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RESEARCH

Association Between Lactate Concentration and Acute Kidney Injury after Cardiac Surgery With Cardiopulmonary Bypass at Dr. Sardjito General Hospital

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ABSTRACT

Background: Cardiac surgery using a cardiopulmonary bypass (CPB) machine is a complex procedure that can trigger systemic inflammatory responses, tissue perfusion disorders, and lactate accumulation. Cardiac surgery-associated acute kidney injury (CSA-AKI) is a serious postoperative complication of cardiac surgery that increases morbidity, mortality, and duration of intensive care unit (ICU) stay.
Objective: This study aims to determine the relationship between lactate concentration and the incidence of CSA-AKI and to establish the lactate cut-off value as a risk marker for CSA-AKI in patients following cardiac surgery using a cardiopulmonary bypass machine at Dr. Sardjito General Hospital Yogyakarta.
Methods: A prospective cohort study (December 2025--February 2026) on elective cardiac surgery patients at Dr. Sardjito General Hospital. Inclusion criteria: age ≥18 years, NYHA <class III, and eGFR ≥60 mL/min/1.73 m². CSA-AKI was defined based on KDIGO 2012 criteria. Lactate concentrations were measured serially at 2 hours, 6 hours, and 24 hours post-CPB. Analysis used comparative statistical tests and Receiver Operating Characteristic (ROC) curve analysis.
Results: Study subjects comprised 43 subjects (from a total of 45 patients, 2 dropouts). Mean age 46.84 ± 12.40 years, male (60.5%), EF 61.97 ± 9.17%. Procedures were dominated by CABG (37.2%) and valve surgery (37.2%), with CPB duration 96.13 ± 23.71 minutes. The incidence of CSA-AKI was 65.1%. ROC curve analysis of lactate 6 hours post-CPB showed AUC 0.800 (p=0.001) with optimal cut-off 3.44 mmol/L (sensitivity 71.4%, specificity 73.3%), while lactate concentration at other time points showed no significant differences. Bivariate analysis showed that the group with lactate ≥3.44 mmol/L had significantly higher CSA-AKI incidence (83.3% vs 42.1%; p=0.005; OR 6.88).
Conclusion: There is a positive relationship between lactate concentration 6 hours post-CPB and the incidence of CSA-AKI, and lactate cut-off value 6 hours post-CPB ≥3.44 mmol/L has potential as a risk marker for CSA-AKI in patients following cardiac surgery with a cardiopulmonary bypass machine at Dr. Sardjito General Hospital Yogyakarta.

Keywords: CSA-AKI, cardiac surgery, cardiopulmonary bypass, lactate.

INTRODUCTION

Cardiac surgery is a crucial definitive intervention in the management of structural and vascular heart disease. In Indonesia, this procedure still has limited coverage. Harapan Kita Heart and Vascular Hospital, as the national referral center, reported 2,019 adult cardiac surgery procedures in 2023. Cardiac surgery patients in Indonesia have different characteristics compared to developed countries, particularly in terms of age, delayed diagnosis, and limited access to healthcare services.[1] The majority of patients are under 60 years old and tend to present in advanced conditions due to limited facilities and unequal distribution of medical services.

CCardiac surgery requires cardiopulmonary bypass (CPB) machine support to maintain systemic perfusion while the heart is stopped. The CPB machine temporarily replaces the function of cardiac and pulmonary circulation by circulating blood through an oxygenator and heat-exchanger.[2] However, CPB use can cause activation of systemic inflammatory response, ischemia-reperfusion injury of cardiac and renal tissue, and accumulation of inflammatory mediators and free radicals.[3-5]

One organ highly susceptible to perfusion disturbances and systemic inflammation due to CPB use is the kidney. Cardiac surgery-associated acute kidney injury (CSA-AKI) is acute kidney injury occurring within seven days post-cardiac surgery, most often caused by ischemia-reperfusion injury, systemic inflammation, and hemodynamic instability related to CPB machine use, with reported incidence between 5% to 42% and associated with increased morbidity, mortality, and healthcare costs.[6] The pathophysiology of CSA-AKI involves complex interactions between ischemia-reperfusion, inflammation, oxidative stress, hemolysis, and nephrotoxic exposure. One important indicator reflecting tissue perfusion disturbance and metabolic stress in this condition is increased postoperative lactate concentration.[7,8]

