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Frequency and factors affecting the development of acute kidney injury following open heart surgery

Açık kalp cerrahisi sonrası akut böbrek yetmezliği gelişme sıklığı ve akut böbrek yetmezliği gelişmesine etki eden faktörler

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Abstract

Aim: Acute kidney injury after cardiac surgery (CSA-AKI) is one of the most common complications in adult patients and associated with high mortality and morbidity. We aimed to evaluate the factors affecting the development of postoperative acute kidney injury, and frequency of hemodialysis in patients with normal preoperative renal function tests, and those with high preoperative renal function tests but no need of dialysis.

Methods: Patients who underwent elective coronary artery bypass, valve surgery, or both surgeries in the Department of Thoracic and Cardiovascular Surgery of the university hospital between January 2009 and December 2009 were retrospectively examined in this cohort study. Preoperative data such as age, gender, body mass index, previous cardiac surgery, history of unstable angina, myocardial infarction and cardiogenic shock, preoperative drug use, history of comorbid diseases, left ventricular ejection fraction (%), intraoperative data such as type of surgery, the total time of surgery and cross-clamping time, postoperative data such as length of hospital and intensive care stay, the requirement of revision surgery and hemodialysis and mortality rates were recorded retrospectively.

Results: Advanced age, long surgery and cross-clamp times were risk factors for CSA-AKI (P=0.002, P=0.03, P=0.02). There was no difference between the groups in terms of previous cardiac surgery, gender, left ventricular ejection fraction, preoperative nephrotoxic drug use and surgery type (P=0.69, P=0.10, P=0.19, P=0.66, P=0.86). The length of hospital and intensive care stay of patients with acute renal failure was longer (P=0.001, P=0.001). The requirement of hemodialysis after surgery was 1.3%, and mortality rate was 2%.

Conclusion: We think that thorough examination of the patients who are at risk for CSA-AKI during the preoperative period and planning the optimal treatment will aid in decreasing postoperative mortality and morbidity.

Keywords: Acute kidney injury, Cardiac surgical procedures, Risk factors

Öz

Amaç: Açık kalp cerrahisi geçirecek yetişkin hastalarda, kardiyak cerrahi ilişkili böbrek hasarı gelişmesi en yaygın komplikasyonlardan biridir ve bu durum yüksek mortalite ve morbidite ile ilişkilendirilmektedir. Kardiyak cerrahi sonrası akut böbrek yetmezliği sıklığı, akut böbrek yetmezliğine, kronik böbrek hasarı üzerine gelişen akut böbrek yetmezliğine yol açan faktörler ve hemodiyaliz gereksinim sıklığının saptanması amaçlanmıştır.

Yöntemler: Üniversite hastanesi Göğüs Kalp Damar Cerrahisi Anabilim Dalı'nda Ocak 2009 ile Aralık 2009 tarihleri arasında elektif koroner arter bypass, kapak cerrahisi veya her iki cerrahiyi geçiren hastalar, bu retrospektif kohort çalışmada incelendi. Hastaların preoperatif yaş, cinsiyet, body mass index, eski kardiyak cerrahi, unstabil anjina, myojard enfarktüs, kardiyojenik şok öyküsü olması, preoperatif ilaç kullanımı, ek hastalık öyküsü, sol ventrikül ejeksiyon fraksiyonu, intraoperatif geçirdiği cerrahi tipi, cerrahi süresi, kros-klemp süresi, postoperatif hastane ve yoğun bakım kalış süresi, revizyon cerrahisi, hemodiyaliz gereksinimi, mortalite verileri retrospektif olarak kaydedildi.

Bulgular: İleri yaş, cerrahi süresinin ve aort kros klemp süresinin uzun olması, açık kalp cerrahisi geçiren hastalarda renal hasar gelişmesi açısından risk faktörleri olarak bulunmuştur (P=0,002, P=0,03, P=0,02). Geçirilmiş kardiyak cerrahi, cinsiyet, sol ventriküler ejeksiyon fraksiyonu, preoperatif ilaç kullanımı, cerrahi tipi ile ilgili gruplar arası farklılığa rastlanmamıştır (P=0,69, P=0,10, P=0,19, P=0,66, P=0,86). Akut böbrek yetmezliği gelişen hastaların hastanede ve yoğun bakımda kalış süresi daha uzun bulunmuştur (P=0,001, P=0,001). Cerrahi sonrası hemodiyaliz ihtiyacı %1,3, mortalite %2 oranında gözlenmiştir.

