International Journal of Anesthesia and Clinical Medicine
2024, Vol. 12, No. 1, pp. 66-69
https://doi.org/10.11648/j.ijacm.20241201.23

Case Report

A Case of Cardiac Surgery-Associated Acute Kidney Injury

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Abstract

Approximately 2 million patients undergo cardiac surgery annually with 20% to 30% developing the cardiac surgery-associated acute kidney injury. Patient who has undergone cardiac surgery in the past week and meets the criteria for acute kidney injury can be classified as a cardiac surgery-associated acute kidney injury. The cardiac surgery-associated acute kidney injury may be caused by various factors during perioperative period. Preoperative risk factors include advanced age, female gender, pre-existing renal insufficiency, heart failure, left main coronary artery disease, diabetes, chronic obstructive pulmonary disease, peripheral vascular disease, liver disease, low cardiac output and hypotension. Intraoperative risk factors include the type of surgery (valve surgery, combined valve and coronary artery surgery, emergency and reoperations), low-flow cardiopulmonary bypass, hypothermic cardiopulmonary bypass, deep hypothermic circulatory arrest, cardiopulmonary bypass duration >100-120 minutes, hemodilution, hemolysis and hemoglobinuria due to prolonged cardiopulmonary bypass duration. We present the case of a 53-year-old female with severe valvular heart disease complicated by infecting human immunodeficiency virus. She experienced an acute kidney injury after cardiac surgery. The rationale for this case report is to learn about the risk factors of cardiac surgery-associated acute kidney injury and take measures to prevent it.

Keywords

Cardiopulmonary Bypass, Cardiac Surgery, Acute Kidney Injury

1. Introduction

Multiple perioperative factors may contribute to the cardiac surgery-associated acute kidney injury with an incidence of 20-30% in cardiac surgery [1]. Compared to predicting AKI using risk factors alone, focusing on AKI-related biomarkers allows for earlier detection and better prediction of a cardiac surgery-associated acute kidney injury. This article reports a case of acute kidney injury occurring in a cardiac surgery patient with a history of human immunodeficiency virus (HIV). Written informed consent was obtained from the patient for the publication of this case report.

2. Case Presentation

A 53-year-old female patient was admitted to hospital due to experiencing fatigue and shortness of breath after activity for over a year, with worsening symptoms in the past seven months. The cardiac ultrasound revealed severe mitral regurgitation with mild stenosis, moderate to severe tricuspid regurgitation and moderate pulmonary hypertension. She admitted to our hospital for further surgical treatment. She had a history of HIV for over 10 years with long-term antiretroviral therapy consisting of tenofovir, lamivudine and efavirenz. Upon this admission, examinations of liver and kidney function, pulmonary function, head computerized tomography (CT), and chest CT showed no significant abnormalities.

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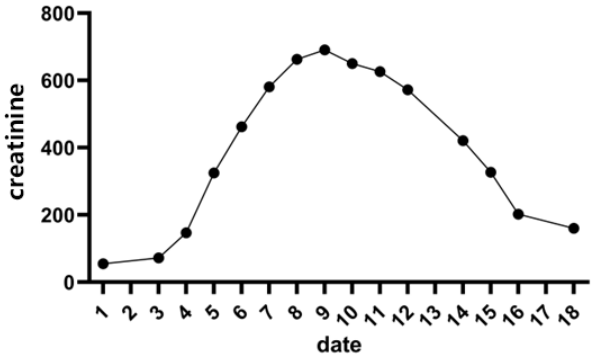
Received: 22 May 2024; **Accepted:** 11 June 2024; **Published:** 21 June 2024

The patient completed preoperative examinations and subsequently underwent mitral valve replacement, tricuspid valve repair under general anesthesia on March 28, 2024. The surgery lasted 3 hours and 58 minutes, with a cardiopulmonary bypass (CPB) time of 129 minutes and an aortic cross-clamp time of 81 minutes. The urine output was 1000 ml with the urine appearing dark tea-colored with rust-like sediment (Figure 1). Postoperatively, the patient was transferred to the intensive care unit (ICU) for continued treatment. Despite having good cardiac function, adequate volume and stable hemodynamics, the patient experienced oliguria, hyperkalemia and poor diuretic response during ICU. The urine remained dark tea-colored with rust-like sediment. The patient's antiretroviral medications were temporarily discontinued. She was treated with Niaoduqing granules to lower creatinine levels and stabilize renal function. Measures were taken to maintain blood volume, promote diuresis and stabilize the internal environment. Trends in the patient's creatinine levels and urine output postoperatively are shown in Figure 2. The patient was discharged on postoperative day 18.

