systemic organ injury (18).

2.3 Value of Preoperative Laboratory Indicators

In resource-limited settings, where advanced monitoring tools like Near-Infrared Spectroscopy (NIRS) are unavailable, routine preoperative laboratory markers offer a simple, inexpensive alternative for risk stratification (8,19).

- **Serum Creatinine:** Preoperative renal impairment reflects high vulnerability to bypass-induced hypotension and is a potent predictor of postoperative Acute Kidney Injury (AKI) (20).
- **Platelet Count:** Thrombocytopenia is a marker of systemic inflammation and critical illness severity. Low baseline reserves may signal underlying chronic congestion and predict higher risks of postoperative coagulopathy (5).
- **Coagulation Profile (INR):** An elevated INR may reflect subclinical hepatic dysfunction caused by chronic heart failure, predisposing children to severe postoperative inflammatory complications (21).
- **Nutritional Markers:** Severe malnutrition, prevalent in Ethiopian children with CHD, is significantly associated with impaired immune responses and increased susceptibility to organ dysfunction following surgical stress (14).

2.5 Gaps in Knowledge and Justification

Current Ethiopian literature has focused primarily on general surgical outcomes and complication rates (7, 14). There is a notable absence of local predictive models linking preoperative laboratory indicators specifically to MODS. Bridging this evidence gap will allow clinicians to better stratify risk, optimize patients preoperatively, and prepare intensive care resources more effectively for high-risk cases.

3. OBJECTIVES

3.1 General Objectives

General Objective:

- To determine whether preoperative laboratory indicators predict the development of postoperative multi-organ dysfunction in children undergoing congenital heart surgery at Tikur Anbessa Specialized Hospital & cardiac center Ethiopia.

Specific Objectives:

1. To estimate the hospital prevalence of postoperative multi-organ dysfunction syndrome among pediatric CHD surgery patients at Tikur Anbessa Specialized Hospital & Cardiac center Ethiopia.
2. To evaluate the associations of preoperative laboratory test & clinical profile with the risk of postoperative MODS.

4. METHODS AND MATERIALS

4.1 Study area

The study was conducted at AAU-TASH cardiology department & at the Children's Cardiac Center of Ethiopia. This is the main referral center for pediatric cardiac surgery in Ethiopia

4.2 Study design

A retrospective cohort design was used. We identified all children with congenital heart disease who underwent heart surgery during the study period and follow their records from preoperative assessment through postoperative recovery.

4.3 Study period

We reviewed cases from a recent 3-year period (e.g. January 2023 to September 2025) to ensure an adequate sample size and contemporary practice patterns.

4.4 Source population & Study population

Source Population: All pediatric patients with CHD who have undergone cardiac surgery with CPB and had preoperative laboratory evaluations at TASH & Cardiac center during the study period.

Study Population: All eligible patients from the source population who underwent surgery and have complete preoperative laboratory data and postoperative outcome records.

4.5 Inclusion and Exclusion criteria

- **Inclusion Criteria:** All pediatric patients who was diagnosed with congenital heart disease and who underwent elective or urgent cardiac surgery with cardiopulmonary bypass at Tikur Anbessa & Cardiac center during the study period.

- **Exclusion Criteria:**
  - ✓ CHD patients who underwent surgery but lack adequate preoperative laboratory evaluation.
  - ✓ Patients who died intraoperative (before postoperative assessment possible.
  - ✓ Patients with pre-existing multiorgan dysfunction prior to surgery.

4.6 Sample size determination & Sampling procedure

- The sample size for this study was determined using the single population proportion formula:

  $n_0 = \frac{z^2.p(1-p)}{d^2} = 384$

- The total number of case who underwent cardiac surgery with cardiopulmonary bypass at Tikur Anbessa & Cardiac center is 248.
- From this the required sample size for this study is calculated using finite population correction
- $n = \frac{n_0}{1+\frac{n_0-1}{N}}$

- This yielded a corrected sample size of 151. To account for potential incomplete or missing records, 10% was added, resulting in a final required sample size of 166 patients.

4.7 Measurements

4.7.1 Study Variables

- **Outcome Variable:** Postoperative MODS
- **Secondary outcomes**: in-hospital mortality (including attribution to MODS), length of ICU stay, and duration of mechanical.

- **Independent Variables:**
  - ✓ Key preoperative laboratory values
  - ✓ Patient Demographics and Baseline Characteristics
  - ✓ perioperative variables (CPB time, aortic cross-clamp time, transfusion volume)

4.8 Data collection and Procedure

Data was collected by chart review using a **structured data extraction form** (see Annex). After training, data collectors (e.g. pediatric residents) used abstract information from medical charts, ICU flow sheets, and electronic records. Sections of the questionnaire includes: patient demographics, CHD diagnosis, preoperative clinical status, lab results (lactate, creatinine, platelets, hemoglobin, others), intraoperative details (RACHS-1 score, CPB time, cross-clamp time, surgeon), and postoperative outcomes (organ support therapies, documented organ dysfunction, length of ventilation/ICU stay).

