International Journal of Cardiovascular and Thoracic Surgery
2026, Vol. 12, No. 2, pp. 28–32
https://doi.org/10.11648/j.ijcts.20261202.12

Research Article

Profile and Predictive Factors of Postoperative Lactic Acidosis in Pediatric Cardiac Surgery Under Extracorporeal Circulation

Elhadji Boubacar Ba[1, 2, *], Papa Amath Diagne[1], Ibrahima Gaye[1], Papa Ibrahima Ndiaye[1], Marie Victoire Sene[2], Abdoulaye Gueye[2], Ulimata Diop[2], El Hadji Malick Diao[2], Etienne Birame Sene[2], Oumar Kane[1, 2]

[1]Department of Anesthesia-Resuscitation, Cheikh Anta Diop University Faculty of Medicine, Dakar, Senegal

[2]Department of Anesthesia-Resuscitation, Fann Hospital, Dakar, Senegal

Abstract

This retrospective study analyzed the profile and predictors of lactic acidosis (LA) in 32 pediatric patients (ages 0-18) following cardiac surgery under cardiopulmonary bypass (CPB). LA was defined as arterial lactate > 2 mmol/L with pH < 7.35 upon ICU admission. Data included demographic, preoperative (EF, TAPSE, creatinine), and intraoperative parameters (CPB duration, cross-clamp time, vasoactive amines). Statistical analysis sought correlations between these factors and LA occurrence. The incidence of LA was 15.6% (5/32). The cohort (mean age 9.8 years, 65.6% male) showed preserved preoperative cardiac function. Surgery was equally split between valvular and congenital heart disease. Mean CPB duration was 110 minutes, with hypothermia used in 81.3% of cases and sympathomimetics in 78.1%. Analysis revealed no significant association between LA and demographic factors, preoperative parameters, or intraoperative data (type of surgery, CPB/clamp duration, amines). However, a non-significant trend showed 4 out of 5 LA cases occurred after congenital heart surgery. Clinically, LA was significantly correlated with a longer ICU stay (mean 3.75 vs. 2.77 days). No significant link was found with overall mortality (6.3%). In this pediatric series, postoperative lactic acidosis, while relatively infrequent, is associated with prolonged ICU stays. The absence of clear preoperative or intraoperative risk factors highlights the multifactorial complexity of this metabolic complication, necessitating vigilant postoperative monitoring.

Keywords

Lactic Acidosis, Pediatric Cardiac Surgery, Extracorporeal Circulation

1. Introduction

Pediatric cardiac surgery with cardiopulmonary bypass (CPB) induces complex metabolic disturbances, foremost among them metabolic acidosis. This phenomenon results from the non-physiological nature of CPB, whose perfusion abnormalities can persistently alter tissue homeostasis [1, 2]. In this postoperative context, lactate levels have become a key

*Correspondence: Elhadji Boubacar Ba (elhadjiboubacar.ba@ucad.edu.sn)

Received: 25 January 2026; **Accepted:** 28 February 2026; **Published:** 10 March 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

prognostic biomarker, reflecting the critical balance between tissue oxygen supply and consumption [3]. Early hyperlactatemia frequently indicates an oxygen debt accumulated during the perioperative phase [2]. The most recent studies published in 2025 highlight that the duration of CPB directly influences the emergence of hyperlactatemia, including in late manifestations [4]. Furthermore, data from 2026 confirm that lactate kinetics, particularly through serial measurements, has superior predictive value for the early identification of patients at risk of major complications or prolonged stays in intensive care [5]. Despite its documented clinical importance, managing these imbalances remains a major therapeutic challenge. Therefore, this retrospective study was conducted to evaluate the incidence of lactic acidosis after cardiopulmonary bypass (CPB) in our department and to identify the perioperative risk factors specifically correlated with this metabolic disturbance in our population.

