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Retrospective investigation of acute kidney injury in postoperative patients in ICU

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ABSTRACT

Aims: The development of acute kidney injury (AKI) in the postoperative period is associated with increased morbidity and mortality. This study aims to determine the incidence of postoperative acute kidney injury (AKI) and the factors affecting the development of AKI in the intensive care unit (ICU) and to evaluate the outcomes of the patients.

Methods: Postoperative patients hospitalized in the ICU between December 2021 and January 2023 were retrospectively analyzed, and 192 patients were included in the study. Kidney disease: patients with and without AKI were identified using the improving global outcomes (KDIGO) criteria.

Results: While 150 of the patients did not develop AKI (non-AKI group), 42 of them developed acute kidney injury (AKI group). The patients were operated on mostly by the orthopedics clinic (58.9%) and operated on at least by the urology clinic (2.1%) were taken to the intensive care unit. 39.6% of the patients underwent emergency surgery, and 60.4% underwent elective surgery. 57.1% of the AKI group and 34.7% of the non-AKI group had emergency surgery (p=0.008).

Conclusion: In our study, age, timing of surgery, use of diuretics, and use of vasopressors were found to be associated with the development of postoperative AKI. In addition, comorbid diseases such as diabetes mellitus, hypertension, coronary artery disease, and cerebrovascular disease have also been found to be associated with AKI. Mortality, length of stay in the intensive care unit, and need for mechanical ventilation (MV) were also higher in our postoperative intensive care patients who developed AKI than in patients who did not develop AKI.

Keywords: Intensive care, acute kidney injury, KDİGO, postoperative, mortality

INTRODUCTION

Acute kidney injury (AKI) is a common complication in patients undergoing major surgery and is associated with both short-term morbidity and mortality and long-term adverse outcomes such as the development of chronic kidney disease.[1] Kidney disease; defined as meeting the criteria for improving global outcomes (KDIGO) within seven days of surgical intervention.[2]

It is important to maintain hemodynamic stability in the perioperative period. All anesthesia techniques are associated with venodilation and intraoperative hypotension.[3,4] Not only blood loss but also preoperative fasting and systemic inflammation are associated with volume reduction and are important in the development of postoperative AKI.[5,6]

Comorbid diseases, and the surgery itself, especially emergency and major surgery in critical patients, are associated with a high incidence of AKI. Nephrotoxic drugs, contrast agents, and diuretics are widely used in the perioperative period and are responsible for a significant portion of AKI.[7]

Careful selection and use of perioperative fluids and vasopressors and appropriate blood management are important to prevent AKI. We aim to investigate the frequency incidence of postoperative AKI after major non-cardiac surgery and the affecting factors in patients with previously normal renal functions.

METHODS

The study was carried out with the permission of Afyonkarahisar Health Sciences University Faculty of Medicine Ethics Committee (Date: 04.11.2022, Decision No: 14). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.This study was conducted retrospectively between December 2021 - January 2023. The clinical data of patients ≥18 years of age who were admitted to the intensive care unit (ICU) postoperatively were analyzed

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retrospectively, and 192 patients were included in the study. Patients with missing data, patients with chronic kidney insufficiency and kidney transplant, patients with sepsis, multi-trauma, and crush syndrome, and patients who were in ICU for less than 48 hours were excluded. All postoperative patients in anaesthesia intensive care unit were included in the study. Since our hospital has branch intensive care units of general surgery, neurosurgery and cardiovascular surgery departments, patients hospitalised in these departments were not included. The flow chart of the patients included in the study is shown in Figure 1. Age, gender, comorbidities, type and timing of surgery (elective-emergency), length of stay in the intensive care unit, and mechanical ventilation (MV) data of all patients included in the study were recorded. We defined and staged AKI according to KDIGO serum creatinine criteria. According to KDIGO, AKI is defined as an increase of ≥0.3 mg/dl in serum creatinine within 48 hours or a 1.5-fold increase in serum creatinine from baseline within seven days or urine output of <0.5 ml/kg/h in the last 6 hours.[8] Postoperative acute kidney injury is defined as AKI occurring within 7 days of an operative intervention using the Kidney Disease Improving Global Outcomes (KDIGO) definition of AKI.[5] In our patients, no classification was made regarding the day on which AKI developed in the first 7 days. The baseline creatinine value was taken as the last value in the last year available in the pre-hospital system. The patients were divided into two groups, as developed AKI and not developed AKI (non-AKI), by the KDIGO classification. The patients were compared according to their clinical features, medications, comorbidities, intensive care and mechanical ventilation durations, and mortality.

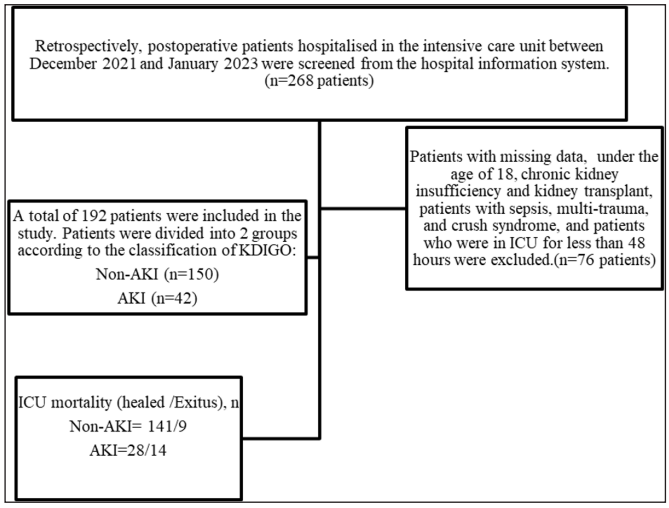

Figure 1. Flow chart shows the patient selection process

Statistical Analysis

IBM SPSS Statistics v.20 was used for statistical analysis. Data were expressed as a ratio, median (min-max), mean±SD, and conformity of variables to normal distribution was determined by visual (histogram) and analytical methods (Kolmogorov-Smirnov test). Student T or Mann-Whitney U tests were used to compare continuous variables, and the Chi-square test was used to compare categorical variables. P values of <0.05 were considered statistically significant.