Sonuç: Sonuç olarak preoperatif dönemde hastaların ayrıntılı incelenmesi ve mümkün olan optimal sağaltımın yapılmasının, operasyon planının iyi yapılarak renal hasar gelişebilecek hastaların önceden tahmin edilerek yaklaşımın buna göre değiştirilmesinin postoperatif mortalite ve morbiditeyi azaltma konusunda önemli bir yer tutacağı kanısındayız.

Anahtar kelimeler: Koroner arter bypass grefleme, Akut böbrek yetmezliği, Risk faktörleri

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Introduction

Acute kidney injury (AKI) is the most common serious complication seen between 3.5-31% of patients undergoing cardiac surgery. Complications based on non-cardiac etiology such as fibrillation, ventricular dysfunction requiring inotropic support, infection, gastrointestinal system disease, acute lung injury, and renal dysfunction may develop frequently after cardiac surgery. In addition, low flow, hypothermia, non-pulsatile perfusion with hemodilution reduce renal blood flow and associated glomerular filtration rate [1,2].

Many studies show that renal blood flow gets impaired, renal vascular resistance and renal blood flow (25-75%) severely decrease, and glomerular filtration rate diminishes in patients after cardiac surgery [3]. The incidence and prevalence of CSA-AKI differ in the literature. The reasons for this difference are the accepted diagnostic values for AKI, differences in inclusion / exclusion criteria, different study designs, patient profile diversity, and treatment differences [4]. It is important that even the smallest postoperative serum creatinine concentration (sCr) increase shown in these studies increases the risk of mortality [5].

Mortality is estimated at 8% in patients after cardiac surgery, and this rate may range from 4% to 22% in patients with CSA-AKI. It reaches 88% in patients requiring RRT (renal replacement therapy). This makes CSA-AKI an independent risk factor that can increase the risk of death up to 8-fold [5,6].

We aimed to evaluate the development of postoperative acute kidney injury, frequency of dialysis treatment and the factors affecting the development of this damage in patients with normal preoperative renal function tests, and those with high preoperative renal function tests but no need for dialysis.

Materials and methods

Study population

This was a retrospective cohort study of patients who underwent coronary artery bypass grafting (CABG), valvular replacement or both between January 2009 and December 2009 in the Department of Thoracic and Cardiovascular Surgery of the University Hospital.

Exclusion criteria

Patients under 18 years of age, those who underwent preoperative renal replacement therapy and off-pump coronary artery bypass grafting were not included in the study.

We reviewed the medical records of 336 patients who underwent cardiac surgery during the specified period. After the exclusion criteria were implemented, 298 patients were included in the study. The upper limit of normal sCr was accepted as 1.5mg / dL, which is the highest value in our laboratory. The estimated glomerular filtration rate (eGFR) was measured automatically using the short MDRD (Modification of Diet in Renal. Disease) formula from the Turkish Society of Nephrology [7]. We defined CSA- AKI as any patient who underwent a cardiac surgery in the past week and who fulfills the KDIGO criteria stage I with an increase in serum creatinine ≥0.3 mg/dL within 48 hours. Postoperative eGFR of each patient was also calculated. We divided the patients into 3 groups:

Group 1: Preoperative sCr <1.5mg/dL, eGFR >60ml/dk, No AKI postoperatively (Two patients with postoperative sCr <1.5 mg/dL but eGFR <60ml/dk were excluded.)

Group 2: Preoperative sCr <1.5mg/dL eGFR <60ml/dk, postoperative AKI (Eleven patients without postoperative AKI were excluded.)

Group 3: Preoperative sCr >1.5mg/dL eGFR <60ml/dL without RRT, postoperative AKI (Thirteen patients without postoperative AKI were excluded.)