2. Patients and Methods

We conducted an observational, descriptive, and retrospective study at the Cardiac Surgery Center of the Fann University Hospital in Dakar, Senegal. The study covers the period from January 2, 2022, to June 30, 2025.

The study included all patients aged 0 to 18 years who underwent elective cardiac surgery with cardiopulmonary bypass. Patients who died during the perioperative period, those with incomplete medical records, and those with pre-existing metabolic disease were excluded.

Lactic acidosis (the primary variable) was defined as an arterial lactate level > 2 mmol/L associated with a pH < 7.35 upon admission to the ICU [1, 5]. Explanatory variables included demographic data (age, sex), preoperative parameters (EF, TAPSE, hemoglobin, GFR), and intraoperative data (duration of cardiopulmonary bypass, duration of aortic clamping, minimum temperature). Arterial blood gas parameters (pH, HCO3-, lactate) were systematically collected within the first hour following admission to the ICU.

Data were extracted from electronic medical records and anesthesia and resuscitation monitoring sheets using a standardized data collection form. Data entry and statistical analysis were performed using Sphinx Plus2 (V5) software. Quantitative variables are expressed as mean (±standard deviation) or median (interquartile range), and qualitative variables as counts and percentages. Logistic regression was applied to identify independent risk factors (significance threshold $p < 0.05$).

3. Results

3.1. Descriptive Results

The observational study was conducted on a sample of 32 patients.

3.1.1. Demographic Characteristics and Preoperative Parameters

The mean age of the cohort was 9.82 years (median: 11.50 years), with a range from 0.08 to 17.00 years. The age distribution revealed that only 2 patients (6.3%) were under 2 years old. There was a male predominance, with boys representing 65.6% (n=21) of the cohort, compared to 34.4% girls (n=11).

In terms of preoperative cardiac and biological functional assessment, the mean left ventricular ejection fraction (LVEF) was 66.97% (median: 68.00%), with a range of 47.00% to 81.00%. Nearly one-third of the patients (31.3%, n=10) had an LVEF of 72% or higher. The mean TAPSE (estimated right ventricular function) was 20.94 mm (median: 20 mm), with a range of 13 mm to 37 mm. The mean hemoglobin (Hb) level was 13.38 g/dL (median: 12.45 g/dL), with a range of 7.50 g/dL to 24.00 g/dL. Finally, the mean serum creatinine was 6.91 mg/L (median: 6.85 mg/L), ranging from 1.80 to 12 mg/L.

3.1.2. Intraoperative Data

The procedures were equally divided between valve surgery (n=16, 50.0%) and congenital heart surgery (n=16, 50.0%). The mean duration of cardiopulmonary bypass (CPB) was 110.28 minutes (median: 97.00 minutes), with a range of 55.00 to 252.00 minutes. Sixty-eight point eight percent (68.8%, n=22) of patients received CPB for less than 120 minutes. The mean duration of aortic clamping was 81.53 minutes (median: 72.50 minutes), with a range of 24 to 193 minutes.

Regarding the minimum temperature during cardiopulmonary bypass (CPB), hypothermia was the predominant thermal strategy, used in 81.3% of patients (n=26). Sympathomimetics were administered intraoperatively in 78.1% of patients (n=25). Individual analysis of sympathomimetics (see Table 1) reveals a majority use of norepinephrine (NAD, 78.1%), followed by milrinone (50.0%). The combination of NAD and milrinone was the most frequent regimen, used in 48.0% of patients receiving amines (see Table 2).

Table 1. *Distribution according to individual use of sympathomimetics.*

Sympathomimetic	Effective	Percentage (%)
NAD	25	78.1
Milrinone	16	50.0
Adrenaline	3	9.4
Dobutamine	2	6.3

Table 2. Distribution of patients according to the combination of sympathomimetics.