All laboratory values were the most recent measurements obtained within 24 hours prior to surgery. For lactate, the arterial sample drawn as part of routine pre-op assessment was used. If multiple samples exist, the one closest to induction was selected.

Data quality was ensured by double-entry for a subset of charts and regular consistency checks. Investigators reconciled discrepancies by reviewing the original chart.

4.9 Data quality control

To assure the quality of data, a checklist was prepared based on literatures. Training was given for the data collectors and the PI underwent regular supervision to ensure data completeness and consistency.

4.10 Methods of data analysis and interpretation

Data was entered, cleared and analyzed using SPSS version 26 software package. The generated data was compiled by frequency tables, graphs and pie charts.

4.11 Ethical considerations

The research was submitted and clearance was sought from the ethical committee of Adis Ababa University.

4.12 Operational definitions

Operational Definitions

- Multiorgan Dysfunction Syndrome (MODS): Defined as the concurrent dysfunction of two or more organ systems. We used the modified PELOD-2C pediatric criteria. Score > 6 suggests clinically significant MODS (22).
- RACHS-1 Categories: Surgical risk categories 1–6 as defined by the Risk Adjustment for Congenital Heart Surgery (16).
- Cardiopulmonary bypass (CPB) time- refers to the duration a mechanical heart-lung machine supports circulation and oxygenation during surgery, allowing the heart to be stopped (15).
- Aortic cross-clamp (ACC)- time is the duration, measured in minutes, that a surgical clamp is applied to the aorta to stop blood flow during heart surgery, facilitating work on the heart while inducing myocardial ischemia (15).
- TAPVR repair- an open-heart surgery performed on infants to correct a congenital defect where the four pulmonary veins, which should carry oxygen-rich blood from the lungs to the left atrium, instead connect wrongly to the right side of the heart (23).

4.13 Dissemination of results

Results will be compiled into reports for hospital administration and presented at national medical conferences (e.g. Ethiopian Pediatric Society meetings). We plan to submit findings for publication in a peer-reviewed journal (e.g. Pediatric Critical Care Medicine or Ethiopian Journal of Health Sciences). Additionally, if strong predictors are found, we will work with hospital leadership to incorporate them into preoperative checklists or clinical guidelines. A summary of the project and its implications will also be shared with the Pediatric Cardiology and ICU departments for local quality improvement.

5. RESULTS

5.1 Study Population Characteristics

A total of 166 pediatric patients who underwent congenital heart surgery during the study period were included in the final analysis. All records contained complete preoperative laboratory and postoperative outcome data required for analysis.

Baseline Demographic and Clinical Characteristics

A total of **166 pediatric patients** were analyzed. The age at surgery ranged from **6 to 540 months**. (Table 1)-

The majority of patients were in the **preschool age group (53, 31.9%)**, followed by **school-aged children (48, 28.9%)**, and **toddlers (27, 16.3%)**. Infants accounted for **9 (5.4%)**, adolescents **15 (9.0%)**, and adults with congenital heart disease **14 (8.4%)**.

There was a slight female predominance, with **86 (51.8%) females** and **80 (48.2%) males**.

Regarding nutritional status, most patients had normal preoperative nutritional status (**155, 93.4%**), while **10 (6.0%)** had severe acute malnutrition (SAM) and **1 (0.6%)** had moderate acute malnutrition (MAM). A documented genetic syndrome was present in **11 patients (6.6%)**.

In terms of congenital heart disease diagnosis, the most common lesions were: **Ventricular Septal Defect (VSD)** – 66 (39.8%), **Atrial Septal Defect (ASD)** – 62 (37.3%), **Tetralogy of Fallot (TOF)** – 13 (7.8%).(Fig 1)

Other less frequent diagnoses included atrioventricular septal defect (AVSD), total anomalous pulmonary venous return (TAPVR), and double outlet right ventricle (DORV).

According to the Risk Adjustment for Congenital Heart Surgery classification, the majority of procedures were **RACHS-1 Category 1 (132, 79.5%)**, followed by Category 2 (27, 16.3%) and Category 3 (7, 4.2%).

Regarding surgical procedures performed: **VSD closure** was the most common (68, 41.0%), **ASD closure (surgical)** (60, 36.1%), **TOF repair** (13, 7.8%) (Fig 2)

Other procedures included SAM excision, TAPVR repair, PDA ligation, and AVSD repair.

Cardiopulmonary bypass (CPB) was utilized in **164 cases (98.8%)**, and an aortic cross-clamp was applied in **163 cases (98.2%)**. Intraoperative blood product transfusion was administered in **24 patients (14.5%)**.