Late-onset hyperlactatemia, defined as increased lactate concentration within 4-24 hours post-operatively, has been associated with risk of organ complications, including acute kidney injury. Although not always directly related to mortality, this condition reflects persistent tissue hypoperfusion or impaired cellular metabolism, and is often accompanied by prolonged mechanical ventilation needs and longer intensive care stay.[9-12]

A study showed that patients with postoperative hyperlactatemia have an increased risk of CSA-AKI, higher transfusion requirements, and longer ICU stays.[13] A study concluded that a lactate concentration >3 mmol/L within the first 10 hours of ICU admission is a strong predictor of complications, including kidney failure.[14] Serial lactate monitoring in post-cardiac surgery patients with CPB is expected to provide useful prognostic information for clinical decision-making and optimization of postoperative management.

METHODS

This is an analytical observational study with prospective cohort design aimed to assess the relationship between postoperative lactate concentration and the incidence of CSA-AKI in elective cardiac surgery patients with CPB machine at Dr. Sardjito General Hospital Yogyakarta during December 2025 - February 2026. Samples were obtained using consecutive sampling method from patients meeting inclusion criteria with a total of 43 subjects recruited from 45 patients (2 patients dropped out due to death during post-operative care).

Inclusion Criteria: Adult patients (age ≥18 years), NYHA classification <class III, and estimated glomerular filtration rate (eGFR) ≥60 mL/min/1.73 m² based on CKD-EPI 2021 formula.

Exclusion Criteria: Patients with history of chronic blood disorders (thalassemia, hereditary hemolytic anemia, sickle cell anemia, or other hematological disorders) that may affect lactate concentration or renal function.

Dropout Criteria: Patients undergoing redo cardiac surgery, experiencing death on table, death during post-operative care, or using perioperative extracorporeal circulation (IABP, hemodialysis, CRRT).

Lactate concentration were measured serially at 2 hours, 6 hours, and 24 hours post-

CPB using arterial blood samples. CSA-AKI was defined based on KDIGO 2012 criteria, assessed from serum creatinine measurement at 24 and 48 hours post-CPB. Determination of optimal lactate cut-off value for predicting CSA-AKI was performed using Receiver Operating Characteristic (ROC) curve by calculating Area Under the Curve (AUC), sensitivity, and specificity. Comparison of categorical variables used Chi-square test or Fisher's exact test, and Mann-Whitney U test for numerical variables. Data were analyzed using SPSS version 26. Significance level α was set at 5% ($p<0.05$).

RESULT

This study obtained a total of 43 research subjects (60.5% male and 39.5% female). Mean age of study subjects was 46.84 ± 12.40 years. The mean preoperative left ventricular ejection fraction was 61.97 ± 9.17%. The most common procedures were CABG (37.2%) and valve surgery (37.2%), congenital (14.0%), and combination (11.6%). As many as 44.2% of subjects had history of hypertension and 20.9% had history of diabetes mellitus. As many as 32.6% of subjects experienced preoperative anemia. CPB duration averaged 96.13 ± 23.71 minutes. The incidence of CSA-AKI in this study was 65.1% (Table 1). ROC curve analysis showed that the lactate concentration 6 hours after CPB provided the best discriminative performance compared to other measurement times, with AUC 0.800 ($p=0.001$; 95% CI 0.67-0.93) and cut-off point 3.44 mmol/L, with sensitivity 71.4% and specificity 73.3%. Preoperative lactate did not show significant predictive ability for CSA-AKI ($p=0.351$; AUC 0.588). (Table 2).

