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Research Thesis

Title: ASSESSMENT OF PREVALENCE AND ASSOCIATED FACTORS OF POSTOPERATIVE METABOLIC ACIDOSIS IN PATIENTS UNDERWENT OPEN HEART SURGERY AT TASH AND CCE, ADDIS ABABA, ETHIOPIA (2025 G.C): A multi-center retrospective cross-sectional study

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Declaration

I, the undersigned, hereby certify that the research titled "Assessment Of Prevalence And Associated Factors Of Postoperative Metabolic Acidosis In Patients Underwent Open Heart Surgery At TASH And CCE, Addis Ababa, Ethiopia (2025 G.C): A multi-center retrospective cross-sectional study" is my original work, submitted in partial fulfilment of the requirements for the Master of Science degree in Cardiovascular Perfusion. I acknowledge that plagiarism is unacceptable, and all directly cited content has been properly referenced.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACC	**Aortic Cross Clamp**
AKI	**Acute Kidney Disease**
AOC	**Area Under the Curve**
AOR	**Adjusted Odds Ratio**
BSA	**Body Surface Area**
CABG	**Coronary Artery Bypass Graft**
CCE	**Cardiac Center of Ethiopia**
CI	**Confidence Interval**
CKD	**Chronic Kidney Disease**
CPB	**Cardiopulmonary Bypass**
CVD	**Cardiovascular Disease**
DM	**Diabetic Mellitus**
ICU	**Intensive Care Unit**
LMICs	**Lower- and Middle-Income Class**
LVEF	**Left Ventricle Ejection Fraction**
MA	**Metabolic Acidosis**
MODS	**Multiple Organ Dysfunction Syndrome**
$PaCO_2$	**Partial Pressure for Carbon-dioxide**
PMA	**Post-operative Metabolic Acidosis**
ROC-AUC	**Area Under the Receiver Operating Characteristic Curve**
SSA	**Sub-Saharan Africa**
TASH	**Tikur Anbesa Specialized Hospital**

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ABSTRACT

Background: Metabolic acidosis is a pathologic process that results in increased hydrogen ion concentration and/or decreased bicarbonate ion concentration. Acidemia is defined by a pH <7.35 and occurs when the body's natural acid/base homeostatic mechanisms are unable to compensate appropriately to the underlying cause. Postoperative metabolic acidosis (PMA) is a critical complication following cardiac surgery.

Objective: To assess the prevalence and associated factors of post-operative metabolic acidosis among patients who undergone open cardiac surgery at TASH and CCE from 2021-2024.

Methodology: An institutional based multi-center retrospective cross-sectional study was done among all patients who underwent cardiopulmonary bypass surgery from 2021to 2024. Data was collected from patient chart review. The collected data was entered into Epi-data version 4.7 and export to Stata 17 for analysis. Descriptive statistics for categorical and continuous variables was done. Variables fitted on univariate analysis was entered into multivariable analysis to show the strength of association and statically significant variable.

Result: A total of 212 patients were included in this study, which 38.68% had postoperative metabolic acidosis. Among these patients 43 (20.28%) and 169 (79.71%) were from TASH and CCE, respectively. Nearly half of the patients were male (48.58%) and the rest (51.42%) were female. Diabetes mellitus (AOR 3.64, p=0.029), surgery time > 4 hours, (AOR 4.43, p=0.028), high hemoglobin after CPB (AOR 0.10, p=0.003), and longer CPB time (AOR 5.92, p=0.04) were significant in the final analysis.

Conclusion: This study revealed a PMA prevalence of 38.68% and identified four significant predictors: diabetes mellitus, surgery duration > 4 hours, elevated hemoglobin levels following CPB, and prolonged CPB time.

Key Words: Adjusted odds ratio (AOR), Cardiopulmonary bypass (CPB), Post-operative metabolic acidosis (PMA)

CHAPTER ONE – INTRODUCTION

1.1 Background

Cardiovascular diseases (CVDs) account for a large portion of fatalities and disability worldwide, making them the leading cause of mortality. Previously thought to be diseases of wealth, cardiovascular ailments are no longer seen as such. More than half a billion people around the world continue to be affected by cardiovascular diseases, which in 2021 alone, CVDs accounted for 20.5 million deaths, comprising approximately one-third of all global deaths and an overall increase on the estimated 121 million CVD deaths. Over three-quarters of CVD-related deaths occur in low- and middle-income countries (LMICs)(1).

Cardiovascular diseases (CVDs) account for a large portion of fatalities and disability worldwide, making them the leading cause of mortality. Previously thought to be diseases of wealth, cardiovascular ailments are no longer seen as such.

Metabolic acidosis is a pathologic process that results an increased hydrogen ion concentration and/or a decreased bicarbonate ion concentration. Acidemia is defined by a pH <7.35 and occurs when the body's natural acid/base homeostatic mechanisms are unable to compensate appropriately for the underlying cause of acidification. There are generally thought to be 3 different mechanisms that lead to the development of metabolic acidosis: increased hydrogen ion production, loss of bicarbonate, and decreased hydrogen ion excretion(2).

The main causes of metabolic acidosis in healthy patients after surgery are hypotonic serum (dilutional acidosis) and excessive infusion of saline 0.9% (hyperchloremic acidosis). Moreover, metabolic acidosis can be brought on by hypotension, hypoxemia, renal failure, cirrhosis, diabetes, and other conditions(3). In the early postoperative phase following heart surgery, metabolic acidosis is frequently observed and partially attributed to the volume and makeup of intravenous fluids used during the procedure. 7.In example, hyperchloremic metabolic acidosis has been linked to the fast infusion of large amounts of sodium chloride 0.9%(4).

Nine out of ten people, or more than 5 billion people, do not have access to basic surgical treatments in low- and middle-income countries (LMICs), demonstrating the complete inadequacy of surgical care access in these nations. Although this problem affects all surgical subspecialties,

cardiac surgery is arguably the most prominent area. Over 100 nations do not have a single heart surgeon, and low-income nations typically have only 0.04 cardiac surgeons per million people, whereas high-income nations have 7.15 cardiac surgeons per million people(5).

In Africa, just one surgeon conducts cardiothoracic surgery for every 4 million patients, which accounts for ~1% of the global capacity. Furthermore, the region has a shockingly small number of cardiac surgery facilities, with Sub-Saharan Africa (SSA), excluding South Africa, possessing just one facility for every 38 million individuals(6). In the remainder of sub-Saharan Africa, there is a cardiac surgery unit for each 38 million. There is only 1 cardiothoracic surgeon per 4 million people in Africa and 1% of global capacity overall. To access a care in cardiothoracic surgery is entirely based upon the economic status of the patient. Therefore, an estimated 4.5 billion people lack access to heart surgery(7).

Epidemiological transition has shifted the principal causes of death and morbidity from infectious to non-communicable diseases. Adequate documentation of heart diseases is normally absent in developing nations, such as Ethiopia. A study at Black Lion and St. Paul's Hospitals found that cardiovascular diseases were among the leading causes of mortality and most frequent causes of admissions. Statistics from the Cardiac Center Ethiopia revealed that the rates of patients suffering from cardiac diseases have increased tremendously over time. Additional data from the Ministry of Health indicate that over 40,000 patients with heart disease have been awaiting cardiac surgery or interventions in Ethiopia since 2020. A report by Cardiac Center Ethiopia indicates that approximately 7,000 patients with heart disease await cardiac surgery (8).

1.2 Statement of problem

Metabolic acidosis post-cardiac surgery has several adverse effects in critically ill individuals. Acidosis induces depression of the myocardium, which will reduce cardiac output and oxygen delivery. Arterial vasodilatation and resultant hypotension are also caused by acidosis. Importantly, decreases in pH and $PaCO_2$ increases are uninduced, potent pulmonary vasoconstrictors. Pulmonary vasoconstriction augments the afterload of the right ventricle, to which the right ventricle may be unaccustomed(2).

An elevation of lactate levels (hyperlactatemia) is detectable in 10% to 20% of patients undergoing CPB and is associated with adverse effects such as increased morbidity and mortality. Type A

hyperlactatemia is the most common type in patients after cardiac surgery and is strongly associated with metabolic acidosis. Some factors that lead to dysoxia during CPB and culminate in increased lactate levels are comorbidities intrinsic to the patient, such as preoperative dehydration, high levels of preoperative serum creatinine, active endocarditis, congestive heart failure, low left ventricular ejection fraction, hypertension, atherosclerosis, low preoperative and perioperative hemoglobin values and preoperative low cardiac output(9).

Open cardiopulmonary bypass, disrupts acid-base balance through several mechanisms: hemodilution lowers bicarbonate buffering capacity, hypothermia compromises mitochondrial metabolism, and ischemia-reperfusion injury increases lactate production(10). Care on CPB continues, however, to be constrained by resources available. For example, chloride-loaded crystalloids (normal saline) are utilized for routine priming on economic grounds, thereby further exacerbating hyperchloremic acidosis, a consequence seen in 70% of CPB cases in similar LMIC settings(11). Additionally, longer CPB duration (>120 minutes), is connected with lactate levels >4 mmol/L and 3-fold higher mortality (12)(13).

