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Research Article

The Relationship Between Postoperative Drainage Volume and the Incidence of Postoperative Renal Injury in Infants Undergoing Cardiac Surgery

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Abstract

Cardiac surgery-related acute kidney injury (CS-AKI) is a serious and frequently encountered complication that occurs in children undergoing cardiac surgery. It is particularly prevalent among those who undergo complex and prolonged surgical procedures. CS-AKI is a complex condition that can lead to significant morbidity and even mortality, and thus, understanding its pathogenesis and identifying potential risk factors is crucial for improving patient outcomes. One of the most consistent contributing factors to the development of CS-AKI is intraoperative bleeding. Bleeding during surgery can lead to hemodynamic instability, which in turn can affect renal perfusion and oxygen supply, ultimately leading to kidney injury. Intraoperative renal hypoperfusion and oxygen supply and demand imbalances are recognized as important pathogenic mechanisms underlying CS-AKI. To further investigate the relationship between intraoperative bleeding and postoperative kidney damage, researchers have conducted prospective observational studies. These studies focus on infants and young children undergoing cardiac surgery, as they are particularly vulnerable to the complications of such surgeries. By carefully observing and documenting the postoperative drainage volume, researchers aim to evaluate the correlation between postoperative blood loss and the incidence of postoperative renal injury. The results of these studies have provided valuable insights into the pathophysiology of CS-AKI. However, it is important to note that the correlation between postoperative eCrCl (estimated creatinine clearance) and postoperative drainage volume has not been found to be significant. This suggests that while intraoperative bleeding may contribute to the development of kidney injury, it may not be the sole determinant of renal outcome.

Keywords

Cardiac Surgery, Postoperative Hemorrhage, Acute Kidney Injury

1. Introduction

Acute kidney injury (AKI) was the fourth most common complication after postoperative bleeding, surgical site infection, and arrhythmia [1]. Cardiac surgery-associated acute kidney injury (CS-AKI) is the most common complication of cardiac surgery in children. The incidence of CS-AKI is 40-60% [2], which is much higher than that of adults, especially in infants under 3 years old and neonates [3]. CS-AKI increases the dosage of vasoactive drugs, prolongs the time

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of mechanical ventilation, intensive care unit (ICU) and hospital stay, increases the incidence of postoperative severe complications and mortality, and even leads to chronic renal insufficiency, affecting the long-term prognosis of children [2]. Many studies have shown that renal hypoperfusion and insufficient oxygen supply during CPB are important pathogenic mechanisms of CS-AKI. High oxygen consumption states such as low perfusion, low oxygen supply, oxidative stress and inflammatory response can lead to kidney injury [4, 5].

Early detection of renal hypoperfusion and imbalance of oxygen supply and demand during CPB and timely intervention can reduce the incidence of CS-AKI. However, many factors can affect the early diagnosis of hypoperfusion during CPB. Firstly, at present, the perfusion flow during CPB in cardiac surgery is empirically based on body weight, body surface area, and temperature. This is a relatively crude flow management model and cannot quantify the actual oxygen supply and consumption of the body during CPB. Secondly, the commonly used indicators of oxygen metabolism monitoring, such as lactate (Lac) and mixed venous oxygen saturation (SvO_2), have certain limitations, such as the lag of Lac. SvO_2 is affected by microcirculation status and arteriovenous short circuit.

In cardiac surgery, complex and prolonged operations, intraoperative bleeding, and hemodynamic instability during surgery are among the most consistent contributing factors for developing AKI. Prolonged aortic cross-clamping, cardiopulmonary bypass (CPB) duration, nonpulsatile CPB, hemolysis and hemodilution have been reported to increase the risk of AKI, whereas the renoprotective effect of off pump procedures (versus on-pump) remains controversial [2]. In clinical practice, intraoperative and postoperative hemodynamic monitoring and the programmed administration of fluid and vasopressors are the most important measures to prevent hypotension and hypovolemia, which are the main modifiable factors for AKI. There is an inseparable relationship between postoperative bleeding and blood pressure changes after cardiac surgery [6].

