Intraoperative Hemodialysis During Open-Heart Surgery in Patients With Severe Chronic Kidney Disease

Takahiro Inoue
Kameda Medical Center
Hiroshi Kuji
Kameda Medical Center
Kanako Nagaoka
Kameda Medical Center
Takafumi Akanuma
St.marianna university
Junko Fukuda
Kameda Medical Center
Hiroki Matsui
The University of Tokyo: Tokyo Daigaku
Hiroaki Tanabe
Kameda Medical Center
Mamiko Ohara
Kameda Medical Center
Tomo Suzuki (suzuki.tomo@kameda.jp)
Kameda Medical Center https://orcid.org/0000-0001-5536-1741

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Abstract

Background:

Acute kidney injury and chronic kidney disease (CKD) after cardiac surgery are associated with increased mortality and renal prognosis. We evaluated the utility of intraoperative hemodialysis (IHD) during open-heart surgery of patients with severe CKD.

Methods:

The present study was a single-center retrospective cohort study employing IHD for non-emergency open-heart surgery in patients with CKD G4 or G5. We compared the patients in IHD group with those in the non-IHD group retrospectively. Primary outcomes were 30-day mortality and initiation of renal replacement therapy (RRT) after surgery.

Results:

Twenty-eight patients were categorized into the IHD group and 33 into the non-IHD group. Comparing the IHD versus the non-IHD, men accounted for 60.7 vs. 50.3%, the age was mean 74.5 (SD 7.0) vs. 72.9 (SD 9.4) years (*p*=0.744), and the rate of CKD G4 patients was 67.9 % vs. 84.8 %. On the other hand, preoperative estimated glomerular filtration rate of the IHD is significantly lower than the non-IHD (19.1 ± 5.6 vs. 22.0 ± 5.2 ml/min/1.73 m^2, *p*=0.039). For clinical outcomes, no significant differences were observed in 90-day mortality (7.1 vs. 3.0 %, *p*=0.482) and 30-day RRT rate (17.9 vs 30.3%, *p*=0.261). In the patients with CKD G4, the 30-day RRT rate was significantly lower in patients in the IHD than in those in the non-IHD (0 vs. 25.0%, *p*=0.037).

Conclusions:

IHD during open-heart surgery reduced the incidence of postoperative dialysis in patients with CKD G4 and may be useful for postoperative management.

Background

Acute kidney injury (AKI) is a common and serious postoperative complication of cardiac surgery. Nephrotoxins, metabolic abnormalities, ischemia and reperfusion injury, pre-existing chronic diseases, inflammation, and oxidative stress may lead to the development of AKI after surgery [1]. Patients with AKI have higher rates of short-term and long-term mortality and prolonged length of hospital stay, and incur higher hospital costs [2]. Among patients with AKI after cardiac surgery, 1–5% require renal replacement therapy (RRT) for severe postoperative AKI, and a strikingly high in-hospital mortality rate exceeding 40% has been reported for these patients [3, 4]. Currently, there is no standardized treatment for AKI. Therefore, prevention and risk factor management are most important during postoperative care after a cardiac surgery.

RRT for severe AKI is frequently required to treat hyperkalemia, excess fluid, uremia, and metabolic acidosis. Although the indications for RRT have been extensively studied, no definitive evidence has been established for the most appropriate criteria and timing for cardiac surgery. A few randomized controlled trials have evaluated the effect of early or preemptive RRT in chronic kidney disease (CKD) patients undergoing cardiac surgery. These studies have suggested that early or preemptive RRT is associated with lower mortality rate and shortened stay in intensive care unit (ICU) [5–8]. Michell et al. have shown that intraoperative hemodialysis (IHD) is safe and prevents hyperkalemia in CKD patients undergoing cardiac surgery [9]. Therefore, IHD was done in patients with severe CKD along with chronic dialysis to ameliorate the fluid overload, acidosis, and electrolyte abnormality in our institution. However, the studies reporting IHD in CKD patients are scarce.

The present study aimed to elucidate the association between IHD and clinical outcomes in severe CKD patients undergoing open-heart surgery. We hypothesized that IHD may contribute to the reduction in mortality rate and ameliorate the deterioration of kidney function in CKD patients undergoing cardiac surgery.

Methods

Study population

The present study was a single-center retrospective cohort study involving patients who underwent non-emergency open-heart surgery between January 2008 and December 2018. Our institution started IHD for CKD patients (mainly chronic hemodialysis patients) in September 2013 due to the change of chief of department of cardiovascular surgery. The flowchart representing patient enrollment and group stratification for the present study is shown in Fig. 1. The patients who underwent emergent surgery, chronic dialysis, and/or kidney transplantation were excluded from the present study.