Exciting European and North American literature has identified modifiable intraoperative determinants like CPB time, chloride load, and lactate clearance(11)(12). These results do not generalize very well to countries like Ethiopia, where there is a delay in operations, resulting in advanced cardiac disease, EuroSCORE risks, and inadequate preoperative optimization of comorbidities (e.g., anemia, CKD).

1.3 Significance of the study

Postoperative metabolic acidosis (PMA) is a critical complication following cardiac surgery, with global studies reporting a prevalence of 20–45% and associations with prolonged ICU stays, organ dysfunction, and mortality.

The findings will also contribute to global literature by contextualizing how socioeconomic disparities amplify PMA risk. For instance, while studies in Brazil and India highlight intraoperative hypothermia and hemodilution as key PMA drivers(10)(13), Ethiopian patients face additional challenges, including malnutrition (28% stunting in adults) and limited access to albumin or bicarbonate replacements. Furthermore, unlike high-income settings where goal-

directed perfusion and chloride-restricted priming are standard, Ethiopian hospitals often rely crystalloids exacerbating hyperchloremic acidosis.

This study will benefit the cardiac team in identifying the factors associated with lactate and its effect on patient's outcome following cardiac surgery under cardiopulmonary bypass. The finding from the study will provide significant benefit in promoting prevention and early control mechanisms, conscious the policy makers and national programs about the need of diagnostic and treatment facilities and will play a fundamental role in reducing morbidity from hyperlactemia.

Therefore, result of this study may contribute important evidence that can be used by the policy makers, program planners and educators to design appropriate strategy to address the problem. Further, the result of the study can be used as a baseline data for future studies in the topic area.

CHAPTER TWO – LITERATURE REVIEW

Cardiac surgery has a high rate of severe adverse events overall and a 2%–3% mortality rate. Multiple organ dysfunction syndrome (MODS) arises in about 5% of patients after cardiac surgery, the most dangerous procedure being under cardiopulmonary bypass (CPB). Postoperative metabolic acidosis is a benign phenomenon after cardiac surgery in a high percentage of individuals. It is characterized by an imbalance in acid and base formation and excretion within the body, leading to an elevation of hydrogen ion (H+) concentration in the blood. It is associated with very serious outcomes, including organ failure, prolonged hospitalization, and increased mortality. Hyperlactatemia occurs in 10%–20% of patients after cardiac surgery, as it could be produced by hypoxic and non-hypoxic mechanisms such as drug therapy, cardioplegia, hypothermia, and CPB(14).

The pathophysiologic mechanism of postoperative metabolic acidosis is complex and multifactorial. These factors include the type of cardiac surgery, cardiopulmonary bypass time, and the utilization of vasopressors. In addition, the use of vasopressors, such as norepinephrine, can also induce metabolic acidosis by increasing the production of lactic acid(15).

When the patient is under cardiopulmonary bypass during cardiac surgery, the heart and lungs are bypassed, furthermore; the body natural capacity for acid-base balance is disturbed. Tissue micro dialysis studies in uncomplicated adult cardiac patients have shown that cardiopulmonary bypass itself causes increased lactate and an increase in lactate pyruvate levels in the myocardium and peripheral tissues. Interestingly, despite bypass delivering adequate calculated tissue perfusion for a given patient, select patients develop early-onset elevated lactate, likely related to variable inflammatory, microcirculatory, and mitochondrial responses during hypothermia and cardiopulmonary bypass. Alternatively, despite delivery of calculated flow, patient still could have elevated lactate. During bypass, it is unclear which tissue beds contribute significantly to serum lactate generation; the myocardium, lungs, intestines, and skeletal muscles have all been implicated. Elevated lactate within the myocardium has specifically been associated with postoperative myocardial dysfunction, perhaps suggesting inadequate cardioplegia and/or ongoing tissue ischemia (16).

2.1 Prevalence of Postoperative Metabolic Acidosis

Postoperative metabolic acidosis (PMA) remains a common complication of cardiac surgery, and prevalence rates nowadays range widely with the diagnostic criteria applied, the type of operation, and the patient population. Systematic reviews indicate that 20-45% will have PMA, with highly increased prevalence rates in severely complicated procedures, such as combined valve and coronary artery bypass graft (CABG) surgery. For example, the use of a pH threshold of <7.35 resulted in a general prevalence of 32.6% in CABG surgery patients(17).

The clinical significance of PMA is realized through its impact on morbidity and mortality. A Brazilian study published in June 2011 demonstrated that postoperative metabolic acidosis (designated as high anion gap with hyperlactatemia) is linked with surgical patient complications and mortality. In this study of 188 patients, postoperative high anion gap with hyperlactatemia patients were distinguished to have greater complication rates in the form of shock 66% versus 48.1% with high anion gap, 47.9% with normal anion gap, and 39.5% in non-acidosis patients ($P < 0.05$). Mortality distinctions were consistent: 14.5% for high anion gap with hyperlactatemia, 10.2% for high anion gap, 6.1% for normal anion gap, and 2.0% for non-acidosis patients ($P = 0.04$)(13). In a prospective study in 2022, PMA was also associated with 4-fold increased odds of acute kidney injury (AKI), and lactate >4 mmol/L as an independent predictor of the requirement for dialysis(18). The above evidence recognizes PMA's role as both a predictor and mediator of adverse outcomes.

Clinical burden of metabolic acidosis is also emphasized by its association with catastrophic postoperative outcomes. Acute kidney injury, cardiogenic shock, and hospital mortality rates were 50.4%, 6.3%, and 10.4%, respectively, in a case-control cohort study of patients who were undergoing cardiac surgery and developed hyperlactatemia and were significantly higher than those of non-acidosis controls ($p < 0.0001$). ICU and ventilation stays were also prolonged (3 vs. 1 day and 0.89 vs. 0.50 days, respectively).(19).

2.2 Associated Factors Influencing Postoperative Metabolic Acidosis

2.2.1 Patient-Specific Factors

Preoperative comorbidities significantly heighten PMA risk. Chronic kidney disease, congestive heart failure, anemia (hemoglobin <12 g/dL), and reduced left ventricular ejection fraction (LVEF <40%) impair oxygen delivery, exacerbating anaerobic metabolism during CPB(12)(9).

One prospective randomized controlled trial study in 2013 informs that patients who go on to develop postoperative acidosis following cardiac surgery often have preoperative risk factors that predispose them to complications. A decreased preoperative left ventricular ejection fraction (LVEF) is much more likely to be found in patients with complications compared to those with no complications (LVEF <40%: 31% vs. 12%; P = .001). In addition, these patients carry higher operative risk scores, as reflected by higher EuroSCORE values (median 7 [interquartile range 5-9] vs. 4 [3-6]; P < .001), and lower preoperative hemoglobin levels (12.6 ± 2.1 vs. 13.3 ± 1.7 g/dL; P = .009)(12).

2.2.2 Surgical and Intraoperative Factors

A Prospective cohort study carried out in Australia on 10 cardiac bypass graft patients in a tertiary center suggested that cardiopulmonary bypass (CPB) typically produces mild metabolic acidosis due primarily to the rise in serum chloride. Studies have confirmed that serum chloride rises from a median of 104.9 mEq/L to approximately 111 mEq/L in the course of CPB, and this produces a mean negative charge increase of 5.83 mEq/L. A precipitous decline in the level of serum albumin is also reported from a median of 33.6 g/L pre-CPB to 19.1 g/L intra-CPB. This decline is primarily an effect of hemodilution caused by pump prime solutions infusion, crystalloids, colloids, and blood loss(11).

Operative duration is an important factor in determining postoperative metabolic acidosis incidence. Based on a study conducted on 2018 in India at Medical College of Kottayam, it was postulated that operating time influence postoperative metabolic acidosis significantly. Postoperative metabolic acidosis had been there, 93.8% among the patients with operation time of >5 hrs, 62.5% among the patients with operative time 2.01-3 hrs, 60.5% among patients with 3.01-4 hrs, and 84.6% among patients with 4.01-5 hrs duration groups. Association between operative time and postoperative metabolic acidosis incidence was significant p values 0.016(10).

Moreover, A 2013 prospective randomized controlled trial study done in Brazil states patients who develop major complications are more likely to undergo valve surgery (37% vs. 31%; P < .001) or combined valve and graft procedures (21% vs. 6%; P < .001). Additionally, patients undergoing combined procedures (e.g., valve + CABG) face higher MA risk due to prolonged ischemia(12).

2.2.3 CPB-Related Mechanisms

A study conducted in 2024 indicates that cross-clamping and cardiopulmonary bypass times and very positive fluid balance at the end of the procedure are linked to higher levels of postoperative lactate, which translates to higher demand for pump support. Using intra-aortic balloon, intensive care >24 h unit stay, red blood cell bleeding requirement, hospital stay, and raised mortality have higher probabilities. Additionally, clamping and CPB an increase in time and a highly positive fluid balance during the end of procedure is associated with an initial increase in postoperative lactate levels, associated with an increased need for IABP support, ICU stay, need for red blood transfusions, hospital stay, and mortality(20).

There was gradual increase in lactate level during CPB which also persistently raised in the postoperative period of the ICU until 6 h. High lactate patients experienced significantly greater CPB time (92.40 ± 26.0 vs. 83.96 ± 28.18 min; P = 0.003) and aortic cross-clamp time (55.8 ± 18.2 vs. 48.4 ± 19.8 min; P = 0.007)(21).

