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Araştırma / *Research Article*

Duration of Acute Kidney Injury After Cardiac Surgery Effects Mortality

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Kardiyak Cerrahi Sonrası Akut Böbrek Hasarı Süresi Mortaliteyi Etkiler

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ABSTRACT

Objective: *Acute Kidney Injury (AKI) development is not a rare complication after cardiac surgery, and is often associated with a high risk of morbidity and mortality. In-hospital mortality rates of patients in need of dialysis can reach up to 70%. Our aim was to determine the risk factors for the development of AKI and the results of AKI development by examining the cases of AKI developed after cardiac surgeries performed in our hospital in a 8 year- period.*
Method: *A total of 594 patients who underwent cardiovascular surgery between January 2010-September 2018 were retrospectively included in the study. Demographic data, preoperative risk factorsi, intraoperative variables, intensive care unit data, and mortality rates were recorded. Clinically important ones among the significant data were again divided into three groups according to duration of AKI in days: 1-3 days AKI (Group 1), 3-7 days AKI (Group 2) and ≥7 days AKI (Group 3).*
Results: *AKI was observed in 31.1% of the patients. Duration of intubation (p<0.001), intensive care unit (ICU) (p<0.001), and hospital stay (p<0.001) and average time to exitus (p<0.001) were significantly longer in this patient group., in all subgroups except for Group 1. Mean time to exitus was longer only in Group 3 (p=0.002).*
Conclusion: *Development of AKI after cardiac surgery is one of the important factors affecting mortality and morbidity after cardiac surgery. It is directly proportionate not only to AKI development after cardiac surgery, but also fundamentally to duration of AKI, duration of ICU, hospital stay and mortality.*

Keywords: *acute kidney injury, cardiac surgery, mortality*

ÖZ

Amaç: *Akut böbrek hasarı (ABH) gelişimi kardiyak cerrahiden sonra ender görülmeyen, ciddi bir komplikasyondur ve sıklıkla yüksek morbidite ve mortalite riski taşır. Diyaliz gereksinimi olan hastaların hastane içi mortalite oranları % 70'lere kadar çıkabilmektedir. Amacımız, hastanemizde 8 yıllık periyod içerisinde yapılan kalp cerrahisi uygulamalarından sonra gelişen ABH olgularını inceleyerek ABH gelişim risk faktörlerini ve ABH gelişimi ile ortaya çıkan sonuçları belirlemekti.*
Yöntem: *Retrospektif olarak Ocak 2010 - Eylül 2018 yılları arasında kliniğimizde kardiyovasküler cerrahi geçiren 594 hasta çalışmaya alındı. Demografik özellikler, preoperatif risk faktörleri, intraoperatif değişlenler, yoğun bakım verileri ile mortalite oranları kaydedildi. Anlamlı olan verilerden klinik olarak önemi olanlar tekrar ABH günlerine göre 1-3 günlük ABH (Grup 1), 3-7 günlük ABH (Grup 2) ve ≥7 günlük ABH (Grup 3) grubu olarak üç gruba ayrıldı.*
Bulgular: *Hastaların %31.1'inde ABH gözlendi. Bu hasta grubunun entübasyon süresi (p<0.001), yoğun bakım yatış süresi (p<0.001) hastane yatış süresi (p<0.001), exitus gün ortalaması (p<0.001) anlamlı olarak daha uzundu. ABH gelişen grupta Grup 1 hariç tüm alt gruplarda yoğun bakım yatış süresi (sırasıyla p=0.001; p<0.001) ile hastane yatış süresi (sırasıyla p<0.001; p=0.001) anlamlı olarak daha uzundu. Yalnızca Grup 3'te exitus gün ortalaması daha uzundu (p=0.002).*
Sonuç: *Kardiyak cerrahiden sonra mortalite ve morbiditeyi etkileyen faktörler arasında ABH gelişimi önemli yer tutmaktadır. Yalnızca kardiyak cerrahiden sonra ABH gelişimi değil, esas olarak ABH süresi, yoğun bakım yatış süresi, hastane yatış süresi ve mortalite ile doğru orantılıdır.*

Anahtar kelimeler: *akut böbrek hasarı, kardiyak cerrahi, mortalite*

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INTRODUCTION

Postoperative renal dysfunction, also known as acute kidney injury (AKI) that increases postoperative patient mortality, morbidity, duration of hospital stays and hospital cost is a serious complication of cardiac surgery [1]. Mortality rates vary between 14.5% and 64% with the development of AKI after cardiac surgery in different studies [2,3]. Dialysis is needed in approximately 1-5% of these cases [4]. It is reported that in-hospital mortality rates of patients who need dialysis increases up to 70% [5].