Variables studied

The preoperative period was defined as the time from the scheduling of the surgery until the arrival of the patient in the operating room. The preoperative data as age, gender, body mass index (BMI, kg/m²), surgical diagnosis, previous history of cardiac surgery, unstable angina, myocardial infarction (MI), cardiogenic shock, history of drug use such as diuretics, ACEinh (angiotensin converting enzyme inhibitors), statins, nonsteroidal anti-inflammatory drugs (NSAIDs), history of comorbidities such as diabetes mellitus (DM), hypertension (HT), chronic obstructive pulmonary disease (COPD), congestive heart failure, left ventricular ejection fraction (LVEF;%), sCr, eGFR during 48 hours were retrospectively recorded.

The intraoperative period was defined as the time from the arrival of the patient in the operating room until the ICU admission. The type of surgery, such as coronary artery bypass grafting (CABG) or valvular surgery, or both, the total time of surgery and cross-clamp time, the lowest intraoperative hemoglobin value, and the need for blood transfusion were recorded.

The postoperative period was defined as the time from ICU admission to hospital discharge. As postoperative data, duration of mechanical ventilation, presence of complications in intensive care unit, need for revision surgery, sCr, eGFR, the need for renal replacement therapy, length of hospital stay, in-hospital mortality data were recorded retrospectively. When necessary, hemodialysis was intermittent because this is the only type of service available.

Ethics

The study was approved by the Ethics Committee of Ege University, Faculty of Medicine (decision no: 13-4/40, date: 06.04.2011). This study complies with the standards defined by the Declaration of Helsinki.

Sample size

We calculated a-priori study sample size using GPower 3 software. We found the minimum required sample size as 207 patients for ANOVA test to compare numerical variables among three groups of the study with a medium effect size of 0.25, type 1 error of 0.05 and a power of 0.90, and 183 patients for Chi-square test to compare the categorical variables among the groups with a medium effect size of 0.30, type 1 error of 0.05 and a power of 0.90. In the light of these findings, we approved the sample size of the study as 207 patients.

Statistical analysis

Statistical analysis was performed using SPSS 17 software. Descriptive data is presented as mean and standard deviation for numerical variables, and frequency and percentage for categorical variables. ANOVA test was used for comparing numerical data, and Pearson Chi-Square was used to compare categorical data among three study groups. Mann-Whitney U test was utilized in the comparison of two independent groups of non-parametric data that do not show normal distribution. Kruskal –Wallis test was used for more than two groups. Multivariate Analysis (Logistic Regression) test was used for the variables potentially associated with the risk of developing AKI. *P*-value <0.05 was considered statistically significant.

Results

We reviewed the records of 273 patients. Demographic, preoperative, and postoperative data of the patients are presented in Tables 1 and 2. A flow diagram is shown in Figure 1.

The mean age of the patients was 58.5 (11.7) years, the mean BMI was 26.7 (3.7) kg/m², and 69.2% of the patients were male. Groups 2 and 3 were significantly older than Group 1 (*P*<0.001). Also, patients with AKI were older than those without AKI (*P*=0.002). There were no differences between the groups in terms of BMI and gender (*P*=0.13, *P*=0.10).

Fourteen patients had a history of unstable angina and 15% had a history of preoperative myocardial infarction (MI). Preoperative diuretic (furosemide, mannitol) use was 59.3%. ACE inhibitors and statins were used by 14.6% and 47%, respectively (Table 1). There were no significant differences between the groups with regards to a history of previous cardiac surgery, previous myocardial infarction, and drug use preoperatively such as diuretics, ACE inhibitors and statins (*P*=0.69, *P*=0.84, *P*=0.66, respectively). The mean LVEF (left ventricular ejection fraction) was 50.6 (9.6) %, which was similar between the groups (*P*=0.19) (Table 2).

Diabetes mellitus (DM) was detected in 27.8% of patients, hypertension (HT) in 49.8%, and chronic obstructive pulmonary disease (COPD) in 8.7%. There were no differences between groups in terms of comorbidities (*P*=0.57, *P*=0.27, *P*=0.31, respectively).

CABG was performed in 188 patients (68.8%), valvular surgery was performed in 71 patients (26 %), and both surgeries were performed in 14 patients (5.1%). The mean aortic cross-clamp time was 69.7(31.8) minutes (Table 3). In our study, there were no differences between the groups with regards to the type of surgery (*P*=0.86, *P*=0.38, *P*=0.57).