Intraoperative hemodialysis

A temporary vascular catheter was inserted by a cardiac surgeon, and hemodialysis was performed in all patients using a hemodialysis machine (DBB-100NS or DCS-100NS) during the surgery. The dialyzer was an ethylene vinyl alcohol membrane with a surface area of 1.5 m^2. The dialysate comprised 140 mEq/L sodium, 2.0 mEq/L potassium, 2.75 mEq/L calcium, and 27.5 mEq/L bicarbonate. Blood flow through the dialyzer was maintained at the flow rate of 150 mL/min and dialysate flow was maintained at 500 mL/min. Additionally, nafamostat mesylate, an anticoagulant and a synthetic serine protease inhibitor, was injected continuously at the rate of 30 mg/hour. Target level of serum potassium was 4.0 mEq/L. Hemodialysis was started at the time using cardiopulmonary bypass was initiated and completed at the end of cardiopulmonary bypass.

Study outcomes

The medical records of the patients who underwent cardiac surgery were reviewed retrospectively. We compared the IHD group after August 2013 with non-IHD group before August 2013. The primary outcomes were 90-day mortality rate and initiation of RRT after surgery. The decision to initiate RRT in patients after cardiac surgery in our hospital was based on the judgement of the nephrologist (for example electrolyte abnormality, uremia, acidosis and fluid overload.). The secondary outcomes were length of hospital stay, duration of postoperative intubation, and renal function at discharge. Further, we examined the parameters during surgery, including the blood transfusion volume, duration of surgery, and use of intra-aortic balloon pumping. For the evaluation of renal function, estimated glomerular filtration rate (eGFR) ml/min/1.73m^2 was calculated according to serum creatinine, sex and age [10].

Statistical analyses

The continuous and categorical variables are presented as mean ± standard deviation. Demographic variables were compared between the groups using the independent t-test and Fisher's exact test was used to analyze the time to morbidity onset. The differences with $p < 0.05$ were considered statistically significant. Statistical analyses were performed with JMP 11.0.0 (SAS Institute Inc., Cary, NC, USA).

Results

Participants

In total, 1198 patients underwent open-heart surgery in our institution, among whom 153 patients were with CKD G4 or G5. Among 153 patients, 92 were excluded due to chronic dialysis (n = 76), emergent surgery (n = 15), and post-kidney transplantation (n = 1). The remaining 61 patients were included in the study, among whom, 28 patients were categorized into the IHD group, and 33 into the non-IHD group. The basic demographic data and preoperative characteristics of the patients in both groups are summarized in Table 1. Comparing the IHD group versus non-IHD group, men accounted for 60.7% vs. 50.3% patients, the age of the patients was 74.5 ± 7.0 years vs. 72.9 ± 9.4 years ($p = 0.744$), the rate of patients was 67.9 % vs. 84.8 % (CKD G4) and 32.1 % vs. 15.2 % (CKD G5). The proportion of patients with diabetic mellitus was 35.7% vs. 42.4% ($p = 0.384$). Thus, baseline characteristics showed no difference between both groups. On the other hand, preoperative estimated glomerular filtration rate of the IHD group is significantly lower than the non-IHD group (19.1 ± 5.6 ml/min/1.73 m^2 vs. 22.0 ± 5.2 ml/min/1.73 m^2, $p = 0.039$).

Intraoperative and postoperative characteristics

Intraoperative and postoperative parameters of the patients are shown in Table 2. Among 61 patients, 26 (42.6%) underwent isolated heart valve surgery, 24 (39.3%) underwent isolated coronary artery bypass grafting surgery, 9 (9.8%) underwent both valve and coronary artery bypass grafting surgery, 3 (4.9%) underwent thoracic aortic aneurysm repair, and 5 (8.2%) underwent other open-heart surgery. Intraoperative variables including the type of surgery, duration of procedure, requirement of intra-aortic balloon pump, and perioperative medication (inotropic agents, diuretics, glucocorticoids, and carperitide) were not significantly different between the two groups. The patients in IHD group had significantly higher volume of blood transfusion than the non-IHD group (1212 ± 600 mL vs. 816 ± 504 mL, $p = 0.001$)

and post-surgery hemoglobin level was significantly higher in the patients of IHD group than the non-IHD group (10.9 ± 1.3 g/dL vs. 9.9 ± 0.9 g/dL, $p = 0.001$).