Many risk factors have been reported for the development of postoperative AKI such as diabetes mellitus, congestive heart failure, use of intra-aortic balloon pump (IABP), age, cardiopulmonary bypass time, cross- clamp time, history of emergency surgical intervention and low cardiac output [6-8].

Even mild increases in serum creatinine levels were found to be associated with decreased survival in the postoperative period [9]. When creatinine returns to preoperative baseline value prior to discharge from the hospital, then correlation between increase in creatinine values and patient survival conveys importance [10].

AKI after cardiac surgery is multifactorial disease, and associated with ischemic renal injury due to perioperatively low cardiac output and insufficient perfusion [11]. Furthermore, free plasma hemoglobin, hydroxyl radicals, elastase, endothelin, free radicals (hydrogen peroxide, superoxide) may form and cause kidney damage during cardiopulmonary bypass [12]. Despite ongoing advances in surgical techniques, patient management, and monitorization and hemodialysis technology, incidence rates of postoperative renal injury have not decreased significantly [5]. Therefore, intensive studies are being performed to avoid AKI after cardiac surgery. In this study, we examined the cases of AKI that developed after cardiac surgery during an 8-year period. The aim of this study was to describe the preventable causes of AKI and the outcomes of AKI development.

MATERIAL AND METHOD

After the approval of the hospital's ethics committee, the files of patients who underwent cardiac surgery at the cardiovascular surgery clinic of Health Sciences University, Mehmet Akif İnan Educational and Research Hospital between January 2010 and September 2018 were evaluated retrospectively and included in the study. Peripheral vascular surgery operations, dissection surgeries and patients whose preoperative serum creatinine levels were higher than 1.5 mg / dL were excluded from the study..

Total number of 634 cardiac surgeries were performed within the 8-year period of which 594 were included in the study. Study population consisted of 213 (35.9%) female and 381 male (64.1%) patients. The patients' demographic characteristics,and smoking status of the patients, accompanying diseases detected during preoperative evaluation, and ejection fraction (EF) were recorded. The surgery that was applied, previous emergency surgical intervention, time between angiography and bypass, cardiopulmonary bypass time and intraoperative urinary excretion were evaluated. Preoperative creatinine levels of the patients were noted.

The patients received oral doses of 5-10 mg diazepam a night before the anesthesia premedication. Electrocardiography (EKG) results, invasive arterial blood pressure, peripheral oxygen saturation, end-tidal CO_2, central venous pressure (measured from the internal jugular vein) and nasopharyngeal temperature were monitored. Following anesthesia induction with standard high doses of opioid, the patients' anesthesia management was maintained with inhaled anesthetics. Dilution was performed with 20-25% hematocrit (Hct). The mean arterial pressure was maintained between 60 and 80 mmHg during cardiopulmonary bypass.

Postoperative intensive care information, duration

of extubation, hourly urine output averages within the first 24 hours, duration of intensive care and hospital stay, the time of death in days of those who died within 28 days of their hospitalisation in post-operative intensive care unit were recorded from the files and follow-up forms of the patients.

The creatinine levels of the patients were recorded on the 1st, 3rd and 7th postoperative days. For the patients who left the hospital before the 7th day. AKI was defined as a 1.5-fold increase in creatinine levels or 0.3 mg/dl increase in line with Stage 1 AKI definition according to AKIN criteria [13]. The patients were primarily divided into the AKI-positive and AKI-negative groups. The AKI-positive group with clinical data was again divided into 3 groups according to the number of days AKI persisted: 1-3 days AKI (Group 1), 3-7 days AKI (Group 2), and ≥7 days of AKI (Group 3).

DATA ANALYSIS METHOD

The data were analyzed with "SPSS for Windows 23.0 version". For the data with normal distribution in the descriptive statistics of the continuous variables, the results were expressed as mean ± standard deviation, and for those without normal distribution, the results were expressed as median (minimum-maximum). Categorical variables were expressed in frequencies and percentages. Normal distribution was evaluated by histogram and One-Sample Kolmogorov- Smirnov test. Student's t-test was used for the data that showed normal distribution in the pairwise group comparisons. Mann-Whitney-U test was used for the data without normal distribution. Kruskal-Wallis test was used for the evaluation of more than 2 groups. As Kruskal-Wallis test did not show a significant p value, any pairwise subgroup comparisons were not made. For the categorical variables, chi-square test was used in the comparisons between the groups. $p<0.05$ was considered as statistically significant.