The total time of surgery was 293.2 (34.1) minutes (min) in Group 1, 299.8 (56.5) min in Group 2, 299.3 (40.5) min in Group 3. Mean cross-clamping time was 67 (27.2) min in Group 1, 77.9 (43.5) min in Group 2, 69.5 (29.7) min in Group 3. The total time of surgery and the cross-clamping time was much longer in Group 2 than Groups 1 and 3 (*P*=0.03, *P*=0.02, respectively). The relationship between the duration of surgery, cross-clamping time and AKI was evaluated, and CSA-AKI was seen to develop more in Group 2.

Complications such as sepsis, embolism and hypotension were observed in 44 patients (16.1%) in the postoperative period. CSA-AKI developed more in patients with complications (*P*<0.001). The length of hospital and intensive care stay in Group 2 was significantly longer than Groups 1 and 3 (*P*<0.001) (Table 4). Postoperatively, 15 patients (5.4%) underwent revision surgery, 3 patients (0.7%) needed hemodialysis and the mortality rate was 2.1% (6 patients) (Table 4).

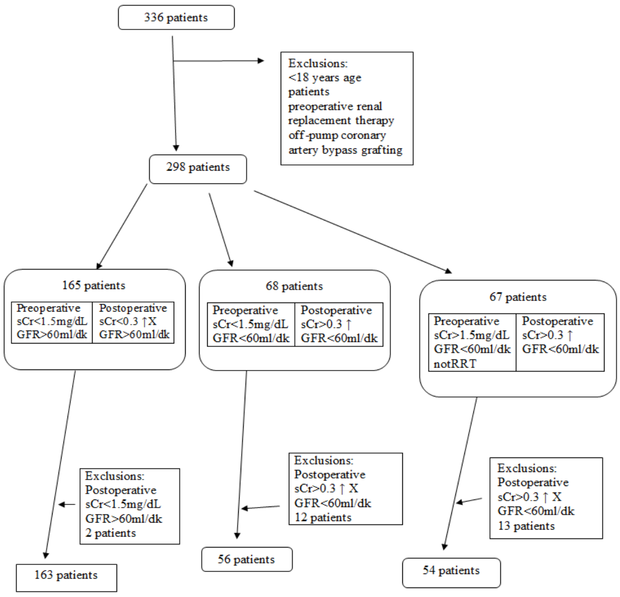

Figure 1: Flow diagram of study patients shows 273 were enrolled in the study after exclusions. Patients were categorized into those with normal kidney function and preexisting CKD without RRT by preoperative and postoperative sCr and eGFR. (RRT: Renal replacement therapy, CKD: chronic kidney disease, sCr: serum creatinine, ↑X: not elevated)

Table 1: Preoperative drug use of patients between groups

	Group 1 n=163	Group 2 n=56	Group 3 n=54	n=273	*P*-value
ACE inh	29 (17.7%)	6 (10.7%)	5 (9.2%)	40 (14.6%)	0.66
Diuretics	95 (58%)	36 (64%)	31 (57.4%	162 (59.3%)	0.19
Statins	27 (16.5%)	15 (26.7%)	5 (9.2%)	47 (17.2%)	0.37