Based on the cut-off value 3.44 mmol/L from ROC analysis, bivariate analysis showed that the group with lactate concentration 6 hours post-CPB ≥3.44 mmol/L had significantly higher CSA-AKI incidence compared to the group with lactate <3.44 mmol/L (83.3% vs 42.1%; $p=0.005$; OR 6.88; 95% CI 1.68--28.09) (Table 3).

DISCUSSION

The mean age of subjects was 46.84 ± 12.40 years, with 60.5% male and 39.5% female. This relatively young mean age reflects the epidemiological pattern of cardiac surgery in Indonesia, where patients tend to present in more advanced conditions due to limited access to healthcare services.[1] Comorbidities found included hypertension (44.2%) and diabetes mellitus (20.9%). Mean EF 61.97 ± 9.17% indicated that most subjects had systolic function that was still compensated. As many as 32.6% of subjects experienced preoperative anemia based on WHO criteria, which is known to increase renal susceptibility to ischemia during CPB15. The distribution of surgery types was evenly distributed between CABG (37.2%) and valve surgery (37.2%), with mean CPB duration 96.13 ± 23.71 minutes. This long CPB duration is relevant, considering that each additional 30 minutes of cardiopulmonary bypass time has been independently associated with increased postoperative morbidity, including renal complications (OR 1.31).[16]

CSA-AKI incidence in this study was 65.1%, higher than the range reported in general literature of 5–42%6. This high incidence is a cumulative result of population characteristics reflecting heavier clinical burden in cardiac surgery patients in Indonesia, including large proportion of valvular disease, younger age with more advanced disease, and relevant comorbidities such as diabetes mellitus and preoperative anemia. As many as 20.9% of subjects had history of diabetes mellitus, which has been identified as an independent preoperative risk factor for CSA-AKI (OR 1.52; 95% CI 1.07–2.16), possibly reflecting the effects of subclinical diabetic nephropathy.[17]

Lactate concentration showed significant increase post-operatively, from median 1.80 mmol/L preoperatively to 3.65 mmol/L at 6 hours post-CPB. This increase reflects tissue hypoperfusion and anaerobic metabolism during and after CPB use. During CPB machine use, tissue perfusion disturbance due to low perfusion pressure, hypothermia, hemodilution, and non-pulsatile blood flow causes decreased cellular oxygenation and lactate production.[8] Additionally, activation of systemic inflammatory cascade through release of pro-inflammatory cytokines such as IL-6 and TNF-α further worsen overall cellular

metabolic conditions. ROC curve analysis of lactate concentration 6 hours post-CPB showed an AUC of 0.800 (p=0.001), indicating good discriminatory power for predicting the occurrence of CSA-AKI. The optimal cut-off value of 3.44 mmol/L provided a sensitivity of 71.4% and specificity of 73.3%. These findings are consistent with previous studies reporting the predictive value of postoperative lactate levels for CSA-AKI.[18] Previous studies have reported that lactate levels ≥3 mmol/L at 6 hours after ICU admission are an independent predictor of major complications, including AKI (OR 3.28; 95% CI: 1.61–6.69; p=0.001). These findings are also consistent with previous research[19], who found that a peak postoperative lactate concentration ≥4 mmol/L was associated with a markedly higher risk of CSA-AKI (OR 6.3; 95% CI: 1.9–20.5). Lactate sampling at 6 hours post-operatively may be useful for capturing the peak of lactate dynamics related to post-CPB complications, while also depicting late-onset hyperlactatemia phenomenon often missed in the intraoperative phase.