Sympathomimetic Association	Effective	Percentage (%)
NAD alone	8	32.0
NAD+Milrinone	12	48.0
NAD+Dobutamine	1	4.0
NAD+Dobutamine+Milrinone	1	4.0
NAD+Adrenaline+Milrinone	3	12.0
No sympathomimetics	7	21.9
Total	39	100

3.1.3. Immediate Postoperative Arterial Blood Gas Data

Biological measurements performed immediately postoperatively produced the following results:

1) pH: The mean pH was 7.34 (median: 7.35), with a range of 7.14 to 7.49.
2) Bicarbonates (HCO3-): The mean level was 25.09 mmol/L (median: 25.05 mmol/L), ranging from 13.70 to 29 mmol/L.
3) Lactates: The mean lactate level was 1.98 mmol/L (median: 1.72 mmol/L), with extreme values from 0.40 to 6.21 mmol/L.

The incidence of lactic acidosis (as defined in the study) was 15.6% (5 out of 32 patients).

3.1.4. Clinical Evolution in Intensive Care

Regarding ventilation and length of stay, two patients (6.3%) died, while 28 patients (87.5%) were extubated in the ICU and 2 patients (6.3%) in the operating room. The mean time to extubation for patients extubated in the ICU was 5.32 hours (median: 3.00 hours), with a range of 1 to 24 hours. The mean length of stay in the ICU was 2.90 days (median: 2.00 days), ranging from 1 to 9 days.

The final prognosis shows that the overall survival rate of the cohort was 93.8% (n=30), and the death rate was 6.3% (n=2).

3.2. Analytical Results

3.2.1. Risk Factor Analysis

(i). Correlation with Demographic and Preoperative Data

Statistical tests did not reveal any significant relationship between the incidence of lactic acidosis and preoperative demographic or clinical variables. Regarding age, no significant difference was observed between the mean age of patients who developed lactic acidosis (9.00 years) and that of non-lactose patients (9.97 years). Fisher's exact test confirmed this lack of statistical significance (p = 26.60%). Similarly, the sex distribution was not significantly associated with lactic acidosis ($\chi^2 = 0.08$, p = 22.69%).

Preoperative cardiac and biological parameters also did not show a significant correlation: preoperative LVEF (1-p = 68.24%), TAPSE (1-p = 67.35%), hemoglobin level (1-p = 36.63%) and serum creatinine (1-p = 75.73%) are not statistically reliable predictors of lactic acidosis in this series.

(ii). Correlation with Intraoperative Data

Parameters related to the surgical intervention also did not reveal a significant dependence on lactic acidosis. The type of surgery (valvular versus congenital heart disease) was only slightly significant ($\chi^2 = 2.13$, 1-p = 85.59%). However, a descriptive trend (not statistically significant) was noted: 4 cases of acute lactic acidosis occurred after surgery for congenital heart disease compared to only 1 after valvular surgery.

Although patients who developed acute aortic stenosis (AL) had a longer mean cardiopulmonary bypass (CPB) duration (134.80 minutes) than non-acidic patients (105.74 minutes), this difference was not statistically significant (p = 77.81%). Similarly, the mean aortic clamping time was longer in patients with AL (94.80 minutes) than in the others (79.07 minutes), but this difference did not reach statistical significance (p = 55.34%). Thermal management (normothermic or hypothermic) and the use of sympathomimetics (amines) during surgery were also not significantly associated with the incidence of AL (p = 75.78% and p = 80.23%, respectively).

3.2.2. Correlation with Clinical Evolution

Analysis of the relationship between the incidence of lactic acidosis (LA) and clinical evaluation criteria showed the following results:

Length of stay: Although there was no statistically significant dependence (1-p = 63.80%), patients with AL had a numerically longer average length of stay in intensive care (3.75 days) than those without AL (2.77 days).

Mortality: The relationship between the incidence of AL and the final outcome (survival or death) was not statistically significant (Chi2 = 1.91; 1-p = 83.33). Of the five patients affected by AL, four survived and one died.