Incidence of metabolic acidosis also differ, with the complication group experiencing longer cardiopulmonary bypass durations (109 ± 36 minutes vs. 93 ± 29 minutes; P < .001), lower hematocrit levels (25% ± 6% vs. 27% ± 5%; P = .019), and reduced venous oxygen saturation (74% ± 11% vs. 82% ± 7%; P < .001) intraoperatively(12).

CPB-induced systemic inflammation and capillary leakage exacerbate microcirculatory hypoperfusion, the major driving force behind Type A hyperlactatemia. Chloride-containing priming solutions and crystalloids infused during CPB exacerbate hyperchloremic acidosis, and hemodilution diminishes the buffering capacity of albumin(11)(22).

2.3 Conceptual Framework

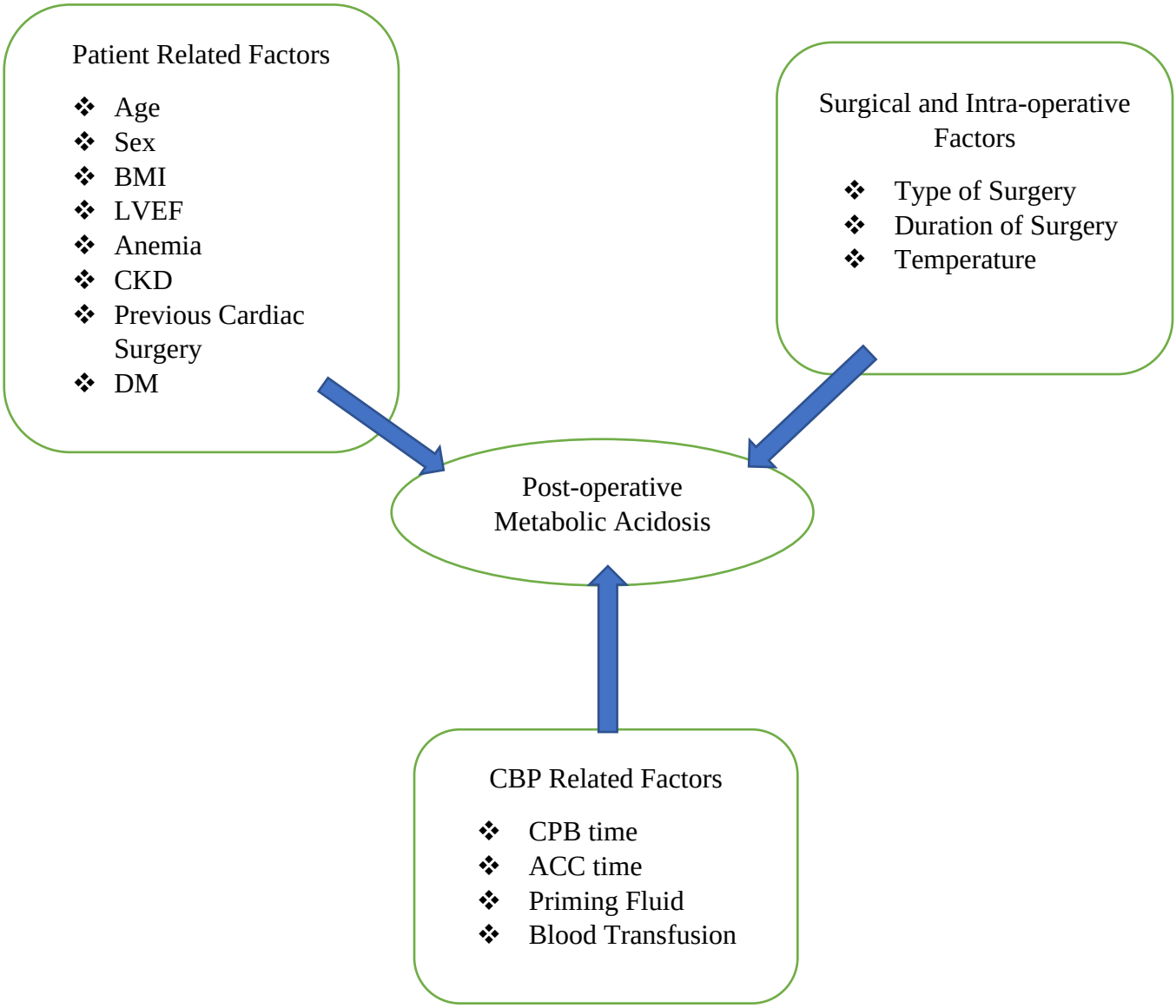

Figure 1: Conceptual framework showing the variables and possible association with post-operative metabolic acidosis

CHAPTER THREE: OBJECTIVE

3.1 General Objective

- To assess the prevalence and associated factors of post-operative metabolic acidosis among patients who undergone open cardiac surgery at TASH and CCE from 2021-2024.

3.2 Specific Objective

- To identify the prevalence of post-operative metabolic acidosis among patients who undergone open cardiac surgery at TASH and CCE from 2021-2024
- To assess the associated factors of post-operative metabolic acidosis among patients who undergone open cardiac surgery at TASH and CCE from 2021-2024

CHAPTER FOUR: METHODOLOGY

4.1 Study area

The study was taken place at TASH and CCE, in Addis Ababa, Ethiopia from January 1 to April 30, 2025. Ethiopia's capital, Addis Ababa, harbour more than 5.5 million people and is growing quickly. There were more than 52 hospitals in Addis as of 2022, comprising over 40 private and 12 state-run facilities. Among these is Black Lion Hospital, which was founded in 1961 and serves as a main teaching hospital for Addis Ababa University. It is the biggest specialty hospital in Ethiopia. It treats more than 500,000 outpatients and 21,000 inpatients a year with 800 beds and 17 operating rooms. It contains one large main operating room, four cardiothoracic surgeons, one perfusionist, trained nurses and five interventional cardiologists. Additionally, it has a dedicated cardiac ICU facility with 7 functional beds.

Cardiac Center Ethiopia is the first cardiac institution in Ethiopia which was inaugurated on February 12, 2009 G.C. This non-profit Center specializes in heart disease and is especially committed to helping children with cardiac problems. The center performs all types of cardiac surgeries for rheumatic, valvular and congenial heart disease for infants, children, adolescents and adults by a qualified Ethiopian team (Twelve particularly trained nurses, three interventional cardiologists, two senior perfusionists and four cardiothoracic surgeons make up the team.), operating on various cardiac surgical interventions with 2 fully dedicated operation theatres, 10 ICU beds and 2 functional Cath-lab machines.

4.2 Study design

A retrospective cross-sectional study was employed to do the research.

4.3 Study period

The study period was from December 2024 to June 2025.

4.4 Population

4.4.1 Source population

All patients who had undergone open cardiac surgery from January 2021 to December 2024, at TASH and CCE

4.4.2 Study population

All patients who underwent elective open cardiac surgery from January 2021 to December 2024 at TASH and CCE within the study period and fulfilled the inclusion criteria.

4.5 Inclusion and exclusion criteria

4.5.1 Inclusion criteria

All selected registered and complete patients who elective underwent cardiopulmonary bypass surgery.

4.5.2 Exclusion criteria

Missed patient charts and charts with missing value were excluded from the study.

4.6 Study variables

4.6.1 Dependent variables

- Post-operative Metabolic Acidosis.

4.6.2 Independent variables

- Age
- Sex
- BSA
- LVEF
- Anemia
- CKD
- Previous Cardiac Surgery
- DM
- Type of Surgery
- Duration of Surgery
- Temperature
- CPB time
- ACC time
- Priming Fluid
- Blood Transfusion

4.7 Operational Definition

Postoperative Metabolic Acidosis (MA): Postoperative Metabolic acidosis is a clinical disturbance defined by a pH less than 7.35 and a low HCO3 level (<22 mEq/L) with high anion gap (>12 mEq/L) and normal anion gap (4-12 mEq/L) in the first arterial blood gas result taken in ICU within 24 hours.

Chronic Kidney Disease (CKD): CKD is defined as kidney damage or an eGFR less than 60 mL/min/1.73 m2, persisting for 3 months or more, irrespective of the cause.

Hyperlactatemia: When the blood lactate level measure >3mmol/dl.

Anemia: is defined using post CPB hemoglobin as normal (>12.5g/dl) mild (12.5-10g/dl), moderate (8-9.9g/dl), and severe (<7.9g/dl).

4.8 Sample size determination

The sample size for the study was determined by using a single population formula by using a 95% confidence interval 39.8% population proportion and a 5% margin of error.

- **$Z1-\alpha/2=1.96$** $Z1-\alpha/2=1.96$ (95% confidence level),
- **p=39.8%** (adjusted prevalence from a 2020 Nigerian study(23)),
- **E=5%** $E=5\%$ (margin of error).

Calculation:

n=Zα/22 x p (q) /d2 = (1.96)2 x 0.398(0.602) / (0.05)2

= $(1.96)^2 \cdot 0.0.398 \cdot 0.602/(0.05)2=368.1 \approx$ **368 participants.**

Since the study population was less than 10,000, sample size reduction was used.