Bivariate analysis proved statistically that the group with lactate 6 hours post-CPB ≥3.44 mmol/L had significantly higher CSA-AKI incidence compared to the low lactate group (83.3% vs 42.1%; p=0.005; OR 6.88). Pathophysiologically, systemic hypoperfusion causing lactate accumulation also directly disturbs renal perfusion, particularly in the proximal tubule which has high oxygen requirements and is highly susceptible to ischemia. Decreased renal perfusion pressure during CPB, combined with hemodilution, oxidative stress from reperfusion, and systemic inflammatory response, creates conditions conducive to acute kidney injury. Previous research has also demonstrated a significant association between lactate concentrations at 3 and 24 hours postoperatively and the incidence of AKI.[19]

Conversely, at 2 hours and 24 hours post-CPB observation, lactate did not show significant predictive ability. In the first 2 hours, this is presumably related in part to acute hemodilution from the cardiopulmonary bypass priming fluid, given that hemodilution on CPB is an independent determinant of early postoperative hyperlactatemia.[20] At 24 hours post-operatively, loss of predictive value is generally influenced by aggressive medical resuscitation intervention in ICU that has optimized hemodynamics therapeutically. Preoperative lactate also did not show significant predictive ability (AUC 0.588; p=0.351), confirming that clinically relevant lactate increase does not originate from pre-operative condition, but is a direct product of physiological disturbance caused by CPB itself.[21,22]

This study is limited to bivariate statistical analysis to maintain the reliability of the results. This approach was adopted as the current sample allocation was optimized for the power of single-variable testing; thus, implementing multivariate analysis was concerned to potentially trigger model overfitting, which would consequently diminish the clinical validity of the findings. Clinical parameters such as vital signs, urine output, postoperative ejection fraction, and other factors were not included for analysis alongside the primary variables.

CONCLUSION

There is a positive correlation between 6-hour post-CPB lactate concentration and the incidence of CSA-AKI, where a 6-hour post-CPB lactate cut-off value of ≥3.44 mmol/L serves as a potential risk marker for the occurrence of CSA-AKI (OR 6.88) in patients following cardiac surgery with a cardiopulmonary bypass machine at RSUP Dr. Sardjito Yogyakarta

RECOMMENDATION

Future studies should use a design that allows multivariable regression analysis to evaluate various risk factors and confounding variables that potentially influence the incidence of CSA-AKI. Future research should include additional clinical parameters for analysis to ensure a more comprehensive evaluation.

REFERENCES

1. Qanitha A, Uiterwaal CSPM, Henriques JPS, Mappangara I, Idris I, Amir M, et al. Predictors of medium-term mortality in patients hospitalised with coronary artery disease