Figure 1. *The urine appearing dark tea-colored with rust-like sediment.*



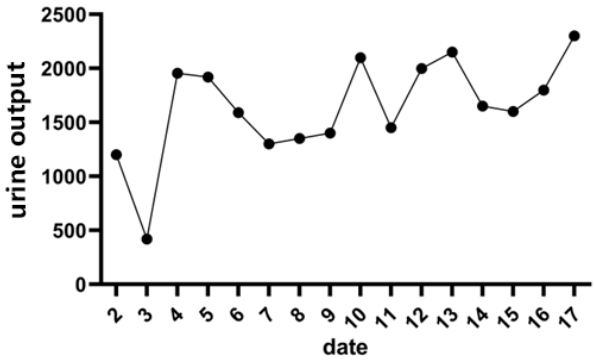


Figure 2. *Trends in the patient's creatinine levels and urine output postoperatively.*

3. Discussion

Acute kidney injury (AKI) refers to a sudden decline in renal function lasting from several hours to days, characterized by a rapid increase in serum creatinine levels and/or decrease in urine output. AKI defined based on serum creatinine (an increase of at least 1.5 times the baseline) and urine output (<0.5 ml/kg/h for at least 6 hours) [2]. Patient who has undergone cardiac surgery in the past week and meets the criteria for AKI can be classified as CSA-AKI. Approximately 2 million patients undergo cardiac surgery annually with 20% to 30% developing CSA-AKI. Studies report an overall AKI incidence of 19% in patients undergoing coronary artery bypass grafting (CABG), 27.5% in valve surgeries and 29% in aortic surgeries [1]. Although only 2%-3% of AKI patients require continuous renal replacement therapy (CRRT), the in-hospital mortality rate and 5-year mortality rate associated with CSA-AKI are 10.7% and 30%, respectively [1]. Patients whose renal function recovers before discharge have a significantly lower long-term mortality risk compared to those with persistent renal dysfunction post-discharge. CSA-AKI is significantly associated with the subsequent development of chronic kidney disease (CKD), end-stage renal disease (ESRD), heart failure and severe adverse cardiovascular events. The pathophysiology of CSA-AKI with various factors playing roles in different ways is not fully understood. The development of CSA-AKI may involve several major injury pathways which included hypoperfusion, ischemia-reperfusion injury, neurohumoral activation, inflammation, oxidative stress, nephrotoxins and mechanical factors.

The risk factors for CSA-AKI can be categorized into preoperative, intraoperative and postoperative factors [3]. Preoperative risk factors include advanced age, female gender, pre-existing renal insufficiency, heart failure, left main coronary artery disease, diabetes, chronic obstructive pulmonary disease (COPD), peripheral vascular disease, liver disease, low cardiac output and hypotension. Intraoperative risk factors include the type of surgery (valve surgery, combined valve and coronary artery surgery, emergency and reopera-

tions), low-flow CPB, hypothermic CPB, deep hypothermic circulatory arrest, CPB duration >100-120 minutes, hemodilution, hemolysis and hemoglobinuria due to prolonged CPB duration. Postoperative risk factors include low cardiac output, hypotension, severe vasoconstriction, sepsis and nephrotoxins. A study compared rewarming patients who underwent CABG surgery to 32 ℃-34 ℃ versus 32 ℃-37 ℃. The randomized trial found that rewarming to 37 ℃ within 10-15 minutes comparing to rewarming to 34 ℃ increased the incidence of AKI [4]. Newland et al. discovered that prolonged hyperthermic perfusion (above 37 ℃) is an independent predictor of increased CSA-AKI [5]. Research indicates that selecting a target oxygen delivery rate greater than 300 ml/min/m ²during CPB results in a lower incidence of AKI compared to conventional perfusion targets [6]. Therefore, individualized oxygen delivery during CPB is necessary rather than using traditional body surface area-based perfusion targets. Several cohort studies have shown that both anemia and transfusion are associated with an increased risk of CSA-AKI. To avoid anemia and transfusion during the perioperative period of cardiac surgery, it is essential to address preoperative anemia, including oral iron supplementation, use of erythropoietin, and supplementation with vitamin B12 and folic acid [7]. During cardiac surgery, blood flow through the extracorporeal circuit and the use of suction devices create shear stress on red blood cells, leading to hemolysis. The kidneys' exposure to free hemoglobin and other hemolysis products exacerbates the inflammatory response and oxidative stress, potentially worsening ischemia-reperfusion injury and endothelial dysfunction, thus promoting tubular cell death. One study indicated that elevated levels of free hemoglobin and decreased levels of haptoglobin are associated with increased CSA-AKI and mortality [8].