Nf = ni/(1+ni/N); Where: -

- nf= final Sample Size
- ni= initial Sample Size
- N= total population

Nf = 368/(1+ 368/420)

Nf = 368/1.86

Nf = 196.14≈196

Nf = 196

nadjusted=196+(196*0.10) = 215.6 participants

nadjusted ≈ 216 participants.

After adding 10% non-response rate the final sample size was 216.

4.9 Sampling technique

Selection of participants was carried out by using systematic random sampling technique by using the Medical Record Number (MRN) from Health Service Management and Information System (HMIS) of patients as a sampling frame. So, sampling interval (k) was calculated as K=N/n = 420/216 ≈ 2, where N = total study population and n = total sample size.

4.10 Data collection tools and procedures

Data collection tool (questionnaire) was used which is adapted from the previous studies. The tools consisted of checklists that was prepared in English version and had three parts (Patient related factors, Surgical and Intra-operative factors, and CBP related factors). The cardiac patient's chart was reviewed retrospectively by using the data collection checklist. To assure the quality of the data one-day training and orientation, about the objective and process of data collection, were given for 2 data collectors and 1 supervisor prior to data collection by principal investigator. Before actual data collection time, the questionnaire was checked for clarity and comprehensiveness. During data collection, the supervisor monitored the data collection process by checking completeness of the data and take corrections on the site of data collection when any problem happened.

4.11 Data processing and analysis

Once data collection was completed, the completed questionnaires was manually reviewed for completeness by the investigating perfusionist. The data was extracted from patient charts using a structured checklist and entered into Epi data version 4.7. Prior to analysis, data quality was ensured through a two-step cleaning process. First, missing values were quantified and assessed for randomness using Little's Missing Completely at Random test. Variables with <20% missingness were imputed using multiple imputation by chained equations, while variables with >20% missingness were excluded from multivariable models.

Descriptive statistics summarized baseline characteristics. Categorical variables (e.g., sex, diabetes status) were reported as frequencies and percentages. Continuous variables were presented as mean ± standard deviation if normally distributed or median and interquartile range if skewed. The prevalence of postoperative metabolic acidosis (PMA) was calculated as the proportion of patients with pH <7.35 and $HCO3^{-}$ <22 mEq/L within 24 hours post-surgery.

Univariate analyses assessed associations between independent variables and PMA. Categorical predictors (e.g., anemia, CKD) were tested using chi-square. Continuous variables (e.g., hemoglobin, CPB time) were analyzed using independent t-tests. Variables with p <0.2 in univariate analyses or clinical relevance (e.g., age, CPB time) advanced to multivariable logistic regression.

Multivariable logistic regression identified independent predictors of PMA. Model assumptions was rigorously checked: multicollinearity was evaluated using variance inflation factors (variance inflation factors >5 indicating exclusion). Backward elimination guided by the Akaike Information Criterion was optimized model parsimony. Adjusted odds ratios with 95% confidence intervals was reported. Sensitivity analyses was included subgroup stratification by surgical center (TASH vs. CCE) and alternative PMA definitions (e.g., pH <7.30 + lactate >4 mmol/L). All analyses were conducted in STATA version 17. Variables with $p < 0.05$ in multivariable analysis were considered significant.

4.12 Ethical Consideration

After receiving ethical clearance from the Ethical Review Board and a letter of authorization from Addis Ababa University College of Health Sciences, the study was carried out. To access the recorded data, informed consent was sought from the appropriate hospital authorities. By ensuring that all data was anonymized, confidentiality was preserved throughout the investigation. All information gathered was also safely maintained to preserve privacy and confidentiality.

4.13 Dissemination of result

The result of this study was submitted for and presented to Addis Ababa University, College Health Science, School of medicine and Department of Cardiology. The final result of this study was given for the hospital and the center where the study conducted, other concerned governmental and non-governmental organizations. Moreover, the findings of the study were disseminated through publication by international journals.

CHAPTER FIVE: RESULT

5.1 Socio-demographic and Clinical Characteristics

From a total of 420 patients whom undergone open cardiac surgery under cardiopulmonary bypass at TASH and CCE from 2021 G.C. till 2024 G.C., 216 patients were selected using systematic random sampling. From these patients, 202 had compete charts, 10 was incomplete and replaced by other charts. Finally, 212 complete patient charts were reviewed for this study. This gives the response rate (the completeness rate) of 98.14%. Among these patients 43 (20.28%) and 169 (79.71%) were from TASH and CCE, respectively. Nearly half of the patients were male (48.58%) and the rest (51.42%) were female. The total number of patients under 18 years were 124 which accounts for 58.49% of the total study population.

This study determined the prevalence of postoperative metabolic acidosis among patients who underwent open-heart surgery under cardiopulmonary bypass. In a cross-sectional study of 212 patients, a high proportion (38.68%; 95% CI 32.08–45.59) developed postoperative metabolic acidosis.

Table 1: Socio-demographic and Co-existing characteristics of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

Variables	Characteristics	Frequency	Percentage	PMA %	
				Yes	No
Age	≤ 18 years	124	58.49	36.29	63.70
	> 18 years	88	41.51	42.04	57.95
Sex	Male	103	48.58	36.89	63.10
	Female	109	51.42	40.36	59.63
Body Mass Index	<18.5 kg/m^2	109	51.42	36.69	63.30
	18.5-24.9 kg/m^2	73	34.43	34.24	65.75
	25-29.9 kg/m^2	28	13.21	53.57	46.42
	≥ 30 kg/m^2	2	0.94	100	-
Diabetes Mellitus	Yes	34	16.04	73.52	26.47
	No	178	83.96	32.02	67.97
Hypertension	Yes	16	7.55	75.00	25.00
	No	196	92.45	35.71	64.28

Pulmonary Hypertension	Yes	116	54.72	41.37	58.62
	No	96	45.28	35.41	64.58
Chronic Kidney Disease	Yes	4	1.89	75	25
	No	208	98.11	37.98	62. 01
Left Ventricle Ejection Fraction	<30%	4	1.89	75.00	25.00
	30-50%	30	14.15	56.66	43.33
	>50%	178	83.96	34.83	65.16
Previous Cardiac Surgery	Yes	7	3.30	85.71	14.28
	No	205	96.70	37.07	62.92

During open cardiac surgical procedures intraoperative parameters are often associated with postoperative adverse outcomes. Identifying and monitoring these parameters are components of the procedure as well as predictors of patient outcomes and prognosis. In this study the result of intraoperative parameters of the patients are stated as follows.

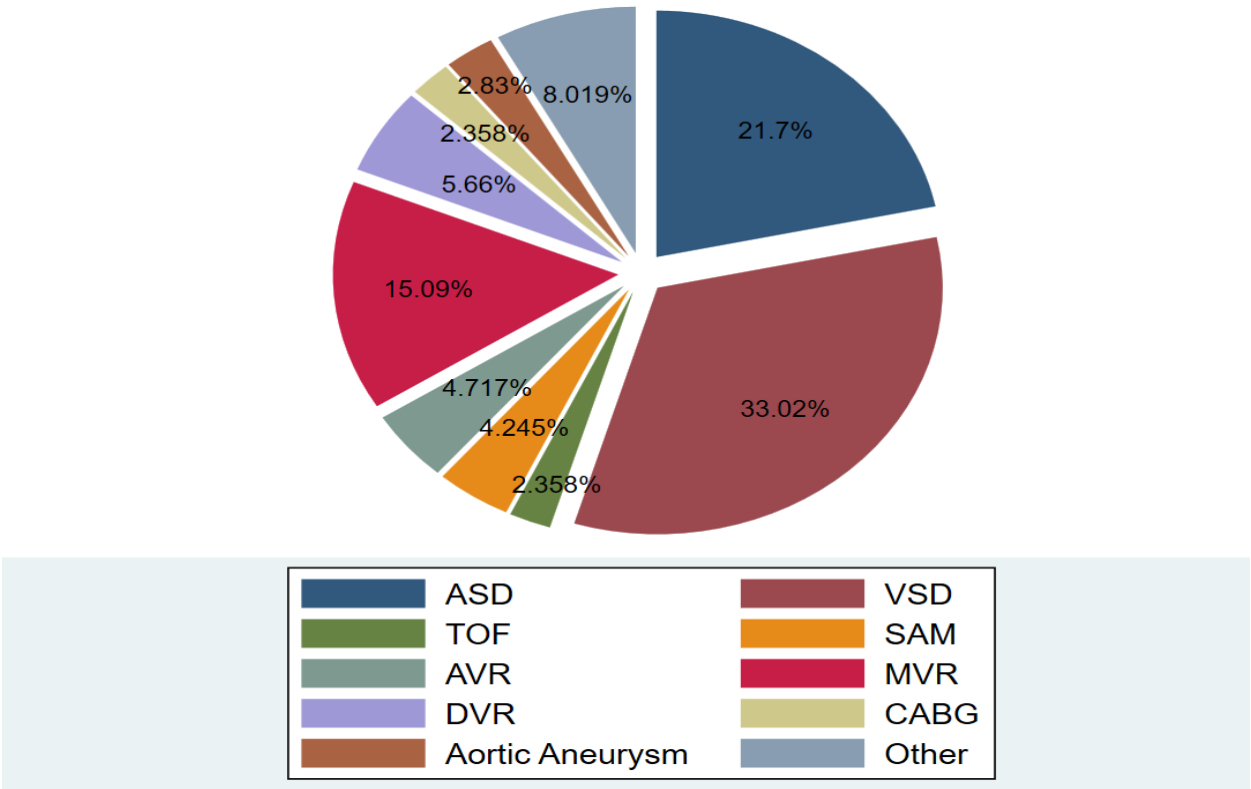

Figure 2: Prevalence of open-heart surgery categories of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (P=0.00) (n=212)