Clinical outcomes

The clinical outcomes are shown in Table 3. No significant differences were observed in 90-day mortality rate (7.1% vs. 3.0%, $p = 0.482$), 30-day RRT rate (17.9% vs. 30.3%, $p = 0.261$), length of hospital stay (32.2 ± 30.2 days vs. 34.2 ± 36.3 days, $p = 0.833$) and duration of postoperative intubation (4.2 ± 8.65 days vs. 2.68 ± 2.90 days, $p = 0.379$) between IHD and non-IHD groups. Renal function at discharge in patients of IHD group was relatively lower than those in non-IHD group (25.9 ± 11.4 ml/min/1.73 m^2 vs. 30.7 ± 9.61 ml/min/1.73 m^2, $p = 0.098$). However, among patients with CKD G4, 30-day RRT rate was significantly lower in IHD group than the non-IHD group (0% vs. 25.0 %, $p = 0.037$). All patients with CKD G4 presented with fluid overload. In contrast, the 30-day RRT rate in patients with CKD G5 was not significantly different between the two groups (55.8% vs. 60.0%, $p = 0.933$).

Discussion

In the present study, we retrospectively evaluated the clinical efficacy of IHD for CKD patients undergoing cardiac surgery. No significant differences were observed in the outcomes between the IHD group and the non-IHD group. However, the rate of postoperative RRT initiation in patients with CKD G4 was significantly lower in IHD group than the non-IHD group despite the lower renal function before operation and the higher blood transfusion volume.

The development of AKI after cardiac surgery (particularly, cardiopulmonary bypass surgery), is associated with prolonged ICU and hospital stay and an increased risk of death [11–15]. Many patients have multiple organ failure, thereby requiring assisted ventilation, intra-aortic balloon counterpulsation, continuous inotropic medication, and at times, the use of extracorporeal life support. It has been estimated that among patients who required hemodialysis recently, 64% required permanent dialysis, and up to 90 % died within 1 year [16, 17]. Additionally, the patients with acute CKD after surgery possibly require maintenance hemodialysis. Therefore, the treatment of severe AKI after surgery, particularly cardiac surgery, is very important.

Durmaz et al. reported that perioperative prophylactic RRT decreased both operative mortality and morbidity in high-risk patients with CKD [18], and Sugahara et al. further reported that early initiation of RRT improved the survival of patients with AKI following cardiac surgery [19]. Thus, prophylactic or early RRT may be useful for CKD patients after cardiac surgery.

In addition, multiple strategies have been commonly used to improve the intraoperative AKI. The use of dopamine, furosemide, fenoldopam, and human atrial natriuretic peptide has been shown to prevent AKI [20, 21]. In the present study, perioperative drugs therapy, the type of surgery, and the patients' characteristics did not differ significantly between the two groups. Further, red blood cell transfusion has been reported to be independently associated with AKI [22, 23]. In our study, IHD during open-heart surgery was associated with a significant reduction in 30-day RRT rate in patients with CKD G4, despite that they had more volume of blood transfusion and the lower renal function before operation than the patients in non-IHD group. This result is noteworthy. This may be because IHD may be associated with the removal of excess fluid, uremic toxins, and inflammatory mediators during cardiopulmonary bypass surgery.

Fluid overload was the most frequent cause of RRT initiation in our study. Fluid overload has been reported to be a risk factor for mortality and is known to cause prolonged postoperative ventilation time [24, 25]. Several studies have shown that hemofiltration in patients with AKI and cardiac shock after surgery improves cardiorespiratory function [6, 26], and metabolic acidosis has been shown to reduce cardiac output [27]. IHD possibly causes better control of the fluid status and improves uremia and acidosis. Owing to the higher volume of blood transfusion in patients in the IHD group in our study, we suggest that IHD may be helpful for an anesthesiologist.

To the best of our knowledge, the studies investigating IHD in CKD patients undergoing cardiac surgery are rare. During liver transplantation in CKD patients, IHD has been shown to ameliorate fluid overload, acidosis, and electrolyte abnormality, and the process has been reported to be safe and effective [28]. IHD may be helpful in achieving even or negative fluid balance with minimal hemodynamic changes during the surgery despite the presence of significant amounts of blood products and crystalloids.

Our study has a few limitations. First, the sample size was small and it was a retrospective observational study conducted at a single center. We observed no significant differences in the primary outcomes between the two groups. Second, the medical and nursing staff were different for the IHD and non-IHD groups. Particularly, the main surgeon was different for patients in IHD group and non-IHD group. However, we confirmed no difference in the duration of surgery between both the groups. Third, dialysis after surgery was initiated at the discretion of each nephrologist. However, the major cause of dialysis was fluid overload. Therefore, we suggest that the impact of nephrologist's discretion on clinical outcomes in this study was minimal. Fourth, the definition of performing IHD for CKD patients at our institution was unclear. In our cohort, all patients with CKD G4 and G5 underwent IHD. However, the patients with CKD 3b were very small. Fifth, the perioperative infusion volume was unknown. It is possible that the anesthesiologists might have changed the strategy of infusion between both groups during the long duration of the study.