4. Discussion

The incidence of 15.6% reported here is at the lower end of the range reported in the literature on pediatric cardiac surgery, where rates of postoperative hyperlactatemia or lactic acidosis vary considerably, from 10% to over 40%, depending on the definitions used and the populations studied [6, 7]. The restrictive definition adopted (association of elevated lactate and acidemia) may explain this relatively low figure, as it focuses on the most biologically severe forms, as opposed to studies

that only consider isolated hyperlactatemia.

The major finding of this study is the absence of a significant correlation between lactate level and all the demographic, preoperative (ejection fraction, TAPSE, hemoglobin, serum creatinine), and intraoperative (duration of cardiopulmonary bypass, aortic clamping, thermal strategy, use of vasopressors) factors tested. This lack of signal contrasts with numerous studies that identify duration of cardiopulmonary bypass, preoperative hemodynamic status, or intraoperative hypoperfusion as key determinants of post-cardiopulmonary bypass hyperlactatemia [8, 9]. Several hypotheses can explain this. First, the limited sample size (n=32) and the small number of events (n=5) give the analysis very low statistical power, making a high risk of type II error (failure to detect a difference that exists) highly probable. The observed differences in mean cardiopulmonary bypass (CPB) duration, such as longer cardiopulmonary bypass (CPB) duration in patients with local anesthesia (LA) (134.8 vs. 105.7 minutes), could become significant in a larger cohort. Second, the study population was relatively homogeneous and in good preoperative condition (mean LVEF 67%, few infants <2 years), which could mitigate the impact of common risk factors. Finally, standardized intraoperative management (predominant hypothermia, frequent use of norepinephrine and milrinone) may have homogenized the risk.

Although not statistically significant, the descriptive trend showing 4 cases of AL out of 16 in the congenital heart disease group versus 1 out of 16 in the valvular group warrants attention. Surgeries for complex congenital heart disease are often associated with longer cardiopulmonary bypass times and greater physiological disturbances, known risk factors for hyperlactatemia [10].

Our study revealed a trend toward a numerically longer mean length of stay in the intensive care unit (ICU) for patients with lactic acidosis (LA), although this association did not reach statistical significance. This finding is consistent with data from the literature, which generally associate postoperative hyperlactatemia with increased morbidity, prolonged mechanical ventilation, and longer hospital stays [11, 12]. This phenomenon could reflect more severe underlying organ dysfunction or slower hemodynamic recovery.

In our limited sample, AL thus appears more as an indirect marker of peri- or postoperative clinical severity than as an entity with clearly identified specific causes. The lack of a statistically significant link between AL and mortality is most likely attributable to the low statistical power of the study.

5. Conclusion

In conclusion, this retrospective study did not identify any significant pre- or intraoperative risk factors for postoperative lactic acidosis in a small cohort of pediatric cardiac surgery patients, most likely due to a lack of statistical power. It does, however, confirm that the occurrence of lactic acidosis is associated with a longer stay in the intensive care unit, making it a marker of clinical interest. These preliminary results need to be validated by larger prospective studies, incorporating dynamic analysis of lactate levels and hemodynamic parameters, to better understand, predict, and prevent this complication.

Abbreviations

AL	Lactic Acidosis
CEC	Cardiopulmonary Cardiovascular Surgery
CHU	University Hospital Center
GFR	Glomerular Filtration Rate
EF	Ejection Fraction
LVEF	Left Ventricular Ejection Fraction
Hb	Hemoglobin
HCO3-	Bicarbonates
NAD	Norepinephrine
pH	Potential of Hydrogen
SvO2	Venous Oxygen Saturation
TAPSE	Tricuspid Annular Plane Systolic Excursion

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Hatherill M, Salie S, Waggie Z, Lawrenson J, Hewitson J, Reynolds L et al. Hyperchloraemic metabolic acidosis following open cardiac surgery. Arch Dis Child December 2005; 90(12): 1288-92. https://doi.org/10.1136/adc.2005.078006