RESULTS

Among 594 patients who underwent cardiac surgery between January 2010 and September 2018 were included in the study, While, 409 of them did not have AKI according to the AKIN criteria, and 185 of them developed AKI. There was no significant difference between the groups in terms of sex. The mean age was significantly higher in patients with AKI ($p<0.001$). There was no significant difference between the groups in terms of additional diseases and smoking status of the patients. EF was lower in the AKI group ($p=0.07$). The time interval between angiography and bypass operation was significantly longer in patients with AKI ($p<0.001$). The demographic data are shown in Table 1.

Table 1. Demographic data.

	All Patients (n=594)	No AKI (n=409)	AKI (n=185)	p
	mean±ss / n(%)			
Age (year)	59.7±10.8	58.7±11	62.1±9.8	<0.001*
Sex				0.084
Female	213 (%35.9)	156 (%73.2)	57 (%26.8)	
Male	381 (%64.1)	253 (%66.4)	128 (%33.6)	
BMI (kg/m^2)	18.1±0.2	17.9±2.4	18.6±2.1	<0.001
DM	208 (%35)	138 (%66.3)	70 (%33.7)	0.332
HT	300 (%50.5)	198 (%66)	102 (%34)	0.129
Smoking	142 (%23.9)	99 (%69.7)	43 (%30.3)	0.799
EF (%)	50.7±7.4	51.4±7.1	49.4±7.7	0.007
Time interval between Angio-Bypass (days)	6.25±4.49	6.12±4.22	6.52±5.03	<0.001

AKI: Acute Kidney Injury, BMI: Body Mass Index, DM: Diabetes Mellitus, EF: Ejection Fraction, HT: Hipertension

Table 2. Case types.

	No AKI (n=409)	Group 1 (n=69)	Group 2 (n=48)	Group 3 (n=68)	p
	n(%)				
Case Type					0.005
Valve operation	41 (87.2%)	4 (8.5%)	-	2 (4,3)	
CABG+ Valve operation	1 (20%)	2 (40%)	-	2 (40%)	
CABG	367 (67.7%)	63 (11.6%)	48 (8.9%)	64 (11.8%)	

AKI: Acute Kidney Injury, CABG: Coronary Artery Bypass Graft

Table 3. Factors affecting AKI.

	All Patients (n=594)	No AKI (n=409)	AKI (n=185)	p
	mean±ss / n(%)			
Emergency / elective				<0.001
Elective	514 (86.5%)	371 (72.2%)	143 (27.8%)	
Emergency	80 (13.5%)	38 (47.5%)	42 (52.5%)	
Duration of Bypass (min)	118±37.9	113.5±36.8	127.9±38.5	<0.001
Duration of Cross clamp (min)	81±60.4	75.6±27	92.8±99.8	0.004
Urine output in the pump (mL)	666.6±416.7	680.4±425.3	636.2±396.6	0.203
Hourly urine on the first day (mL/day)	167.3±66.2	179.4±68,2	141.3±53.3	0.006
Preop creatinine (mg/dL)	0.87±0.47	0.81±0.26	0.99±0.74	<0.001

AKI: Acute Kidney Injury

Four of 5 (80%). patients who underwent CABG + valve surgery developed AKI The highest rate of kidney injury was in this group (p<0.001). Among 542 patients, 175 (32.3%) cases that underwent isolated CABG, and 6 of 47 (12.8%) patients who had isolated valve surgery developed AKI., Patients who developed AKI and experienced CABG + valve surgery were in Groups 1 and Group 3 with equal number of patients in both groups. Group 3 included highest number of patients who developed AKI and had isolated CABG. The type of operation that was performed, and the duration of kidney injury were found to be related.

The rate of development of AKI was higher in the patients who underwent emergency operations. Additionally, the duration of bypass and cross clamp cardiac surgery was significantly longer in the patients with AKI (p>0.001 and p=0.04, respectively) (Table 3). In this patient group, higher preoperative creatinine levels, lower urine output wthin the first 24-hour and longer intubation times, intensive care unit stay and the hospitalization were detected (p<0.001, p=0.006, p<0.001, p<0.001 and p<0.001, respectively). There was no significant differences in the rates of mortality between the two groups (p=0.439), but the mean day of exitus was significantly higher in the AKI group (p=0.001). When we grouped the patients by their days of exitus, mortality rate was higher in 0-1 days in the group without AKI, the rates of exitus in all other days were higher in the AKI-positive group (p=0.001) (Table 4).