ACE inh: Angiotensin converting enzyme inhibitors

Table 2: Demographic data of patients

Characteristics	Group 1 n=163	Group 2 n=56	Group 3 n=54	n=273	*P*-value
Age(year)	54 (11)	61(8)	67(8)	58.5(11.7)	0.002
Gender (male/female)	M:109 (66.9%) F:54 (33.1%)	M: 43 (76.8%) F:13 (13%)	M:37 (68.5%) F:17 (31.5%)	M: 189 (69.2%) F: 84 (30.8%)	0.10
BMI (kg/m²)	27.1 (3.9)	26.6 (3.5)	25.7(3.3)	26.7 (3.7)	0.13
Preop sCr mg/dL	0.86 (0.18)	0.94 (0.22)	1.40 (0.34)		
Preop eGFR mL/min/1.73 m²	103.7 (27.7)	81.4 (22.4)	48.5 (8.9)		
Postop sCr mg/dL	0.94 (0.2)	1.75 (0.9)	2.1 (1.7)		
Postop GFR mL/min/1.73 m²	94.5 (22.7)	4 (16)	40.4 (12)		
Comorbidities					
DM	41 (25%)	13(23%)	22 (40%)	76 (27.8%)	0.57
HT	72 (44%)	30(53%)	34 (64%)	136 (49.8%)	0.27
COPD	11 (6%)	12(21%)	1 (1.8%)	24 (8.7%)	0.31
Preop history of unstable angina	12 (7.4%)	2(3.6%)	0	14(5.1%)	0.26
Preop history of MI	19 (11.7%)	9 (16.1%)	13 (24%)	41(15%)	0.84
LVEF %	51.3 (9.2)	50.5 (8.7)	48.5 (11.2)	50.6 (9.6)	0.19

Preop: Preoperative, Postop: Postoperative, BMI: body mass index, eGFR: estimated glomerular filtration rate, MI: myocardial infarction, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, HT: hypertension, LVEF: Left ventricular ejection fraction

Table 3: The surgery type and time of surgery between groups

	Group 1 n=163	Group 2 n=56	Group 3 n=54	n=273	*P*-value
History of previous cardiac surgery (n %)	22 (13.5%)	10 (17.9%)	7 (13%)	39 (14.2%)	0.69
CABG (1)	111 (68.1%)	37 (66.1%)	40 (74.1%)	188 (68.8%)	0.86
Valvular surgery (2)	49 (30.1%)	16 (28.6%)	6 (11.1%)	71 (26%)	0.38
1+2	3 (1.8 %)	3 (5.4%)	8 (14.8%)	14 (5.1%)	0.57
Total time of surgery (min)	293.2 (34.1)	299.8 (56.5)	299.3 (40.5)	295.47 (40.8)	0.03
Aortic cross- clamp time (min)	67 (27.2)	77.9 (43.5)	69.5 (29.7)	69.7 (31.8)	0.02

CABG: coronary artery bypass grafting, min: minutes

Table 4: Postoperative data of groups

	Group 1 n=163	Group 2 n=56	Group 3 n=54	n=273	*P*-value
Postop complications (sepsis, embolism, hypotension)	16 (9.8%)	14(25%)	14(25.9%)	44 (16.1%)	0.001
Length of intensive care stay(day)	1.6(0.9)	3.5(4.9)	3.35(4.1)	4.8(6.9)	0.001
Revision surgery	6 (3.6%)	3 (5.4%)	6 (11.1%)	15 (5.4%)	0.2
Length of hospital stay(day)	12.1(4.9)	15.4(8.3)	15.2(7.5)	10.4 (7.1)	0.001
Mortality in hospital	1 (0.6%)	2 (3.6%)	3(5.6%)	6 (2.1%)	0.76
RRT	0	0	3(5.6%)	3 (0.7%)	0.34

Postop: Postoperative, RRT: Renal replacement therapy

Discussion

AKI is the most common complication of cardiac surgery. The incidence of CSA-AKI varies from 5% to 42%. CSA AKI is the second most common cause of AKI after sepsis in intensive care patients. It increases intensive care stay, hospitalization time and cost of care. It is characterized by a rapid loss of renal function within hours to days, with a wide range of triggering agents [8,9].

No clear consensus exists on the definition of CSA-AKI. There are over 35 different definitions in the literature. The authors used AKIN (Acute Kidney Injury Network) and RIFLE (Risk, Injury, Failure, Loss, End stage kidney disease) criteria. KDIGO group (the Kidney Disease: Improving Global Outcomes) defined AKI as an increase in serum creatinine by ≥ 0.3 mg/dL within 48 hours (h), or an increase in serum creatinine to ≥ 1.5–1.9 times baseline levels, which is known or presumed to have occurred within 7 days or urine output < 0.5 ml/kg/h for 6 hours [10]. However, the use of these criteria may cause problems in patients who have undergone cardiac surgery due to the widespread use of fluid resuscitation and fluid overload during priming in CPB with a pump. Serum creatinine values may vary according to fluid balance, which leads to underdiagnosis of AKI. sCr is not an ideal marker for assessing renal injury because it may be normal with a greater than 50% reduction in eGFR and may not rise as soon as tubular injury has occurred. eGFR<60 mL/min/1.73 m^2 is the best definition of reduced renal function, and the lower the value, the higher the risk of worsening. Although sCr is not an ideal biomarker, it is still the only reliable marker for the diagnosis of AKI [11,12]. In our study, we used both sCr and eGFR for diagnosing CSA-AKI.