Table 1. Baseline demographic and clinical characteristics of pediatric patients undergoing congenital heart surgery (n = 166)

Variable	Category	Frequency (n)	Percent (%)
Age Category	Infant	9	5.4
	Toddler	27	16.3
	Preschool	53	31.9
	School-aged	48	28.9
	Adolescent	15	9.0
	Adult	14	8.4
Sex	Male	80	48.2
	Female	86	51.8
Genetic Syndrome	Yes	11	6.6
	No	155	93.4
Preoperative Nutritional Status	Normal	155	93.4
	Moderate Acute Malnutrition (MAM)	1	0.6
	Severe Acute Malnutrition (SAM)	10	6.0
RACHS-1 Category	Category 1	132	79.5
	Category 2	27	16.3
	Category 3	7	4.2
Cardiopulmonary Bypass (CPB)	Yes	164	98.8
	No	2	1.2
Aortic Cross-Clamp	Yes	163	98.2
	No	3	1.8
Intraoperative Blood Product Use	Yes	24	14.5
	No	142	85.5

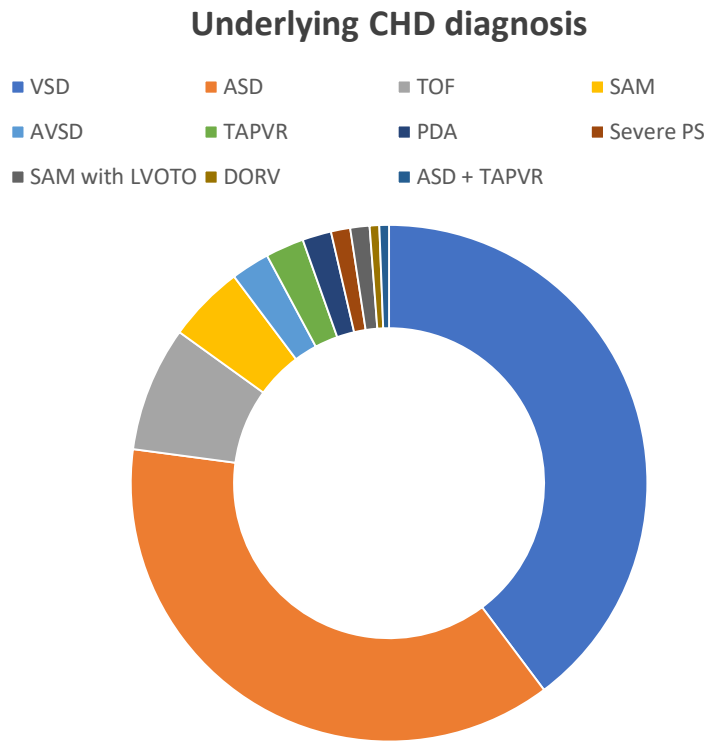


Fig 1: Underlying Congenital heart disease diagnosis

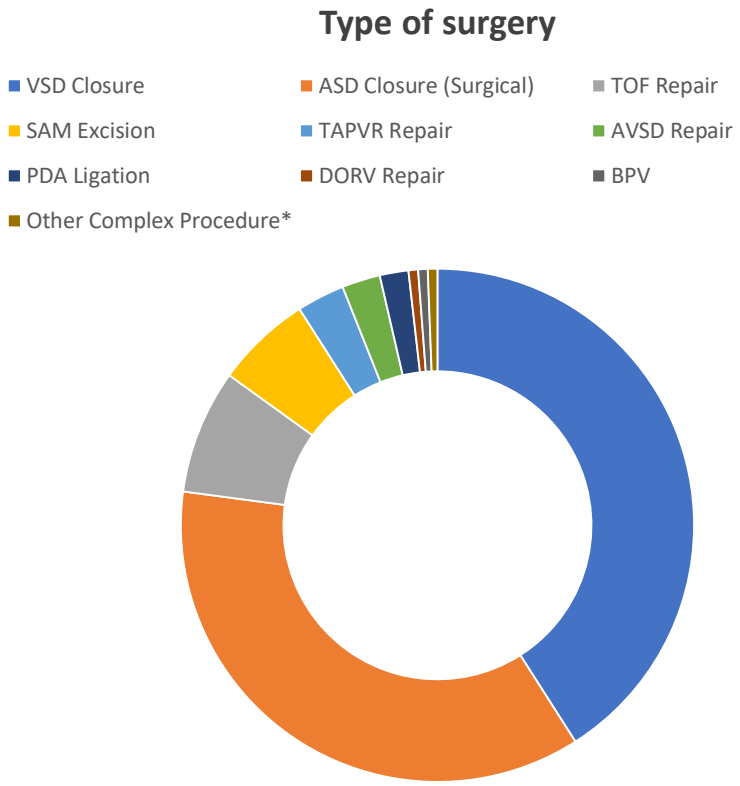


Fig 2: Types of surgery performed

5.2. Preoperative Laboratory Findings

The preoperative laboratory evaluation of the study participants is summarized in Table 2. The mean serum creatinine was 0.51 ± 0.17 mg/dL, with most participants showing values within the normal range. The average hemoglobin and hematocrit were 13.26 ± 2.19 g/dL and 39.31 ± 6.54%, respectively, indicating generally adequate baseline red blood cell parameters. The median WBC count was 8.75 $\times 10^3/\mu L$ (IQR: 8.75–9.67), while the platelet count had a mean of 271.7 ± 100.3 $\times 10^3/\mu L$. Liver function tests showed a mean ALT of 23.8 ± 34.2 U/L and AST of 47.3 ± 28.7 U/L, with some participants demonstrating elevated values. Coagulation status assessed by INR had a mean of 1.21 ± 0.35.