Certain perioperative medications can induce renal injury, including antibiotics (aminoglycosides, β-lactams, vancomycin), ACE inhibitors/ARBs, NSAIDs, diuretics and intravenous contrast agents. A systematic review indicates that postoperative fluid resuscitation with balanced crystalloids, compared to saline solutions, can reduce the incidence of CSA-AKI. The use of hydroxyethyl starch for fluid resuscitation in the perioperative period is associated with an increased risk of AKI [9]. Therefore, the use of hydroxyethyl starch is contraindicated in high-risk AKI patients undergoing cardiac surgery. This patient has been diagnosed with HIV for over 10 years and has been on long-term antiretroviral therapy with tenofovir, lamivudine, and efavirenz. Efavirenz is a selective non-nucleoside reverse transcriptase inhibitor for HIV-1, with less than 1% of the drug excreted unchanged in the urine, indicating that renal impairment has minimal impact on its clearance. Tenofovir is not recommended for patients with CrCl <15 mL/min who are not on dialysis, as there is a potential risk of nephrotoxicity due to prolonged exposure to low levels of tenofovir. Lamivudine, a nucleotide analog, is metabolized intracellularly to lamivudine-5'-triphosphate, selectively inhibiting the replication of HIV-1 and HIV-2. It is primarily excreted unchanged in the urine, and in patients with moderate to severe renal impairment, decreased clearance results in elevated plasma concentrations of lamivudine. Use of antiretroviral medications in this patient, along with an intraoperative CPB duration exceeding 120 minutes, and hemoglobinuria induced by CPB, may be contributing factors to the development of CSA-AKI in this patient.

The diagnostic criteria for CSA-AKI are based on elevated serum creatinine levels and reduced urine output. However, post-cardiac surgery patients often undergo fluid resuscitation, which increases the distribution volume and dilutes serum creatinine, potentially delaying diagnosis and underestimating the severity of renal injury. Compared to predicting AKI using risk factors alone, focusing on AKI-related biomarkers allows for earlier detection and better prediction of CSA-AKI, thereby preventing its occurrence and progression. Interleukin-18 (IL-18) mediates renal ischemia and inflammatory injury, and its urinary levels significantly increase 4-6 hours after CPB in patients with CSA-AKI [10]. Kidney injury molecule-1 (KIM-1) is a transmembrane protein that is shed from the cell surface into the urine following renal injury. Urinary KIM-1 concentrations peak as early as 3 hours after renal injury, making KIM-1 an earlier biomarker for CSA-AKI compared to serum creatinine [11].

4. Conclusions

AKI is a common complication following cardiac surgery and is associated with poorer outcomes compared to patients who do not develop AKI postoperatively. Although the pathogenesis of CSA-AKI is complex and involves multiple factors, the common outcome is tubular injury and a decline in glomerular filtration rate. Novel biomarkers can detect CSA-AKI earlier, allowing for timely interventions to prevent AKI. It is recommended to discontinue nephrotoxic drugs before elective cardiac surgery, optimize chronic medication regimens, and treat anemia. Additionally, during the intraoperative and postoperative phases, balanced crystalloids should be used for resuscitation, and goal-directed hemodynamic strategies should be employed to optimize cardiac output and renal perfusion pressure.

Abbreviations

COPD	Chronic Obstructive Pulmonary Disease
HIV	Human Immunodeficiency Virus
CT	Computerized Tomography
CPB	Cardiopulmonary Bypass
ICU	Intensive Care Unit
AKI	Acute Kidney Injury
CSA-AKI	Cardiac Surgery-Associated Acute Kidney Injury
CKD	Chronic Kidney Disease
ESRD	End-Stage Renal Disease

COPD	Chronic Obstructive Pulmonary Disease
CABG	Coronary Artery Bypass Grafting
CRRT	Continuous Renal Replacement Therapy

Author Contributions

Xia Wang: Data curation, Writing – original draft
Jiaqi Yang: Resources
Xuejie Li: Writing – review & editing

Funding

This case report was not funded by any funding.

Data Availability Statement

The datasets are available from the corresponding author on request.

Conflicts of Interest

The authors declared that they have no competing interests.

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