Among these data, those with clinical significance were re-classified based on the duration of kidney injury (Table 5). Duration of bypass and cross-clamping period were significantly different among all subgroups of the AKI group, but the mean bypass duration was the highest in Group 2, and the mean cross-clamp time was the highest in Group 1. Group 2 had the highest mean value of preoperative creatinine level followed by Group 3. There was no signifi-

Table 4. Hospital stay and mortality.

	All Patients (n=594)	AKI (n=409)	No AKI (n=185)	p
		n(%)		
Duration of intubation (days)	11.4±16.9	9.8±13.9	15.1±22	<0.001
Duration of ICU stay (days)	3.33±3.1	2.83±2.26	4.45±4.24	<0.001
Duration of hospital stay (days)	8.22±4.22	7.74±3.69	9.32±5.07	<0.001
Exitus	70 (%11.8)	35 (%8.6)	35 (%18.9)	0.439
Exitus (days)	5.8±6.5	4.1±6.5	7.5±6.2	0.001
Grouping by exitus days				0.001
0-1 day	32 (%45.7)	24 (%68.6)	8 (%22.9)	
1-3 days	7 (%10)	1 (%2.9)	6 (%17.1)	
3-7 days	8 (%11.4)	3 (%8.6)	5 (%14.3)	
7-28 days	23 (%32.9)	7 (%20)	16 (%45.7)	

AKI: Acute Kidney Injury, ICU: Intensive Care Unit

cant difference between Group 1 and the group without AKI. The mean peak creatinine level was the highest in Group 3. The frequency and percentage of peak creatine change over 100% and above were higher in Group 3 (29, 80.5%), and the frequency and percentage of those with a percentage change below 100% were higher in Group 1 (64, 42.9%). The hourly urine output was significantly lower in all 3 groups with AKI than the group withoutI, but the lowest mean hourly urine output was detected in Group 2. Intubation time was significantly different among the groups, but the longest intubation time was detected in Group 2. Hospitalization period and intensive care unit stay were not significantly different in Group 1, but they were significantly longer in the other groups. The mean day of exitus was significantly different only in Group 3 (p=0.002).

DISCUSSION

A total of 594 elective and emergency cases that underwent cardiac surgery between January 2010 and September 2018 at our center were included in the study. Among these, 184 patients (31.1%) had AKI. The incidence of AKI development after cardiac surgery varies depending on the definition, ranges widely between 5% and 35% [6,14]. In the study, the rates of AKI development were similar to those of previous studies.

In terms of smoking status, DM and HT, which were determined as risk factors for kidney injury in previous studies, any significant difference was not found between groups [1,2,15]. However, the mean age of the group with kidney injury was higher similar to those of previous studies, but EF was lower [8,9].

Ranucci et al. [16] reported that an interval of less than 24 hours between angiography and bypass was a serious risk factor for the development of kidney injury. At our clinic, one needed to wait for a minimum of 48 hours for elective operations. However, for emergency operations, the patient does not need to wait, and AKI developed in 52.5% of the patients who were taken to emergency operations. In a similar study, Del Duka et al. [17] found that the incidence of development of AKI was significantly higher in operations performed within 5 days after angiography, and the highest incidence was found in the patient group who underwent surgery between 0 days and 1 day after angiography. Since the time interval between the angiography and bypass was given as the mean value in this study, and these values were over 6 days, a statistically significant but clinically insignificant difference was found between the groups who developed and did not develop AKI.

Duration of bypass and cross clamp time are important in the development of AKI after cardiopulmo-

Table 5. Classification of data according to the duration of kidney injury.

					P		
	No AKI (n=409)	Group 1 (n=69)	Group 2 (n=48)	Group 3 (n=68)	No AKI/ Group 1	No AKI/ Group 2	No AKI/ Group 3
	mean±ss / n(%)						
Duration of bypass (min)	113.5±36.8	126.3±43.1	129.6±22.5	128.4±42.8	0.032	<0.001	0.006
Duration of cross clamp (min)	75.6±27	85.5±35.5	82.8±21.5	83.2±20.5	0.043	0.018	0.016
Hourly urine on the first day (mL/day)	179.4±68.2	145±40.2	129.6±47.6	145.9±66.8	<0.001	<0.001	<0.001
Peak creatinine	0.9±0.3	1.3±0.3	1.8±1.5	2.1±1.5	<0.001	<0.001	<0.001
Peak creatinine % change					<0.001	<0.001	<0.001
<%50	409 (%100)	37 (%53.6)	25 (%52.1)	13 (%19.1)			
%50-99	-	27 (%39.1)	21 (%43.8)	26 (%38.2)			
%100-199	-	5 (%7.2)	2 (%4.2)	21 (%30.9)			
>%200	-	-	-	8 (%11.8)			
Duration of intubation (hours)	9.8±13.9	12.5±14.5	17.3±23.9	16.3±27.1	0.004	<0.001	0.012
Duration of ICU stay (days)	2.83±2.26	3.42±3.92	4.22±3.46	5.67±4.75	0.511	0.001	<0.001
Duration of hospital stay (days)	7.74±3.69	8.36±4.53	10.73±6.07	9.36±4.69	0.122	<0.001	0.015
Exitus (day)	4.1±6.5	6.2±6.8	8.4±7.2	8.3±5.6	0.113	0.060	0.002