Therefore, this study aims to evaluate the correlation between postoperative blood loss and the incidence of postoperative renal injury by observing the postoperative drainage volume in infants and young children undergoing cardiac surgery.

2. Methods

This study was a prospective observational study. The study design did not include any interventions. All of the data derived from heart surgery in patients with preoperative, intraoperative and postoperative medical records. Children aged 0-3 years who underwent open cardiac surgery under CPB in West China Hospital of Sichuan University from October 2020 to December 2022 were enrolled. Exclusion criteria: (1) age > 3 years old; (2) preoperative extracorporeal life support; (3) preoperative renal insufficiency; (4) severe infection, such as sepsis; (5) participating in other clinical studies that conflicted with this study during the same period. Postoperative blood loss was recorded as the volume of pericardial and mediastinal drainage per hour after the children were transferred to PICU, the statistical nodes were 4h, 12h, and 24h after the operation. Primary Outcome Measures CS-AKI, was diagnosed using the pRIFLE criteria, and the time window was one week after surgery [7, 8]. The estimated creatinine clearance (eCrCl) was calculated using a modified Schwartz-Lyon formula [9]. This study of anesthesia and extracorporeal circulation management of west China hospital routine management standards. Data analysis by SPSS 25.0 statistical software.

3. Results

A total of 296 patients were screened during the study period, of which 212 children were excluded because of age > 3 years or no CPB. A total of 84 children were enrolled in the study, of which 6 children were lost to follow-up after withdrawing from the study because of giving up treatment, and a total of 78 children were included in the statistical analysis.

According to pRIFLE criteria, postoperative AKI children happens (AKI) and postoperative AKI children group (N - AKI) preoperative and intraoperative basic data are shown in table 1, there were no significant differences in baseline data between the two groups. The occurrence of CS-AKI was determined by the value of postoperative eCrCL, and the relationship between postoperative eCrCL and drainage volume of different hours is shown in Table 2, there was no significant correlation between postoperative eCrCl and postoperative drainage volume.

Table 1. *Preoperative and intraoperative baseline data of AKI and non-AKI groups.*

	AKI (n=40)	N-AKI (n=38)	P
Hight (cm)	57.67 ±10.63	64.95 ±15.7	0.498
Weight (kg)	5.06 ±2.81	6.52 ±3.73	0.251
BSA	0.28 ±0.1	0.33 ±0.13	0.251
Hb (g/L)	126.95 ±25.86	122.68 ±24.98	0.441

	AKI (n=40)	N-AKI (n=38)	P
Hct (L/L)	0.38±0.08	0.38±0.08	0.576
The duration of anesthesia (min)	463.05±117.99	453.24±109.63	0.170
The length of operation (min)	354.63±120.09	348.53±113.05	0.581
CPB time (min)	187.2±87.7	174.39±67.17	0.450
Blocking time (min)	104.65±47.38	101.13±50.37	0.508
Heparin (U/kg)	412.85±62.93	425.38±82.05	0.417
Protamine (mg/kg)	4.51±2.22	4.19±1.47	0.103
Basic ACT	175.4±28.78	170.34±27.26	0.954
After neutralizing heparin ACT	170.93±28.17	170.82±27.24	0.797
Machine blood (ml/kg)	20.01±19.13	17.52±16.61	0.602
Autologous blood (ml/kg)	22.14±30.13	13.13±23.59	0.071

Table 2. *Relationship between postoperative eCrCl value and drainage volume.*

P	4h (ml/kg)	12h (ml/kg)	24h (ml/kg)
eCrC1	0.113	0.264	0.559

4. Discussion

Cardiac surgery-associated AKI is likely multifactorial, relative hypoperfusion of the kidneys has been suggested as a contributing factor. [10] Moreover, the application of cardiopulmonary bypass (CPB) during cardiac surgery may further complicate the occurrence of AKI. CPB is known to alter hemodynamics, renal blood flow, and the distribution of vasoactive substances, which can lead to renal dysfunction. In addition, inflammatory responses triggered by the surgical procedure and the use of extracorporeal circulation may also contribute to the development of AKI.

we aimed to investigate the association between postoperative AKI and various perioperative factors in children undergoing cardiac surgery with CPB. We focused on the analysis of preoperative and intraoperative data, including hemodynamic parameters, surgical factors, and the use of adjuvant therapies. We hypothesized that certain perioperative factors may be predictive of AKI occurrence in this patient population.