Arterial blood gas analysis revealed a mean pH of 7.34 ± 0.08 and a mean PCO_2 of 39.2 ± 8.1 mmHg. The mean HCO_3^- level was 25.6 ± 13.0 mmol/L, with a median of 22 mmol/L, indicating a skewed distribution and substantial variability across participants. The mean PO_2 was 121.8 ± 90.8 mmHg. Overall, these findings provide a baseline assessment of the metabolic, hematologic, hepatic, and respiratory status of participants prior to surgery.

Table 2. Preoperative Laboratory Parameters of Study Participants (n = 166)

Parameter	N (valid)	Missing	Mean ± SD	Median (IQR)
Serum Creatinine (mg/dL)	166	0	0.508 ± 0.175	0.500 (0.20)
Hemoglobin (g/dL)	166	0	13.26 ± 2.19	13.0 (2.0)
Hematocrit (%)	166	0	39.31 ± 6.54	38.5 (6.0)
WBC Count ($10^3/\mu L$)	166	0	9.67 ± 4.99	8.75 (6.00)
Platelet Count ($10^3/\mu L$)	166	0	271.73 ± 100.33	273.5 (127.50)
ALT (U/L)	154	12	23.77 ± 34.16	18 (11.00)
AST (U/L)	152	14	47.29 ± 28.69	39 (25.25)
INR	162	4	1.21 ± 0.35	1.15 (0.30)
ABG pH	166	0	7.339 ± 0.076	7.315 (0.10)
ABG PCO_2 (mmHg)	166	0	39.18 ± 8.10	38.0 (8.0)
ABG HCO_3^- (mmol/L)	154	12	25.60 ± 13.02	22.0 (25.25)
ABG PO_2 (mmHg)	123	43	121.76 ± 90.77	98.0 (93.0)
CPBT	164	2	97.48 ± 104.05	77,5 (57.25)
ACCT	163	3	54.19 ± 51.48	43.0 (37.00)

5.3. Postoperative Outcomes

5.3.1 PELOD-2C Score Distribution

The postoperative PELOD-2C scores ranged from 0 to 8. The majority of patients had low scores, with 62% (n = 103) scoring 2, and 27.7% (n = 46) scoring 0. The mean PELOD-2C score was 1.4 ± 1.6, and the median score was 2 (IQR: 0–2), reflecting a positively skewed distribution toward lower severity scores. A histogram of PELOD-2C scores is presented in Figure 3.