AKI: Acute Kidney Injury, ICU: Intensive Care Unit

nary bypass surgery. These two components are characterized by being among the risk factors that may be intervened. The need for kidney injury and renal replacement therapy with CABG in a beating heart is significantly reduced [18]. At our clinic, CABG is not performed on a beating heart. When we look at our patients, both the duration of the bypass surgery and cross clamp time were significantly prolonged in the AKI group. As seen in the table where we divided kidney injury into groups of days, in all groups, namely the 1-3-day, 3-7-day and >7-day AKI groups, these time periods were found to be significantly longer in comparison to the group that did not develop AKI. In their study, Karim et al. [19] reported that longer bypass and cross-clamp times led to the development of AKI. They stated that development of AKI was associated with >70-min bypass and >60-min cross clamp times. They also indicated that the amount of urine output in the pump was not related to the development of AKI. They attributed this condition to the finding that the rate of patient's urinary output in the pump did not fall below 1 ml/kg/min. As a possible reason of this, they implicated mannitol solution added to the priming solution. They also indicated that proper perfusion of kidney tissue was effective. Similarly, hourly urine output in the pumps were similar in both groups in our study. However, hourly urine output within 24 hours after the patient was taken to the intensive care unit was significantly lower in the AKI group. This was expected. When we grouped the patients according to duration of AKI in days, the mean urine output was significantly lower in all groups compared to the group without AKI. The lowest mean urine output was detected in Group 2, without any clinical significance.

Although there are studies indicating a correlation between the type of operation and development of AKI [1,14], recent studies has not indicated the presence of any relationship [20,21]. In our study, the development rate of AKI was high only in patients who underwent CABG + valve operations. For these patients, the extended duration of bypass and cross clamp surgeries may be the basis for AKI development.

Development of kidney injury after cardiac surgery increases mortality, and morbidity rates and duration of hospitalization. In addition to this information, Brown et al. [15], showed that persistence of kidney injury also negatively affects long-term sur-

vival . In our study, intensive care unit and hospital stays were longer in the group that developed AKI. However, when we grouped them based on persistence of AKI in days, there was no significant difference in the durations of intensive care unit and hospital stays in Group 1 in comparison to the group that did not develop AKI. Probably, the prolonged duration of AKI extended the durations of intensive care unit stay and hospital stay. Early recovery of AKI did not affect the durations of intensive care unit stay and hospital stay.

Although there was no significant difference in the rate of exitus between the patients with and without AKI (35: 8.6% vs 35: 18.9%) based on their days of exitus, while the rate of exitus developed between 0 and 1 day was high in the group without AKI, the rates of death occurring between 1-3, 3-7 days and 7- 28 days were higher in the group with AKI. As there were patients who had died on the operating table, even during the initial hours of intensive care, before control test for creatinine could be performed, these patients had to be included in the group that did not develop AKI due to missing data. This was the probable reason why the death rates were higher in the group that did not develop AKI in the 0th and 1st days. The fact that the rates of exitus on other days were high in the AKI group also supports the findings of previous studies [9,22]. Longer duration of AKI influenced ICU stay, hospital stay and mortality rates.

CONCLUSION

AAKI development is an important factor that affects mortality and morbidity after cardiac surgery. Advanced age, high BMIs, emergency surgical operation, short duration between angiography and operation, low EF, long duration of bypass surgery and long clamp time during operation and preoperatively high creatinine levels are risk factors for the development of AKI. Even if serum creatine levels return to preoperative values, development of AKI results in significant long-term results. Development of AKI is not only associated with increased mortality but it is also important causative factor for other end-organ damage.

End-organ dmage is directly proportional not only to the development of AKI after cardiac surgery, but mainly to the duration of AKI, extensive care unit stay, hospitalization and mortality. Development of AKI and duration of AKI have important implications for patient care. These may help clinicians to assess the risk of death during hospitalisation and after discharge.

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