in a resource-limited South-East Asian setting. Open Heart. 2018;5(2):e000801. doi:10.1136/openhrt-2018-000801.
2. Kaplan JA, Reich DL, Savino JS, editors. Kaplan's cardiac anesthesia: the echo era. 6th ed. St. Louis (MO): Saunders/Elsevier; 2011.
3. Cremer J, Martin M, Redl H, Bahrami S, Abraham C, Graeter T, et al. Systemic inflammatory response syndrome after cardiac operations. Ann Thorac Surg. 1996;61(6):1714-1720. doi:10.1016/0003-4975(96)00055-0.
4. Dixon B, Santamaria JD, Campbell DJ. Plasminogen activator inhibitor activity is associated with raised lactate levels after cardiac surgery with cardiopulmonary bypass. Crit Care Med. 2003;31(4):1053-1059. doi:10.1097/01.CCM.0000055390.97331.DB.
5. Chen S, Hua F, Lu J, Jiang Y, Tang Y, Tao L, et al. Effect of dexmedetomidine on myocardial ischemia-reperfusion injury. Int J Clin Exp Med. 2015;8(11):21166-21172.
6. Wang Y, Bellomo R. Cardiac surgery-associated acute kidney injury: risk factors, pathophysiology and treatment. Nat Rev Nephrol. 2017;13(11):697-711. doi:10.1038/nrneph.2017.119.
7. Corral-Velez V, Lopez-Delgado JC, Betancur-Zambrano NL, Lopez-Sune N, Rojas-Lora M, Torrado H, et al. The inflammatory response in cardiac surgery: an overview of the pathophysiology and clinical implications. Inflamm Allergy Drug Targets. 2015;13(6):367-70. doi:10.2174/1871528114666150529120801.
8. Mak NTJ, Iqbal S, de Varennes B, Khwaja K. Outcomes of post-cardiac surgery patients with persistent hyperlactatemia in the intensive care unit: a matched cohort study. J Cardiothorac Surg. 2016;11:33. doi:10.1186/s13019-016-0411-5.
9. Maillet JM, Le Besnerais P, Cantoni M, Nataf P, Ruffenach A, Lessana A, et al. Frequency, risk factors, and outcome of hyperlactatemia after cardiac surgery. Chest. 2003;123(5):1361-366. doi:10.1378/chest.123.5.1361.
10. O'Connor E, Fraser JF. The interpretation of perioperative lactate abnormalities in patients undergoing cardiac surgery. Anaesth Intensive Care. 2012;40(4):598-603. doi:10.1177/0310057X1204000404.
11. Lindsay AJ, Xu M, Sessler DI, Blackstone EH, Bashour CA. Lactate clearance time and concentration linked to morbidity and death in cardiac surgical patients. Ann Thorac Surg. 2013;95(2):486-92. doi:10.1016/j.athoracsur.2012.07.020.
12. 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. doi:10.1186/cc5113.
13. Aubourg C, Collard A, Léger M, Gros A, Fouquet O, Sargentini C, et al. Risk factors and consequences of late-onset hyperlactatemia after cardiac surgery with cardiopulmonary bypass: a single-center retrospective study. J Cardiothorac Vasc Anesth. 2022;36(11):4077-4084. doi:10.1053/j.jvca.2022.07.007.
14. Kogan A, Preisman S, Bar A, Sternik L, Lavee J, Malachy A, et al. The impact of hyperlactatemia on postoperative outcome after adult cardiac surgery. J Anesth. 2012;26(2):174-178. doi:10.1007/s00540-011-1287-0.
15. Fowler AJ, Ahmad T, Phull MK, Allard S, Gillies MA, Pearse RM. Meta-analysis of the association between preoperative anaemia and mortality after surgery. Br J Surg. 2015;102(11):1314-1324. doi:10.1002/bjs.9861.
16. Salis S, Mazzanti VV, Merli G, Salvi L, Tedesco CC, Veglia F, et al. Cardiopulmonary bypass duration is an independent predictor of morbidity and mortality after cardiac surgery. J Cardiothorac Vasc Anesth. 2008;22(6):814-22. doi:10.1053/j.jvca.2008.08.004.
17. Yi Q, Li K, Jian Z, Xiao YB, Chen L, Zhang Y, et al. Risk factors for acute kidney injury after cardiovascular surgery: evidence from 2,157 cases and 49,777 controls - a meta-analysis. Cardiorenal Med. 2016;6(3):237-50. doi:10.1159/000444094.
18. Hajjar LA, Almeida JP, Fukushima JT, Rhodes

A, Vincent JL, Osawa EA, et al. High lactate levels are predictors of major complications after cardiac surgery. J Thorac Cardiovasc Surg. 2013;146(2):455-460. doi:10.1016/j.jtcvs.2013.02.003.
19. Radovic M, Bojic S, Kotur-Stevuljevic J, Lezaic V, Milicic B, Velinovic M, et al. Serum lactate as reliable biomarker of acute kidney injury in low-risk cardiac surgery patients. J Med Biochem. 2019;38(2):118-125. doi:10.2478/jomb-2018-0018.
20. Ranucci M, Carboni G, Cotza M, Bianchi P, Di Dedda U, Aloisio T, Surgical and clinical outcome research (SCORE) group. Hemodilution on cardiopulmonary bypass as a determinant of early postoperative hyperlactatemia. PLoS One. 2015;10(5):e0126939. doi:10.1371/journal.pone.0126939.
21. Van Hall G. Lactate kinetics in human tissues at rest and during exercise. Acta Physiol (Oxf). 2010;199(4):499-508. doi:10.1111/j.1748-1716.2010.02122.x.
22. Brooks GA. The science and translation of lactate shuttle theory. Cell Metab. 2018;27(4):757-785. doi:10.1016/j.cmet.2018.03.008