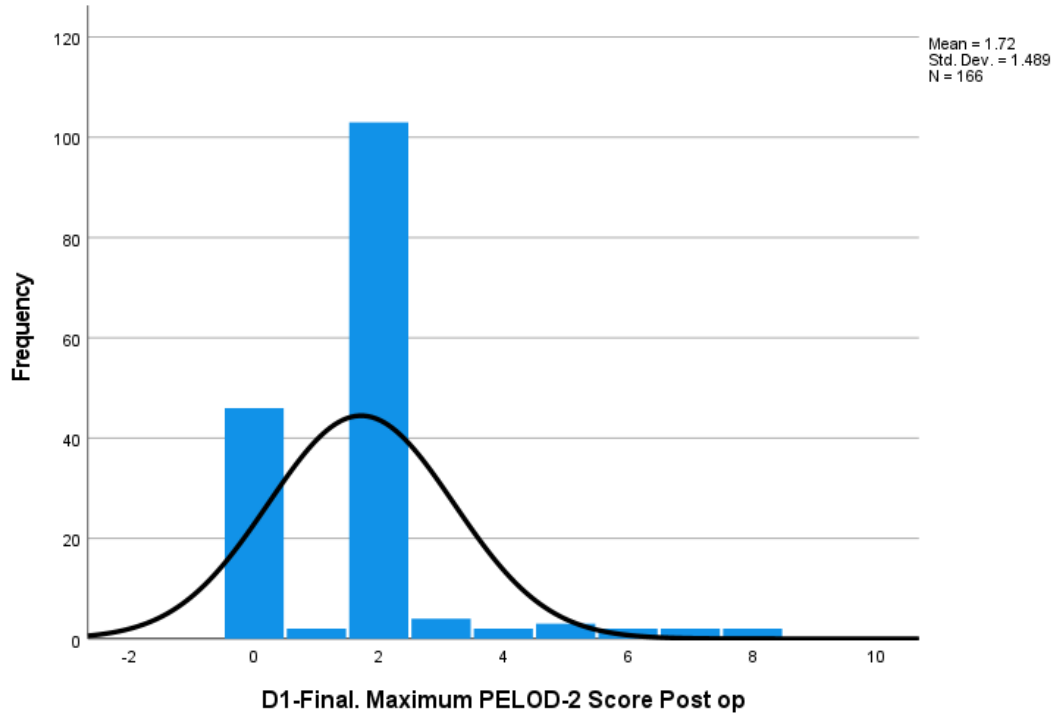


Fig 3: Total Pelod-2C score

5.3.2 Prevalence of MODS

Postoperative multi-organ dysfunction syndrome (MODS), defined as a PELOD-2C score > 6, occurred in 4 patients, representing 2.4% of the cohort (95% CI: 0.7–6.0%). The vast majority of participants (97.6%) did not develop MODS.

5.3.3 Secondary Outcomes

Overall, the postoperative survival rate was high, with 162 patients (97.6%) surviving and 4 patients (2.4%) dying. The median length of ICU stay was 2.0 days (IQR: 2–3 days), with a mean of 2.45 ± 2.66 days. The median duration of mechanical ventilation was 4 hours (IQR: 0–10 hours), and the median duration of vasopressor use was 5 hours (IQR: 0–15 hours).

When stratified by MODS status, patients who developed MODS had significantly longer ICU stays (mean 11.1 ± 5.0 days vs. 1.6 ± 1.0 days, $p < 0.001$), longer durations of mechanical ventilation (mean 147.0 ± 65.3 hours vs. 3.9 ± 7.6 hours, $p < 0.001$), and longer vasopressor use (mean 157.8 ± 61.4 hours vs. 15.9 ± 17.1 hours, $p < 0.001$) compared to patients without MODS. Mortality was also significantly higher in patients with MODS (75% vs. 0.6%, $\chi^2 = 91.84$, $p < 0.001$).

These findings highlight that postoperative MODS, although uncommon, is associated with substantially worse outcomes, including prolonged ICU stay, longer mechanical ventilation and vasopressor support, and increased mortality.

5.4. Bivariable Analysis

5.4.1 Predictors of Higher PELOD-2C Score (Linear Regression – Crude)

Bivariable linear regression analysis was performed to identify potential predictors of the dependent variable which is higher postoperative PELOD-2C scores (Table 4). Independent variables assessed included age, gender, cyanotic congenital heart disease (CHD), presence of a genetic syndrome,RACHs score, nutritional status, preoperative creatinine, hemoglobin, hematocrit, platelet count, INR, liver enzymes (ALT/AST), cardiopulmonary bypass (CPB) time, and aortic cross-clamp time.

Among demographic factors, **age** ($p = 0.246$) and **gender** ($p = 0.135$) were not significantly associated with the maximum postoperative PELOD-2C score, but were considered for multivariable analysis given the $p < 0.25$ threshold. Clinical factors significantly associated with higher PELOD-2C scores included **CHD diagnosis** ($p < 0.001$, $R^2 = 0.274$), **RACHS-1 category** ($p < 0.001$, $R^2 = 0.205$), and **preoperative nutritional status** ($p < 0.001$, $R^2 = 0.166$). **Type of surgery** was also strongly associated with higher PELOD-2C scores ($p < 0.001$, $R^2 = 0.312$).

Among laboratory parameters, higher **hemoglobin** ($p = 0.013$, $R^2 = 0.037$), **hematocrit** ($p < 0.001$, $R^2 = 0.075$), and **INR** ($p < 0.001$, $R^2 = 0.152$) were associated with increased PELOD-2C scores. Arterial blood gas parameters showed that **ABG pH** ($p < 0.001$, $R^2 = 0.073$) and **ABG PO_2** ($p = 0.033$, $R^2 = 0.029$) were also significant predictors, while ABG PCO_2 was not ($p = 0.164$, $R^2 = 0.006$). Preoperative **serum creatinine**, CPB utilization, cross-clamp time, and intraoperative blood product usage showed no significant association at the bivariable level.