AKI is considered an independent risk factor for postoperative mortality. The mortality rate can reach up to 60%. In retrospective studies, a 30% decrease in GFR increased mortality by 4-6% in patients after cardiac surgery [11-14]. In a prospective cohort study of 43,642 patients after CABG and valvular surgery, the 30-day mortality was 64 % in patients needing hemodialysis after surgery, and 4% in patients without renal injury [15]. Welten et al. [16] reported that a 10 % reduction in creatinine clearance in patients after CABG that was transient (improved within 3 days) and CSA-AKI increased the risk of mortality by 4 -7-fold within 30 days. The need of hemodialysis after cardiac surgery occurs in approximately 1% and most of these patients remain dialysis dependent. In our study, the rate of hemodialysis in the postoperative period was 1.3%, while mortality rate was 2%.

Renal dysfunction following cardiac surgery is multifactorial and its pathogenesis is not clearly understood [17-19]. The combination of tissue ischemia-reperfusion, inflammatory processes, nephrotoxicity and atheroembolic mechanisms is thought to cause this condition [4]. Renal hypoperfusion is the most common factor leading to AKI after cardiac surgery. Renal medulla is already known to be susceptible to hypoxia and hypoperfusion [19]. Recent cardiac damage or severe cardiac valve diseases which reduce cardiac output and hypotension cause renal hypoperfusion. Low cardiac output is a common trigger for AKI development in the early postoperative period. Renal damage due to hypoperfusion in GFR occurs if low cardiac output or low hypotension persists. Prolonged renal ischemia causes structural tubular damage and tubular dysfunction. Renal hypoperfusion and tubular damage are also seen in case of oxidative damage and inflammation [20]. Wang et al. [21] evaluated 4603 patients after cardiac surgery. They found 28% patients' CrCl <60 mL/min/1.73 m² with normal sCr levels. In these patients, mortality and renal replacement therapy rate had increased, along with the comorbidity rate of cardiovascular, respiratory, neurological, and infectious complications. Wijeysundera et al. [22] reported that 13% of the patients developed AKI although sCr was within normal limits. They found that mortality rate and dialysis requirement increased by 3-fold in these patients. Common preoperative risk factors for the development of cardiac surgery-related AKI are female sex, advanced age, presence of comorbidities (previous cardiac surgery history, chronic obstructive pulmonary disease (COPD), diabetes mellitus (DM), hypertension(HT), hypercholesterolemia, congestive heart failure, LVEF < 35% and obesity [23,24]. Chertow et al. [20] reported the perioperative risk factors for the development of AKI as female gender, LVEF <35%, preoperative intra-aortic balloon pump (IABP), DM, COPD and high preoperative sCr. Chywinski et al. [18] found no differences in the development of AKI in patients with DM. O'Neil et al. [25] stated that patients with HT, DM, recent MI, left ventricular dysfunction and COPD were at increased risk for AKI after cardiac surgery. Magro et al. [26] reported that patients undergoing cardiac surgery were older and had more comorbidities than before. Therefore, they stated that the prognosis of the patients may deteriorate, and the recovery process may go slower. Santos et al. [27] suggested the age of 63 years or older was an independent risk factor for AKI because GFR decreased due to diminished renal functional reserve with age. In our study, patients in which postoperative AKI developed were older than the others, but we found no significant differences between groups in terms of gender, LVEF, previous cardiac surgery or comorbidities such as DM, COPD, HT.