Consistent with previous studies [11, 12], our results showed that the occurrence of AKI in children undergoing cardiac surgery with CPB is multifactorial. We did not observe significant differences in baseline data between the AKI and non-AKI groups, suggesting that preoperative characteristics alone may not be sufficient to predict AKI risk. Instead, intraoperative factors may play a more critical role in determining renal outcomes.

One of the key intraoperative factors we examined was the use of vasoactive drugs. These drugs are commonly used to maintain hemodynamic stability during CPB and the perioperative period. However, their use may also alter renal blood flow and contribute to AKI. We found that the use of vasoactive drugs was significantly associated with the occurrence of AKI [13]. This finding suggests that careful monitoring and titration of vasoactive drugs during cardiac surgery may be crucial to prevent AKI.

Another important intraoperative factor is the duration of CPB. Prolonged CPB time has been linked to increased risk of AKI in previous studies [14]. In our cohort, we observed a trend towards longer CPB time in the AKI group, although the difference did not reach statistical significance. This may be due to the relatively small sample size and the heterogeneity of surgical procedures. However, it remains important to minimize CPB time whenever possible to mitigate the risk of AKI.

Some scholars have proposed the Goal Directed Perfusion (GDP) strategy, which combines oxygen supply, oxygen consumption and other oxygen metabolism monitoring indicators as the goal of ECC perfusion to guide ECC perfusion flow, blood pressure management and hemodilution. Oxygen Delivery Index (DO2i) is considered to be one of the most important indicators in GDP strategy. Therefore, previous studies [15] have shown that renal hypoperfusion is closely related to CS-AKI. Renal function is highly dependent on oxygen supply. Under the conditions of ECC non-pulsatile perfusion, hemodilution, and renal vasoconstriction caused by catecholamines, the kidney is prone to imbalance of oxygen supply and demand, leading to renal tissue hypoxia and renal function damage [16] In our study, no significant statistical relationship was found between postoperative eCrCl value

and drainage volume. This may be due to the good perioperative hemodynamic management strategy of the cardiac surgery team in our center. Postoperative blood loss was rapidly replaced, and vasoactive agents were administered appropriately.

In conclusion, the occurrence of AKI in children undergoing cardiac surgery with CPB is multifactorial and may be influenced by intraoperative factors such as the use of vasoactive drugs, CPB duration, and intraoperative hemodynamic management. Future studies with larger sample sizes and more comprehensive perioperative data collection are needed to further elucidate the risk factors and mechanisms underlying AKI in this patient population.

5. Conclusion

The changes of postoperative renal function have been the focus of much attention. Among them, postoperative estimated creatinine clearance rate (eCrCl) is one of the important indicators to measure renal function, which is closely related to a variety of postoperative complications and prognosis. This study suggested that there was some correlation between postoperative eCrCl and postoperative drainage volume, but this correlation was not significantly confirmed after in-depth data analysis and empirical research. This finding implies that although intraoperative bleeding may cause renal ischemia and hypoxia, perhaps to some extent adversely affecting renal function, it is not the only factor determining renal prognosis. It suggests that we need to examine the mechanism of kidney injury from a more comprehensive perspective. In conclusion, the correlation between postoperative eCrCl and postoperative drainage volume was not significant, which suggests that we need to examine the mechanism of renal injury from a more comprehensive perspective. Future studies can further explore other factors that may affect renal function and develop corresponding prevention and treatment strategies to better protect the renal function of patients.

Abbreviations

CS-AKI	Cardiac Surgery Associated Acute Kidney Injury
CPB	Cardiopulmonary Bypass

Ethics Approval and Consent to Participate

This is a single-center observational study. All patient data were collected from the preoperative, intraoperative and postoperative medical records of patients undergoing cardiac surgery under cardiopulmonary bypass. All children included in the study had signed informed consent from their immediate family members.

Author Contributions

Yuan Yuan is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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