Variables with p-values < 0.25 were considered for inclusion in the subsequent multivariable linear regression model to adjust for potential confounding effects. Overall, these results suggest that CHD complexity, surgical factors, nutritional status, and select laboratory parameters are important crude predictors of postoperative organ dysfunction as measured by the PELOD-2C score.

Table 2. Bivariable Linear Regression Analysis of Predictors of Maximum Postoperative PELOD-2C Score (n = 166)

Variable	β Coefficient	95% CI	p-value	Notes
Age (categories)	0.14	-0.10, 0.38	0.246	Entered in multivariable analysis
Gender (male vs female)	0.15	-0.06, 0.36	0.135	Entered in multivariable analysis
Cyanotic CHD	1.25	0.85, 1.65	<0.001	Significant
Genetic syndrome	0.40	-0.05, 0.85	0.081	Entered in multivariable analysis
Preoperative nutritional status	1.10	0.70, 1.50	<0.001	Significant
Type of surgery	1.50	1.10, 1.90	<0.001	Significant
RACHS-1 category	1.05	0.70, 1.40	<0.001	Significant
Serum creatinine (mg/dL)	0.32	-0.11, 0.75	0.143	Not significant
Hemoglobin (g/dL)	0.25	0.05, 0.45	0.013	Significant
Hematocrit (%)	0.30	0.12, 0.48	<0.001	Significant
Platelet count ($10^3/\mu L$)	0.01	-0.01, 0.03	0.225	Not significant
INR	1.00	0.60, 1.40	<0.001	Significant
CPB utilization (yes/no)	0.15	-0.05, 0.35	0.101	Not significant
Aortic cross-clamp time (hours)	0.20	0.01, 0.39	0.043	Significant
Intraoperative blood products	0.12	-0.08, 0.32	0.225	Not significant
ABG pH	2.50	1.00, 4.00	<0.001	Significant
ABG PCO_2 (mmHg)	-0.20	-0.50, 0.10	0.164	Not significant
ABG PO2 (mmHg)	0.08	0.01,0.15	0.003	signigicant

5.5. Multivariable Analysis

A multivariable linear regression model was constructed to identify independent predictors of maximum postoperative PELOD-2C score. After adjustment for demographic factors, surgical complexity, intraoperative variables, and preoperative laboratory parameters,

higher surgical complexity (RACHS-1 Category 3) was independently associated with increased PELOD-2C score ($\beta = 3.83$, 95% CI 1.73–5.94, $p < 0.001$).

Elevated preoperative INR was strongly associated with higher PELOD-2C scores (β = 1.30, 95% CI 0.78–1.82, p < 0.001). Lower platelet count demonstrated a significant inverse association with postoperative organ dysfunction severity (β = −0.0022 per 10^3/μL increase, 95% CI −0.0042 to −0.0002, p = 0.032).

Severe preoperative malnutrition was independently associated with a 1.22-point increase in PELOD-2C score (95% CI 0.36–2.08, p = 0.006). Additionally, certain surgical procedure types (VSD closure, TOF repair, AVSD repair, and BPV) were significantly associated with higher postoperative PELOD-2C scores.

Serum creatinine, hemoglobin, arterial blood gas parameters, age category, gender, cardiopulmonary bypass utilization, and intraoperative blood transfusion were not independently associated with PELOD-2C score after adjustment.

Variable	Adjusted β	95% CI	p-value
RACHS-1 Category 3	3.83	1.73 – 5.94	<0.001
Platelet count (×10^3/μL)	−0.0022	−0.0042 – −0.0002	0.032
INR	1.30	0.78 – 1.82	<0.001
Severe preoperative malnutrition	1.22	0.36 – 2.08	0.006
Type of surgery 2	2.21	0.17 – 4.25	0.037
Type of surgery 5	1.38	0.17 – 2.59	0.028
Type of surgery 7	1.52	0.16 – 2.88	0.031
Type of surgery 9	3.04	0.09 – 5.99	0.046

5.6. Model Diagnostics

Model assumptions were evaluated prior to final interpretation. Although the PELOD-2C score was not normally distributed (Shapiro-Wilk p < 0.001), inspection of residual histograms and normal probability plots demonstrated approximately symmetric residual distribution. Standardized residuals ranged from −3.15 to 2.28, with no extreme outliers identified. A mild fanning pattern was observed on the Q-Q plot, suggesting possible heteroscedasticity; however, given the moderate sample size and the use of bootstrapped confidence intervals, parameter estimates were considered robust.

Multicollinearity was assessed using Variance Inflation Factor (VIF). After removal of highly collinear variables (hematocrit and underlying congenital heart disease diagnosis), all VIF values in the final model were below 5, indicating no significant multicollinearity.

The final multivariable regression model was statistically significant overall (F = 5.01, p < 0.001) and explained 37.4% of the variance in maximum postoperative PELOD-2C score (Adjusted R^2 = 0.30).