Conclusions

IHD during open-heart surgery may reduce the incidence of postoperative dialysis in patients with severe CKD. Further studies including a randomized control trial and a larger sample size, are needed to elucidate the safety and effectiveness of IHD.

Abbreviations

AKI: Acute kiney injury; CKD: Chronic kidney disease; eGFR: estimated glomerular filtration rate; IHD: Intraoperative hemodialysis; ICU: Intensive care unit; RRT: Renal replacement therapy;

Declarations

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Author's Contributions

TI wrote the first draft. MO, HM, HT, and TS contributed to the review and revision of the manuscript. HM checked statistical analysis. TI, HK, KN, TA, JF, HT, MO and TS took clinical care of the patients and contributed to the interpretations of clinical data. All authors have read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics and consent to participate

The present study was a retrospective study carried out using the opt-out method for the case series of our hospital. The study was approved by the Ethics Committee of Kameda Medical Center (approval no. 19-080) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was waived by our IRB, because the study was retrospective and no interventional.

Consent of publication

Not applicable.

Competing Interests

The authors have no conflicts of interest to declare.

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Tables

Tables pptx is available in the Supplemental Files section.

Figures

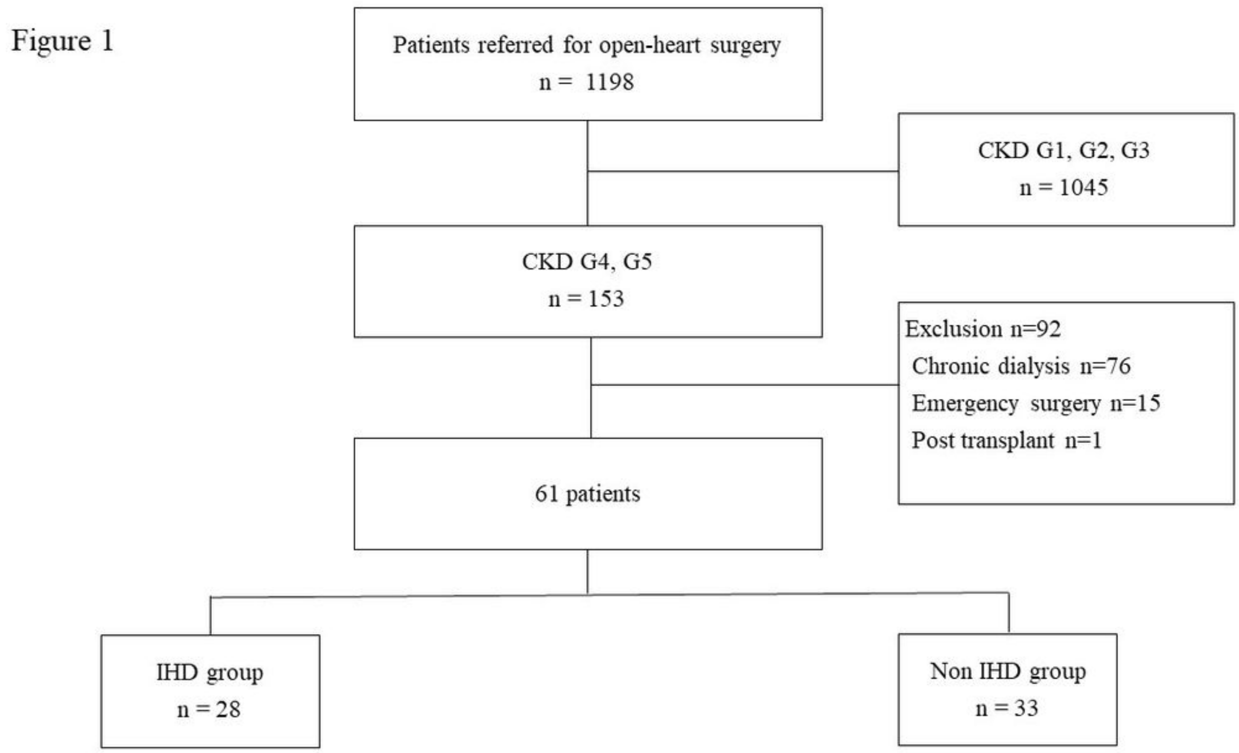

Figure 1

Study flow chart.

Supplementary Files

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- IHDTable.pptx