Patients become more susceptible to CSA-AKI by the frequent administration of NSAIDs, diuretics, ACE inhibitors, or angiotensin receptor blockers, which also contribute to impaired glomerular hemodynamics. ACE inhibitors are routinely used in the standard treatment of heart failure due to their beneficial effects on impaired left ventricular function after myocardial infarction, reducing mortality and morbidity. They cause renal tubular damage [20]. We found no significant differences in terms of preoperative ACEinh usage. Potentially nephrotoxic drugs (such as NSAII, aminoglycosides, radiocontrast agents, ACEinh, Angiotensin receptor blockers) are recommended to be discontinued in patients scheduled for cardiac surgery, if possible [14]. A retrospective study indicated that prophylactic use of statins in the preoperative period would have a prophylactic effect on the prevention of postoperative AKI. However, other large randomized controlled trials in the literature found that statin use did not reduce hospital mortality due to postoperative AKI or cardiac surgery [28-31]. We found no significant differences in patients with preoperatively used statins.

Common intraoperative risk factors for AKI after cardiac surgery include surgery type (valvular, valvular and coronary, emergent or redo surgery), cardiopulmonary bypass time greater than 100-120 minutes, presence of hemodilution, hemolysis and embolism [11]. Jang et al. [14] reported that surgery type was not a risk factor for AKI after cardiac surgery. In this retrospective study, 30.6% CABG, 40% isolated valvular surgery and 4.8% both surgeries were performed. Rodrigues et al. [32] suggested that valvular surgery is a risk factor for AKI because of the complexity and the long duration. Ramos et al. [33] found no significant difference between the patients with and without AKI with respect to surgical procedure performed. In their study, CABG was performed in 19 (30.64%) of the 62 patients with AKI and in 37 (46.25%) of the 80 patients without. Valve replacement alone was performed in 40 patients (64.51%). We found no significant differences between the groups regarding the type of surgery.

Suen et al. [34] observed that significant risk factors for CSA-AKI were cardiopulmonary bypass time (CPB) >140 min, preoperative congestive heart failure, and diabetes mellitus. Ninni et al. [35] stated that increased duration of surgery is a risk factor for CSA-AKI. Prolonged duration of CPB and aortic cross-clamping are accepted as some factors that influence renal blood flow and trigger renal ischemia. In our study, total surgery time and cross-clamping time were significantly different between the groups. Group 2 had a longer total time of surgery than Groups 1 and 2. CSA-AKI developed more in patients with longer surgery and cross-clamping times.

Renal dysfunction after cardiopulmonary bypass is a common finding affecting ICU and hospital stay times and raising hospital costs [2,8]. In our study, patients with renal dysfunction were found to have longer hospital and intensive care unit stays. Avoidance of AKI by preventive measures remains the mainstay management in patients with an elevated risk [11].

Limitations

Our study has several limitations. First, our study outcomes are short term outcomes, which are probably not sufficient to estimate long-term efficiency, success, and side effects of surgery. Second, our study is a single-center study with a relatively small sample size, which limits the generalization of the outcomes to the entire patient population. This causes a validity issue for the study. The retrospective design of the study gives us limited chance to consider causation between effects (preoperative renal function tests and preoperative need for dialysis treatment) and outcomes (presence of postoperative acute kidney injury, postoperative complications, preoperative radio-contrast exposure etc.). The estimations directly affect the validity, exactness, and reliability of the retrospectively gained data, and these limitations should be kept in mind when interpreting the results.

There are so many potential bias sources in retrospective studies such as inappropriate inclusion and exclusion criteria for selection bias, and irregular or missed patient records for information bias. We defined the inclusion and exclusion criteria at the planning stage. We adhered strictly to these criteria in the patient enrollment stage. We gathered study data from patient records, which gave us a chance to avoid some type of information biases, such as recall bias. Nevertheless, missing data is a big issue for the accuracy and the validity of the outcomes of the studies in which data are obtained from patient file records. Because of this, we had to exclude the patients with missing data from the study.

Conclusion

In our study, advanced age, longer surgery time and cross-clamping time were risk factors for CSA-AKI. Patients with AKI after surgery had longer intensive care and hospital stays. There is no pharmacological or non-pharmacological specific treatment for acute renal injury due to cardiac surgery. Preservation of the patient's existing renal function, prevention of AKI and continuation of effective supportive treatment are cornerstones of treatment management.

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