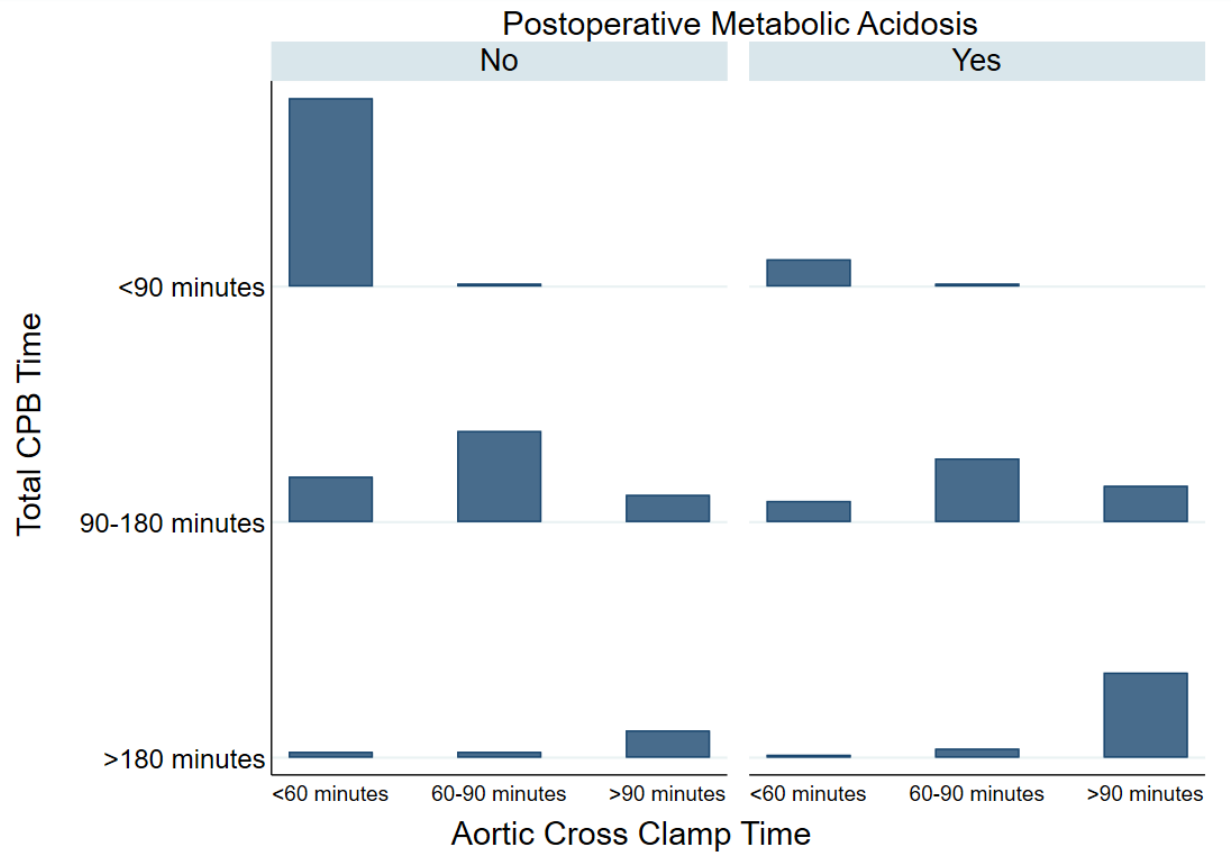

Figure 3: Characteristics of CPB and ACC time over postoperative metabolic acidosis of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

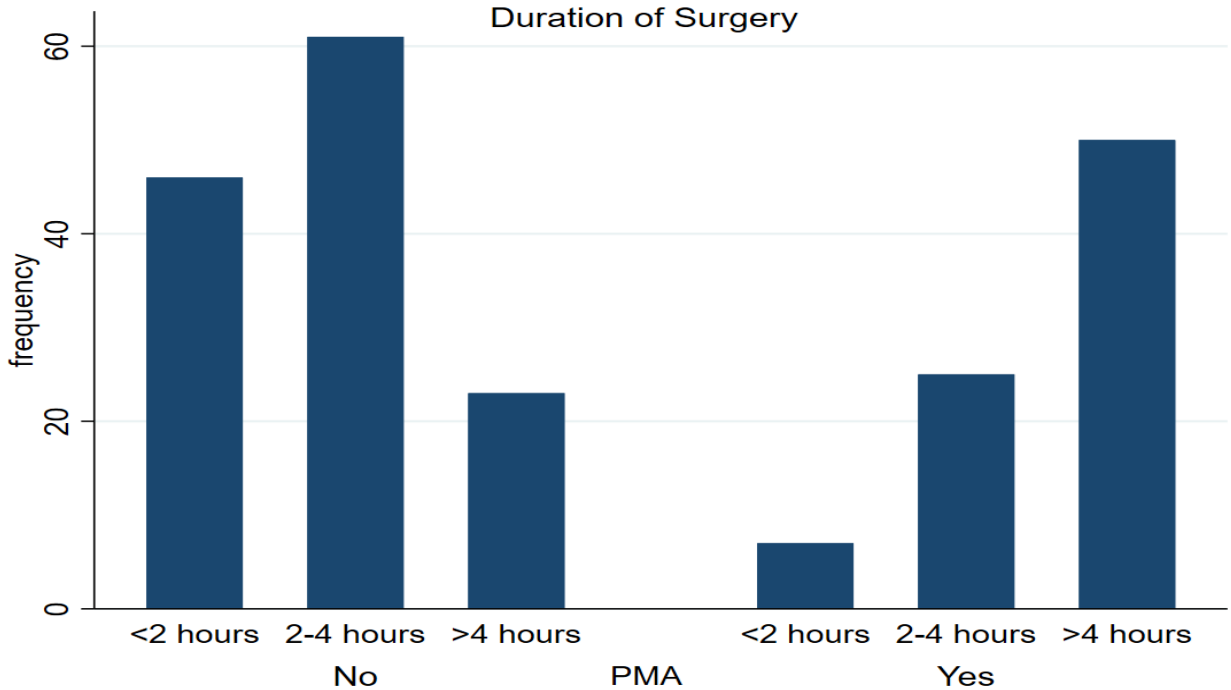

Figure 4: Characteristics of duration of surgery over postoperative metabolic acidosis of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

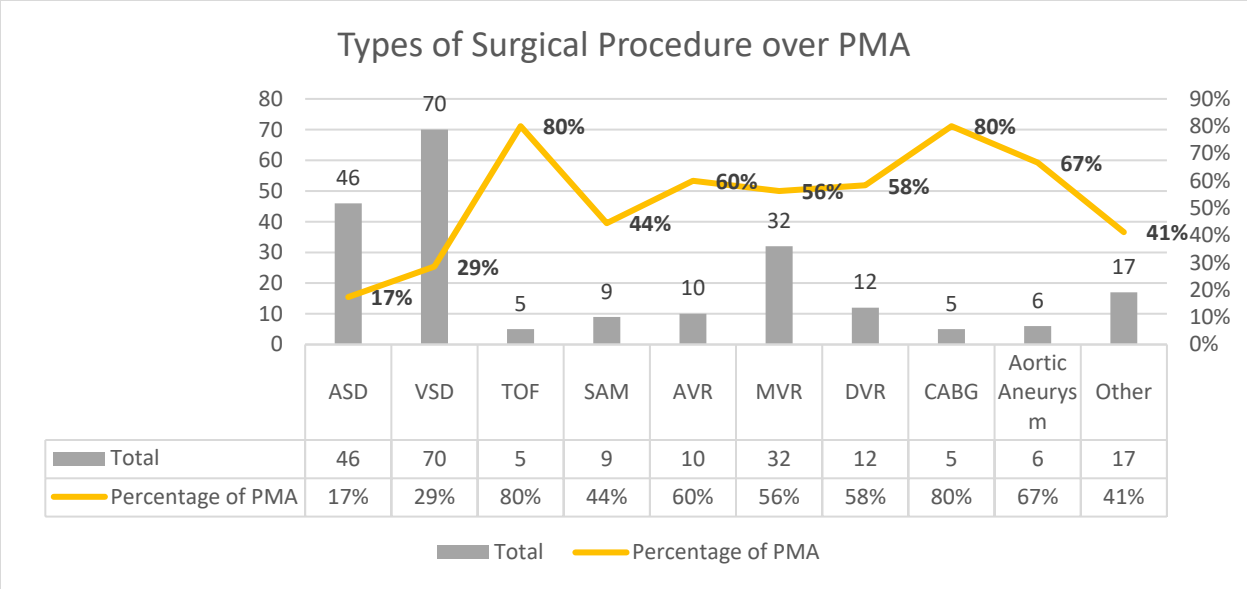

Figure 5: Percentile of postoperative metabolic acidosis on different types of open-heart surgical procedure done at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