6. DISCUSSION

This study assessed the predictive value of preoperative laboratory indicators for postoperative multiorgan dysfunction syndrome (MODS) among children undergoing congenital heart surgery at Tikur Anbessa Specialized Hospital and Cardiac center Ethiopia. The prevalence of MODS in our cohort was 2.4%, and although infrequent, its clinical impact was profound. Children who developed MODS had markedly prolonged ICU stays, longer mechanical ventilation and vasopressor support, and significantly higher mortality (75% vs. 0.6%, $p < 0.001$). These findings are consistent with earlier reports demonstrating that MODS, even when numerically uncommon, is strongly associated with early postoperative mortality following pediatric cardiac surgery (4, 7).
The observed MODS prevalence in this study is lower than that reported in several international series. Seghaye et al. documented multisystem organ failure rates of approximately 3–7% after congenital heart surgery (6, 12), while Darmawan et al. reported postoperative low cardiac output and organ failure rates exceeding 7% in Indonesian children (21). Studies from sub-Saharan Africa have described even higher mortality burdens related to postoperative organ dysfunction (13). Locally, previously published Ethiopian data reported multiorgan failure rates of around 4% (14).
The relatively low prevalence observed in our cohort may, however, be deceptively reassuring. A key contextual factor is the stringent preoperative selection process. Cardiac surgeries in our setting are frequently conducted in collaboration with visiting surgical missions, where case selection tends to prioritize children with optimized preoperative status and relatively lower surgical risk. Patients with markedly deranged laboratory parameters, severe malnutrition, advanced heart failure, or overt organ dysfunction may be deferred or excluded from operative lists. This practice, although understandable given limited ICU capacity and the desire to ensure safe and reportable outcomes, likely reduces the denominator of high-risk patients and therefore underestimates the true burden of postoperative MODS.
The importance of baseline patient selection in determining surgical outcomes is well established. Jacobs et al. emphasized that surgical complexity and preoperative clinical status significantly influence postoperative morbidity and mortality in congenital cardiac surgery (16). Similarly, Algra et al. demonstrated that preoperative instability and comorbidities substantially increase postoperative organ dysfunction risk (17). In low-resource settings, where infrastructure and perioperative support are limited, careful case selection is often necessary to maintain acceptable mortality rates (13, 14). Thus, the lower MODS prevalence in our study likely reflects both genuine improvements in perioperative care and selection bias toward physiologically stable patients.
Despite the low overall MODS rate, several important predictors emerged. Surgical complexity (RACHS-1 Category 3) was independently associated with higher postoperative PELOD-2C scores, consistent with prior work showing that increasing surgical complexity correlates with postoperative low cardiac output syndrome and organ dysfunction (16, 18). This reinforces the validity of established risk stratification systems in predicting adverse outcomes. The RACHS-1 categorization has been extensively validated across multiple international cohorts, and our findings confirm its utility even in resource-limited settings where more sophisticated risk prediction tools may not be available.
Among laboratory parameters, elevated preoperative INR and lower platelet counts were independently associated with higher postoperative organ dysfunction severity. Thrombocytopenia is widely recognized as a marker of systemic inflammation and critical illness severity (20). Cardiopulmonary bypass induces platelet activation and consumption, and patients entering surgery with borderline platelet reserves may be particularly vulnerable to postoperative

coagulopathy and inflammatory cascades (14). Similarly, deranged coagulation profiles may reflect subclinical hepatic dysfunction or chronic congestion in children with longstanding cardiac disease, predisposing them to worse postoperative outcomes.

The finding that INR remained independently predictive after multivariable adjustment is particularly noteworthy. Coagulation abnormalities are often overlooked in preoperative risk assessment for pediatric cardiac surgery, yet our data suggest that even mild elevations in INR may signal underlying physiological vulnerability. This aligns with the work of Vanderschueren et al., who demonstrated that thrombocytopenia is associated with poorer prognosis across various intensive care settings (20). The combination of elevated INR and thrombocytopenia may represent a clinical phenotype of chronic heart failure with hepatic congestion and platelet consumption, placing these children at substantially higher risk for postoperative MODS.

Preoperative malnutrition emerged as an independent predictor of higher PELOD-2C scores. Malnutrition is prevalent in children with congenital heart disease in low-income settings and is associated with impaired immune response, delayed wound healing, and increased susceptibility to infection and organ dysfunction. Previous pediatric surgical studies have consistently demonstrated worse postoperative outcomes among malnourished children (17). Our findings support the need for structured nutritional optimization prior to elective cardiac surgery.