[2] Nasr VG, Staffa SJ, Boyle S, Regan W, Brown M, Smith-Parrish M, et al. Predictors of increased lactate in neonatal cardiac surgery. J Cardiothorac Vasc Anesth. 2021 Jan; 35(1): 148-153. https://doi.org/10.1053/j.jvca.2020.06.009

[3] Bowers PJ, Daley M, Shrimpton NYR, et al. Hyperlactataemia Following Crystalloid Cardiopulmonary Bypass Prime in Pediatric Cardiac Surgery: A Retrospective Cohort Study. Children (Basel). 2024; 11(11): 1379. https://doi.org/10.3390/children11111379

[4] Tüzün B, Ergün S, Özalp Ş, Önalan MA, Tan Recep BZ, Recep E, et al. Effect of cardiopulmonary bypass on late-onset hyperlactatemia after pediatric cardiac surgery. Turkish Journal of Thoracic and Cardiovascular Surgery. 2025; 33(1): 27-35. https://doi.org/10.5606/tgkdc.dergisi.2025.26627

[5] Sanchez-Felix E, Olivera-Mar A, Santaularia-Tomas M, Johnson-Herrera J, Ortiz-Vera L, Perez-Navarrete A, et al. Prognostic value of serial lactate measurement in pediatric cardiac surgery patients with congenital heart disease in southeastern Mexico. Med. Sci. 2026; 14(1): 35. https://doi.org/10.3390/medsci14010035

[6] Duke T, Butt W, South M, Karl TR. Early markers of major adverse events in children after cardiac operations. J Thorac Cardiovasc Surg. 1997 Dec; 114(6): 1042-52. https://doi.org/10.1016/S0022-5223(97)70018-7

[7] Cheung PY, Chui N, Joffe AR, Rebeyka IM, Robertson CM. Postoperative lactate concentrations predict the outcome of infants aged 6 weeks or less after intracardiac surgery: a cohort follow-up to 18 months. J Thorac Cardiovasc Surg. 2005 Sep; 130(3): 837-43. https://doi.org/10.1016/j.jtcvs.2005.04.029

[8] Rossi AF, Khan DM, Hannan R, Bolivar J, Zaidenweber M, Burke R. Goal-directed medical therapy and point-of-care testing improve outcomes after congenital heart surgery. Intensive Care Med. 2005 Jan; 31(1): 98-104. https://doi.org/10.1007/s00134-004-2504-1

[9] Ranucci M, De Toffol B, Isgrò G, Romitti F, Conti D, Vicentini M. Hyperlactatemia during cardiopulmonary bypass: determinants and impact on postoperative outcome. Crit Care. 2006; 10(6): R167. https://doi.org/10.1186/cc5113

[10] Charpie JR, Dekeon MK, Goldberg CS, Mosca RS, Bove EL, Kulik TJ. Serial blood lactate measurements predict early outcome after neonatal repair or palliation for complex congenital heart disease. J Thorac Cardiovasc Surg. 2000 Jul; 120(1): 73-80. https://doi.org/10.1067/mtc.2000.106838

[11] Hatherill M, Sajjanhar T, Tibby SM, Champion MP, Anderson D, Marsh MJ, et al. Serum lactate as a predictor of mortality after pediatric cardiac surgery. Arch Dis Child. 1997 Sep; 77(3): 235-8. https://doi.org/10.1136/adc.77.3.235

[12] Munoz R, Laussen PC, Palacio G, Zienko L, Piercey G, Wessel DL. Changes in whole blood lactate levels during cardiopulmonary bypass for surgery for congenital cardiac disease: an early indicator of morbidity and mortality. J Thorac Cardiovasc Surg. 2000 Jan; 119(1): 155-62. https://doi.org/10.1016/s0022-5223(00)70231-5.