Table 2: Intraoperative characteristics of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

Variables	Characteristics	Frequency	Percentage	PMA %	
				Yes	No
Intraoperative CPB Temperature	<20 ^{0}C	2	0.94	50	50
	20-28 ^{0}C	3	1.42	66.66	33.33
	28-32 ^{0}C	109	51.42	54.71	45.28
	>32 ^{0}C	98	46.23	21.42	78.57
Postoperative Glucose Level	<126 g/dl	10	4.72	30.00	70.00
	126-200 g/dl	115	54.25	30.43	69.56
	>200 g/dl	87	41.04	50.57	49.42
Post CPB Hemoglobin Level	<7.9 g/dl	22	10.38	63.63	36.36
	8-9.9 g/dl	96	45.28	44.79	55.20
	>10 g/dl	94	44.34	26.59	73.40
Previous Cardiac Surgery	Yes	7	3.30	85.71	14.29
	No	205	96.70	37.07	62.92
Priming Fluid	Crystalloid	145	68.40	37.93	62.06
	Blood Products	67	31.60	40.29	59.70

Intraoperative Blood Transfusion	None	179	84.43	36.31	63.68
	≤ 2 units	29	13.68	48.27	51.72
	>2 units	4	1.89	75	25
Postoperative Hyperlactemia	Yes	86	40.57	79.06	20.93
	No	126	59.43	10.56	89.43
Postoperative Base Excess	-2 to +2 mmol/L	120	56.60	11.11	88.88
	≤ −3 to > −6 mmol/L	63	29.72	68.25	31.74
	≤ −6 to > −10 mmol/L	22	10.38	90.90	9.09
	≤ −10 mmol/L	7	3.30	100	-
Postoperative Bicarbonate	<22 mEq/L	54	25.47	83.33	16.66
	22-28 mEq/L	154	72.64	24.02	75.397
	>28 mEq/L	4	1.89	-	100

5.2 Associated factors with postoperative metabolic acidosis among patients underwent cardiopulmonary bypass surgery

The Hosmer-Lemeshow test and the logistic regression ROC-AUC was used to evaluate its discriminating power as well as calibration. The Hosmer-Lemeshow test ($\chi^2(8) = 7.04$, $p = 0.5324$) confirmed that the model is well-calibrated since its forecasted risks are extremely close to real outcomes. In addition, its ROC-AUC value of 0.8621 indicated superior discriminatory power where the model discriminates correctly between event and non-event cases in 86.76% of the comparisons. This better AUC indicates the model was highly accurate and superior to the default threshold (AUC > 0.7). Overall, these results confirmed the model to be reliable, well-calibrated, and highly effective and therefore suitable for clinical risk assessment and research.

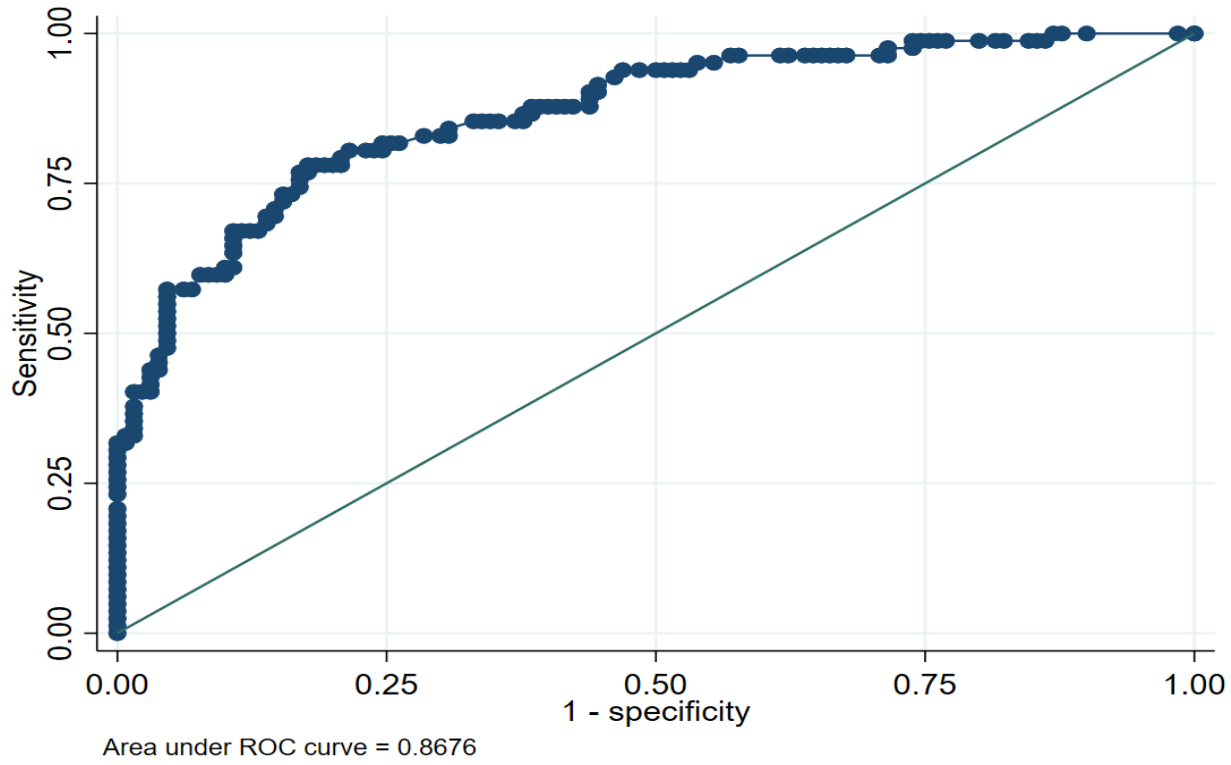

Figure 6: Area under ROC of the multivariate logistic regression result of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

Logistic regression modelling was implemented to ascertain independent predictors of postoperative metabolic acidosis. The analysis began with a univariate logistic regression to identify possible candidate variables and their unadjusted association with the outcome. A liberal significance level of $p < 0.25$ was used during the preliminary univariate screening process so that variables with limited and potentially significant associations could be included in the subsequent multivariate logistic regression. The unadjusted variables of clinical interest included **Diabetes Mellitus, Hypertension, Chronic Kidney Disease, Surgical Procedure, Surgery Duration, Post-CPB Hemoglobin, Previous Cardiac Surgery, CPB time, Aortic Cross-Clamp-time, and Intraoperative Blood Transfusion.**

The subsequent multivariable logistic regression model was constructed to assess the independent effects of these variables and control for any confounding variables. Diabetes Mellitus was identified as a significant risk factor with the adjusted odds ratio (AOR) being 3.64 (95% CI: 1.14, 11.59), $p = 0.029$ meaning patients with diabetes had 3.64 times higher odds of developing postoperative metabolic acidosis than patients without diabetes after adjusting for the covariates. Longer duration of surgery was also independently associated with increased odds of postoperative

metabolic acidosis (AOR: 4.43, 95% CI: [1.17, 16.68], p = [0.028]). This indicates that a surgical case that exceeded 4 hours then had almost 4.5 times greater odds of acidosis.

Furthermore; Lower post-CPB hemoglobin levels were independently associated with higher odds of postoperative metabolic acidosis (AOR: 0.10, 95% CI: [0.02, 0.46], p = [0.003]). This means that having a post-CPB hemoglobin greater than 10 g/dl, on average patients are 90% less likely to develop metabolic acidosis postoperatively. Finally, longer cardiopulmonary bypass (CPB) time were independently associated with higher odds of postoperative metabolic acidosis (AOR: 5.92, 95% CI: [1.08, 32.30], p = [0.040]). This finding shows those patients with CPB duration more than 180 minutes had 5.92 times more risk of developing postoperative metabolic acidosis.

Table 3: Multivariate logistic regression analysis of factors associated with postoperative metabolic acidosis of patients who undergone open heart surgery under cardiopulmonary bypass at TASH and CCE, Addis Ababa, Ethiopia, June 2025 (n=212)

Variables	Category	PMA (count)		Univariate	Multivariate
		No	Yes		
Age	≤ 18 years	79	45	1	-
	> 18 years	51	37	1.27 [0.72, 2.22]	-
Sex	Male	65	38	1	-
	Female	65	44	1.15 [0.66, 2.01]	-
BMI	< 18.5 kg/m^2	69	40	1	-
	18.5-24.9 kg/m^2	48	25	0.89 [0.48, 1.64]	-
	25-29.9 kg/m^2	13	15	1.99 [0.86, 4.60]	-
	≥ 30 kg/m^2	0	2	1 [-, -]	-
DM	No	121	57	1	1
	Yes	9	25	5.89 [2.58, 13.44]	**3.64 [1.14, 11.59]**
HTN	No	126	70	1	1
	Yes	4	12	5.4 [1.67, 17.37]	6.91 [0.97, 49.15]
Pulmonary HTN	Yes	68	48	1	-
	No	62	34	0.77 [0.44, 1.35]	-
CKD	Yes	1	3	1	1
	No	129	79	0.20 [0.02, 1.99]	1.31 [0.05, 31.75]
LVEF	≤ 30%	1	3	1	-
	30-50%	13	17	0.43 [0.04, 4.68]	-
	> 50%	116	62	0.17 [0.01, 1.74]	-
Duration of surgery	< 2 hours	46	7	1	1
	2-4 hours	61	25	2.69 [1.07, 6.76]	0.88 [0.26, 2.98]
	> 4 hours	23	50	14.28 [5.60, 36.42]	**4.46 [1.17, 16.68]**