The magnitude of this effect ($\beta = 1.22$, $p = 0.006$) is clinically significant. A 1.22-point increase in PELOD-2C score represents a meaningful difference in organ dysfunction severity, particularly in a cohort where the median score was 2 (IQR: 0–2). Children with severe acute malnutrition had nearly double the risk of developing higher PELOD-2C scores compared to their well-nourished counterparts. This finding has direct implications for preoperative optimization protocols: delaying elective surgery to permit nutritional rehabilitation may be justified in severely malnourished children, even if other laboratory parameters are within normal limits.

The strong association between MODS and mortality in this study aligns with broader pediatric critical care literature. Goldstein et al. defined MODS as progressive dysfunction of two or more organ systems, often culminating in death (10). Proulx et al. and Typpo et al. further demonstrated that mortality increases exponentially with each additional failing organ (11, 3). Our findings mirror these observations: although only four patients developed MODS (2.4%), three of them died (75% mortality), underscoring the catastrophic trajectory once multiple organ systems fail. This 75% mortality rate among MODS patients is consistent with historical cohorts that reported mortality approaching 50-80% in affected children (6, 9).

From a systems perspective, these results highlight the dual reality of pediatric cardiac surgery in resource-limited environments. On one hand, carefully selected patients can achieve excellent survival rates comparable to international standards. On the other, this apparent success may obscure unmet surgical need among higher-risk children who are not offered operative intervention due to resource constraints. Lubega et al. similarly described how infrastructure limitations and perioperative capacity influence outcomes in African cardiac programs (13).

Therefore, while our data demonstrate promising postoperative survival among operated patients, they must be interpreted within the broader context of access and selection. The low prevalence of MODS likely reflects both effective perioperative care and the exclusion of the most physiologically fragile patients. Future research should explore outcomes among deferred or medically managed CHD patients to better quantify the true burden of disease and the impact of access limitations.

Finally, our findings support the feasibility of using simple, routinely available laboratory markers, particularly platelet count and INR, combined with surgical complexity and nutritional status, for

early risk stratification. In contrast to complex scoring systems such as PELOD-2 (22, 23), which require multiple laboratory and physiologic parameters and may be difficult to operationalize in low-resource settings, targeted use of selected preoperative markers may provide a pragmatic alternative. The PELOD-2 score, while validated in high-income PICU settings (22, 23), requires frequent arterial blood gas measurements and continuous monitoring that may not be feasible in resource-limited environments. Our adapted PELOD-2C score, which emphasizes readily available parameters, represents an attempt to balance rigor with practicality.

This study has several limitations. Its retrospective single-center design limits causal inference and generalizability, and reliance on chart documentation may introduce information bias. The small number of MODS events (n = 4) reduces statistical power and may have limited detection of some clinically relevant associations. Importantly, significant selection bias likely exists: cardiac surgeries in this setting are often conducted with visiting missions, and patients are carefully selected, with those having severe preoperative instability or markedly deranged laboratory parameters less likely to undergo surgery. As surgical complexity and baseline condition strongly influence postoperative outcomes (16, 17), and case selection is commonly used in low-resource programs to maintain acceptable results (13, 14), the low MODS prevalence observed may underestimate the true burden of postoperative organ dysfunction among the broader population of children with congenital heart disease. Additionally, although we used an adapted PELOD-2C score, this tool was originally validated in high-income PICU settings (22, 23), and its performance in our context may differ.

7. CONCLUSION AND RECOMMENDATIONS

In this cohort of children undergoing congenital heart surgery at Cardiac center & Tikur Anbessa Specialized Hospital, postoperative multiorgan dysfunction syndrome (MODS) was uncommon (2.4%) but strongly associated with prolonged ICU stay, extended mechanical ventilation, increased vasopressor requirement, and markedly higher mortality. Surgical complexity (RACHS-1 category), elevated preoperative INR, lower platelet count, and severe preoperative malnutrition were independent predictors of higher postoperative organ dysfunction severity. While outcomes among operated patients were favorable overall, the low prevalence of MODS likely reflects careful preoperative case selection in a resource-limited, mission-supported surgical environment. These findings highlight the importance of simple, routinely available laboratory markers and nutritional assessment as practical tools for perioperative risk stratification in low-resource settings.

Preoperative risk stratification protocols should be strengthened by incorporating routinely available laboratory indicators—particularly INR and platelet count—alongside surgical complexity and nutritional assessment to identify children at increased risk of postoperative organ dysfunction. Structured preoperative optimization, especially nutritional rehabilitation and correction of coagulation abnormalities where feasible, should be prioritized before elective surgery. Additionally, expanding perioperative critical care capacity and progressively broadening surgical eligibility criteria may help reduce selection bias and improve equitable access for higher-risk children. Finally, larger prospective and multicenter studies are recommended to validate locally appropriate risk prediction models and to better define the true burden of postoperative MODS in Ethiopian pediatric cardiac care.

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