Intraoperative temperature	< 20 ^{0}C	1	1	1	-
	20-28 ^{0}C	1	2	2 [0.05, 78.24]	-
	28-32 ^{0}C	51	58	1.13 [0.06, 18.64]	-
	> 32 ^{0}C	77	21	0.27 [0.02, 4.54]	-
Surgical Procedure	ASD	38	8	1	1
	VSD	50	20	1.9 [0.75, 4.77]	1.89 [0.55, 6.47]
	TOF	1	4	19 [1.86, 193.36]	7.31 [0.38, 140.87]
	SAM	5	4	3.8 [0.83, 17.37]	3.87 [0.56 ,26.33]
	AVR	4	6	7.12 [1.62, 31.20]	0.34 [0.03, 3.44]
	MVR	14	18	6.10 [2.17, 17.17]	1.72 [0.41, 7.24]
	DVR	5	7	6.65 [1.67, 26.37]	0.43 [0.06, 2.85]
	CABG	1	4	19 [1.86, 193.36]	2.73 [0.12, 58.26]
	Aortic Aneurysm	2	4	9.5 [1.47, 61.07]	0.31 [0.02, 4.11]
	Other	10	7	3.32 [0.97, 11.38]	2.96 [0.63, 13.70]
Postoperative glucose level	< 126 g/dl	7	3	1	-
	126-200 g/dl	80	35	1.02 [0.24, 4.17]	-
	> 200 g/dl	43	44	2.38 [0.57, 9.84]	-
Post-CPB Hemoglobin	≤ 7.9 g/dl	8	14	1	1
	8-9.9 g/dl	53	43	0.46 [0.17, 1.20]	0.23 [0.05, 0.93]
	> 10 g/dl	69	25	0.20 [0.07, 0.55]	**0.10 [0.02, 0.46]**
Previous surgery	Yes	1	6	1	1
	No	129	76	0.09 [0.01, 0.83]	0.23 [0.01, 3.95]
CPB time	< 90 minutes	63	10	1	1
	90-180 minutes	54	40	4.66 [2.13, 10.20]	3.78 [1.02, 13.95]
	> 180 minutes	13	32	15.50 [6.13, 39.21]	**5.92 [1.08, 32.30]**
ACC time	< 60 minutes	79	17	1	1
	60-90 minutes	33	25	3.52 [1.68, 7.36]	1.03 [0.30, 3.53]
	> 90 minutes	18	40	10.32 [4.80, 22.17]	2.59 [0.63, 10.51]
Priming fluid	Crystalloid	90	48	1	-
	Blood product	38	36	1.10 [0.61, 1.99]	-
Intraoperative blood transfusion	None	114	65	1	1
	≤ 2 units	15	14	1.63 [0.74, 3.60]	0.79 [0.23, 2.73]
	> 2 units	1	3	5.26 [0.53, 51.62]	6.63 [0.39, 111.95]

CHAPTER SIX: DISCUSSION

Annually, almost 2 million cardiac surgeries are performed around the world, which reflects the enormous burden of cardiovascular disease. While surgical techniques and perioperative care have improved significantly over the past several decades, cardiac surgery still carries a considerable risk of mortality (2% to 6%) and a reasonable risk of postoperative complications(24). Hypoperfusion and increased lactate level are frequently attributed to metabolic acidosis in a patient under bypass. Recently there is increasing evidence that demonstrates metabolic acidosis is not solely due to perfusion, but also there are many competing factors (i.e., operative time, fluid composition, CPB time, etc.) that contribute to the acidemia(25).

This study focused on both prevalence and association between patient related factors, intraoperative and surgical related factors, and cardiopulmonary related factors with postoperative metabolic acidosis in TASH and CCE using patient data from January 2021 to Dec 2024. The prevalence of postoperative metabolic acidosis among patients who underwent open-heart surgery under cardiopulmonary bypass is 38.68% (95% CI 32.08–45.49). This correlates with the a retrospective study done at the Tristate Heart and Vascular Center in Nigeria(23). From the types of surgical procedure done TOF and CABG have the highest proportion with 70% followed by Aortic Aneurysm surgery while ASD and VSD were the least to develop postoperative metabolic acidosis.

The findings suggest that diabetes mellitus, with an adjusted odds ratio (AOR) of 3.64 (95% CI: 1.14, 11.59; $p = 0.029$), is a significant risk factor for developing postoperative metabolic acidosis. This AOR of 3.64 means that, after accounting for other possible confounding factors, patients with diabetes have a 3.64 times higher risk of experiencing metabolic acidosis after surgery compared to those without diabetes. It's crucial to make this adjustment because it shows that the link isn't influenced by other measured variables, indicating a distinct and independent relationship between diabetes and postoperative metabolic acidosis. This finding aligns a retrospective observational cohort study, with 121 adults with type 2 diabetes and 83 control group, done at Bergen, Norway in 2024 which stated that, 12 hours post-surgery, 41% of diabetic patients (without renal failure) had BE $\leq$ -3 mmol/L (indicating ketosis) vs. 8% of controls ($P < 0.001$)(26). Furthermore; it also align with an observational study conducted in Spain back in 2011(27).

From a clinical perspective, this result implies that diabetes mellitus is a relevant risk factor for a severe theoretical postoperative complication and can be the result of disruptions in glucose metabolism due to reduction in the production of insulin or the effects of chronic microcirculatory damage to organ system. Thus, diabetic patients following cardiac surgical intervention can only be watched more cautiously by preoperative glucose control and postoperative scrutiny of acid-based conditions. The discovery is essential not only because it opens up opportunities for targeted preventive measures, but also emphasizes the critical aspect of proper diabetes care in surgical patients. This development is not only statistically significant but also clinically relevant and methodologically sound.

Increased operative time (i.e., greater than 4 hours) is associated with increased risks of postoperative metabolic acidosis, which was characterized by an adjusted odds ratio (AOR) of 4.43, 95% CI: [1.17, 16.68], p = [0.028]. An AOR of 4.43 indicates that, after adjustment for confounding variables, longer than 4-hour surgeries have approximately four and half the risk of metabolic acidosis compared to surgeries lasting less than 2 hours. This finding is corroborated by a prospective observational study carried out on 109 patients at Kottayam, India in the year 2018, which found that patients who had surgery lasting over 4. hrs vs the surgical time of 2-3 hours were found to have 94.9% vs 60.5% metabolic acidosis (10) and an article published by Cleveland Clinic Foundation (28).

This is probably because of a cumulative physiological insult from extended cardiopulmonary bypass, including tissue hypoperfusion, inflammatory activation, and impaired acid clearance. Clinically, prolonged surgery is known to increase physiological stress: extended anesthesia, tissue trauma, fluid/electrolyte shifts, hypoperfusion, cellular metabolism, or blood loss can disrupt acid-base homeostasis by impairing renal or respiratory compensation or accumulating metabolic wastes (e.g., lactic acid). This finding aligns with broader evidence that longer procedures elevate the risks of multiple postoperative complications that can exacerbate organ dysfunction, delay recovery, or require intervention.

Hemoglobin levels immediately after cardiopulmonary bypass (CPB) demonstrated a profound association with postoperative metabolic acidosis. Patients having hemoglobin levels >10 g/dL exhibited 90% lower adjusted odds of acidosis (AOR 0.1; 95% CI: [0.02, 0.46], p = 0.003) compared to their anemic counterparts. One of the many reasons why this could be is that,

whenever post-CPB hemoglobin is low, tissues (especially those stressed by surgery) cannot receive adequate oxygen. This forces cells to switch to anaerobic metabolism (energy production without oxygen), which generates lactic acid as a toxic end product(29)(22).

The study identified a significant correlation between longer cardiopulmonary bypass (CPB) times with elevated risk of postoperative metabolic acidosis. Specifically, the adjusted odds ratio (AOR) of 5.92, 95% CI: [1.08, 32.30], with a p-value of 0.04 indicates that patients who underwent open heart surgery under CPB for more than 180 minutes had nearly six times higher odds of developing postoperative metabolic acidosis compared to those with shorter CPB durations. This finding is consistent with the studies done in the United Kingdom, Italy, Brazil, and India(25)(30)(9)(21). For instance, the study done in India stated that patients with acidosis had significantly longer CPB time (92.40 ± 26.0 vs. 83.96 ± 28.18 min; P = 0.003). Furthermore; the paper done in Italy which consisted 500 open heart surgical patients also stated that, extended cardiopulmonary bypass time is associated with acidosis with AUC=0.80 (95 CI; 0.68–0.89) P value of 0.001.

One reason could be that, the effect of CPB on the body's microcirculation is related to prolonging CPB periods. Even when systemic perfusion is normal, constricted or permeable small vessels can decrease tissue oxygenation. Second, CPB activates the body's inflammatory response (via contact of blood with the bypass circuit), causes endothelial damage, and disrupts coagulation. Finally, the kidneys and lungs are two critical organs in the physiological process that regulates the acid-base balance. Prolonged CPB typically injures renal function (acute kidney injury, or AKI) by reducing perfusion to the kidneys, decreasing their ability to excrete acid. Similarly, lung injury secondary to bypass (e.g., "post-pump lung") disrupts the elimination of carbon dioxide, worsening metabolic acidosis.

Perfusionist-driven strategies including leukocyte filtration, usage of anti-inflammatory medications, minimized circuit volume, and avoidance of deep hypothermia could decrease the effect of prolonged cardiopulmonary bypass time on metabolic acidosis.

CHAPTER SEVEN: CONCLUSION

This study assessed the prevalence and risk factors of postoperative metabolic acidosis after open-heart surgery with cardiopulmonary bypass (CPB) at two institutions, from 2021 to 2024 G.C. One of the key baseline findings was the 38.68% (95% CI: 32.08–45.49) occurrence of metabolic acidosis, a result consistent with previous worldwide research and demonstrating persistent burden of this complication in cardiac surgery.

Four risk factors were independently identified to significantly elevate the risk of acidosis: diabetes mellitus (a 264% rise in risk; AOR 3.64, p=0.029), surgery time greater than four hours (more than four times the risk; AOR 4.43, p=0.028), reduction in hemoglobin after CPB (<10 g/dL; 90% rise in risk in anemic patients; AOR 0.10, p=0.003), and longer CPB time (>180 minutes; 5.92 times increased risk; AOR 5.92, p=0.04). The four risk factors for patient co-morbidity (diabetes), procedural severity (surgery/CPB duration), and physiological disturbances in the patient (post-CPB anemia) have varied causal mechanisms for the development of acidosis. For instance, through diabetes-mediated metabolic derangements, to ischemia-associated lactic acidosis (low hemoglobin), and additive inflammatory/renal stress (prolonged CPB).

CHAPTER EIGHT: STRENGTH AND LIMITATION OF STUDY

This study has a limitation in some aspects. This is a retrospective study design which reliance on historical medical records and could introduce potential gaps in data completeness and accuracy. Furthermore; Critical confounders like nutritional status, inflammatory biomarkers (e.g., IL-6), and perioperative medication use (e.g., vasopressors, insulin protocols) were not analysed due to data scarcity. Finally, the data did not have some important variables like; Infection and electrolyte results.

The study has a good strength and quality. It uses a well calibrated and fitted model to assess the prevalence and associated factors to postoperative metabolic acidosis. Even if the statical analysis method accounts for the known confounders, the study attempted to use rigorous statistical regression analysis to control for confounders. Additionally, the research is conducted in multicenter setup. Finally, the study also used logistic regression analysis model to identify the association degree to the best possible way.

CHAPTER NINE: RECOMMENDATION

Recommendation for Health Professionals (Perfusionist and Cardiac case team)

Perfusionists and cardiac care units play a role in reducing the risk of postoperative metabolic acidosis (PMA) through some measures. They should attempt to maintain hemoglobin levels >10 g/dL by conserving blood intraoperatively and restricting fluid administration. Since longer cardiopulmonary bypass (CPB) times (>180 minutes) increase the risk of PMA, coordination with surgeons to shorten procedures is required. Further, maintaining a tight control of blood sugar levels in diabetics and serially monitoring acid-base status, i.e., lactate levels, will identify problems early. Problem risk of PMA can be significantly minimized and patient outcomes can be enhanced with these measures.

Recommendation for Researchers

This study indicates key aspects of future research for postoperative metabolic acidosis (PMA) following cardiac surgery. First, established risk factors like diabetes, long operation, anemia, and long CPB must be studied in larger trials, especially in low-resource settings. Second, we should explore how these factors result in PMA, e.g., how diabetes causes increased acidosis beyond hyperglycemia and how anemia affects tissue oxygenation. Trials must also evaluate methods of reducing PMA, including the comparison of surgical interventions and maximizing lactate clearance. Finally, long-term studies must determine if reducing PMA yields better outcomes, like decreased kidney injury or death rates. Collaborating with research networks can also permit knowledge dissemination.

Recommendation for Health Sector Stakeholders

Stakeholders must institute measures to reduce postoperative metabolic acidosis (PMA) in cardiac surgery. This means improving point-of-care testing and blood bank facility infrastructure, developing guidelines for blood glucose control and CPB performance, and perfusionist and cardiac staff education. In low-resource environments like Ethiopia, local production of balanced crystalloids and non-physician perfusionist training become critical. Improving data systems for monitoring PMA outcomes and collaboration with international organizations will also improve cardiac care.

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ANNEX I: INFORMATION SHEET

Title of the Research Project: Assessment of prevalence and associated factors with post-operative metabolic acidosis patients who underwent open heart surgery in addis ababa, ethiopia: a multicenter retrospective cross-sectional study

Name of Principal Investigator: Mr. Dagim Adane

Name of the Organization: Addis Ababa University, College of Medicine, Department of Cardiology.

Introduction: Greetings! My name is Dagim Adane. I am a student at Addis Ababa University College of Medicine Department of Cardiology in MSc in Cardiovascular Perfusion. As part of this degree, I am undertaking a research project "**Assessment of prevalence and associated factors with post-operative metabolic acidosis patients who underwent open heart surgery in Addis Ababa, Ethiopia: a multicenter retrospective cross-sectional study."**

Purpose of the Research Project: The aim of this study to assess the prevalence and associated factors of post-operative metabolic acidosis among patients who undergone open cardiac surgery at TASH and CCE from 2021-2024. The information gained from this research will be used to minimize perioperative complications and improving patient outcomes and to select the best alternative solution.

Procedure: The data collection will be conducted in Tikur Anbesa Specialized Hospital (TASH) and Cardiac Center of Ethiopia (CCE). Standard questioner is prepared to collect necessary information from patient, chart and from the monitoring device used in the operation room.

Risk and /or Discomfort: The data will be taken from patient medical records, so it will not impose any harm on patients.

Confidentiality: During data collection the patients name will not be taken, instead they will be identified by their card number in the chart. All questionaries collected will be kept confidential and destroyed two years after the end of the project. The information collected will be used only for research purpose. The thesis will be submitted for marking to Addis Ababa

University College of Medicine Department of Cardiology and displayed in the University Library and website. This study is also intended to be submitted for publication in scholarly journals.

Right to Refusal or Withdraw: Approval of the manager of the hospital and participant will be required to start data collection.

Person to contact: If you have any further questions or would like to receive further information about the project, please contact:

1. Dagim Adane (Principal investigator): +251945467840
2. Prof. Birhanu Nega (MD, Cardiothoracic Surgeon) (Advisor): +251911217472

ANNEX II: CHECKLIST

Date: ___/____/__

Code. _____

Instruction: For each of the questionaries, please Encircle the Letter that fit the response and/or provide appropriate response accordingly.

PART I: Questions on socio-demographic and patient status

Sr.no	Questions	Response	Code
101	Hospital	_____	
102	MRN	_____	
103	Age(years)	A. <18 years B. >18 years	
104	Sex(M/F)	A. Male B. Female	
105	BMI	A. <18.5 kg/m^2 B. 18.5-24.9 kg/m^2 C. 25-29.9 kg/m^2 D. ≥30 kg/m^2	
106	Diagnosis	_____	
107	Post-CPB Anemia	A. Normal (>12.5g/dl) B. Mild (12.5-10g/dl) C. Moderate (8-9.9g/dl) D. Severe (<7.9g/dl)	
108	DM	A. YES B. NO	
109	CKD	A. YES B. NO	

110	Previous cardiac surgery	A. YES B. NO	
111	HTN	A. YES B. NO	
112	LVEF	A. <30% B. 30-50% C. >50%	

PART II. Questions about surgical and intra-operative characteristics

Sr.no	Question	Response	Code
201	Surgical procedure done	_____	
202	Duration of Surgery	A. <2 hours B. 2-4 hours C. >4 hours	
203	Postoperative Glucose Level	A. <126 g/dl B. 126-200 g/dl C. >200 g/dl	
204	Intraoperative CBP Temperature	A. >32 ˚C B. 32-28 ˚C C. 28-20 ˚C D. <20 ˚C	

PART III. CPB related parameter measurements.

Sr.no	Question	Response	Code
301	CPB time	A. ≤90 min B. 90-180 min C. >180 min	

302	ACC time	A. ≤60 min B. 60-90 min C. >90 min	
303	Priming Fluid	A. RL B. Blood Product	
304	Intraoperative Blood Transfusion	A. 1 unit B. 2-4 unit C. >4 unit	
305	Postoperative pH Level	A. <7.35 B. 7.35–7.45 C. >7.45	
306	Postoperative Lactate Level (mmol/L)	A. ≤2.0 mmol/L B. 2.1–3.9 mmol/L C. ≥4.0 mmol/L	
307	Postoperative Base Excess	A. −2 to +2 mmol/L B. ≤ −3 to > −6 mmol/L C. ≤ −6 to > −10 mmol/L D. ≤ −10 mmol/L	
308	Postoperative Bicarbonate level	A. <22 mEq/L B. 22–28 mEq/L C. >28 mEq/L	
309	Postoperative PCO_2	A. < 35 mmHg B. 35-45 mmHg C. > 45 mmHg	