RESULTS

A total of 192 patients, 92 women and 100 men, were included in the study. While 150 of the patients did not develop AKI (non-AKI group), 42 (21.9%) developed AKI (AKI group). While there was no statistically significant difference between the groups in terms of gender (p=0.149), a significant difference was found regarding age (p=0.006). If we evaluate the clinics where the patients were operated, they were operated mainly by the orthopedics clinic (58.9%) and the least operated by the urology clinic (2.1%). 39.6% of the patients underwent emergency surgery, and 60.4% underwent elective surgery. Emergency surgery was performed in 39.6% and elective surgery in 60.4% of the patients. While 57.1% of the group who developed AKI underwent emergency surgery, 42.9% had elective surgery, 34.7% of the non-AKI group underwent emergency surgery, and 65.3% had elective surgery, and there was a significant difference between the two groups (p=0.008) (Table 1).

Table 1. Demographic data of the patients

	AKI (n=42)	Non-AKI (n=150)	Total (192)	p
Gender F/M	16 (38.1) / 26 (61.9)	76 (50.7)/ 74 (49.3)	92 (47.9)/ 100 (52.1)	0.149*
Age, years, median (min-max)	72 (48-98)	67 (18-97)	68.50 (18-98)	0.006#
Surgical department, n(%)				
Orthopedics	26 (61.9)	87 (58)	113 (58.9)	
Thoracic surgery	3 (7.1)	21 (14)	24 (12.5)	
General surgery	7 (16.7)	18 (12)	25 (13)	
Ear, noseandthroat	3 (7.1)	12 (8)	15 (7.8)	0.072*
Plastic surgery	0	3 (2)	3 (1.6)	
Brain surgery	0	8 (5.3)	8 (4.2)	
Urology	3 (7.1)	1(0.7)	4 (2.1)	
Surgical status, emergency/elective	24 (57.1)/ 18 (42.9)	52 (34.7)/ 98 (65.3)	76 (39.6)/ 116 (60.4)	0.008#

Data are given as the number of patients (%), and median (minimum-maximum). #Mann Whitney U, *Chi-Square

The patients' additional disease and drug use histories are shown in Table 2. While there was a difference between the groups in terms of diabetes mellitus (DM), hypertension (HT), coronary artery disease (CAD), and cerebrovascular disease (CVD) history, there was no difference in terms of chronic obstructive pulmonary disease (COPD) history. No significant difference was observed between the patients in terms of the use of other drugs and erythrocyte suspension (ES) except for the use of diuretics and contrast agents.

Table 2. Comorbidities and drug use history

	AKI (n=42)	Non-AKI (n=150)	Total (n=192)	P*
Hypertension, yes/no	27 (64.3)/ 15 (35.7)	62 (41.3)/ 88 (58.7)	89 (46.4)/ 103 (53.6)	0.008
DM, yes/no	18 (42.9)/ 24 (5.,1)	38 (25.3)/ 112 (74.7)	56 (29.2)/ 136 (70.8)	0.027
CAD, yes/no	15 (35.7)/ 27 (64.3)	18 (12)/ 132 (88)	33 (17.2)/ 159 (82.8)	<0.001
CVD, yes/no	5 (11.9)/ 37 (88.1)	5 (3.3)/ 145 (96.7)	10 (5.2)/ 182 (94.8)	0.027
COPD, yes/no	6 (14.3)/ 36 (85.7)	13 (8.7)/ 137 (91.3	19 (9.9)/ 173 (90.1)	0.281
ACE use, yes/ no	11 (26.2)/ 31 (73.8)	21 (14)/ 129 (86)	32 (16.7)/ 160 (83.3)	0.061
Diuretic use, yes/no	19 (45.2)/ 23 (54.8)	41 (27.3)/ 109 (72.7)	60 (31.2)/ 132 (68.8)	0.027
ES usage, yes/ no	33 (78.6)/ 9 (2.,4)	114 (76)/ 36 (24)	147 (76.6)/ 45 (23.4)	0.728
Steroid use, yes/no	16 (3.1)/ 26 (61.9)	66 (44)/ 84 (56)	82 (42.7)/ 110 (57.3)	0.494
Ab use, yes/no	37 (88.1)/ 5 (11.9)	116 (77.3)/ 34 (22.7)	153 (79.7)/ 39 (20.3)	0.125
Contrast agent use, yes/no	17 (40.5)/ 25 (59.5)	40 (26.7)/ 110 (73.3)	57 (2.7)/ 135 (70.3)	0.083
Vasopressor use, yes/no	7 (16.7)/ 35 (83.3)	6 (4)/ 144 (96)	13 (6.8)/ 179 (93.2)	0.004

Data are given as the number of patients (%). *Chi-Square, DM: Diabetes mellitus, CAD: Coronary artery disease, CVD: Cerebrovascular disease, COPD: chronic obstructive pulmonary disease, ACE: Angiotensin-converting enzyme inhibitors, ES: Erythrocyte suspension, Ab: Antibiotics

There was a significant difference between the groups regarding the length of stay in the intensive care unit, discharge, need for dialysis, and need for mechanical ventilation and APACHE II scores. (Table 3, p<0.001).

The biochemical values of the patients by groups are shown in Table 4. Except for creatinine, no significant difference was observed between the groups regarding Na, leukocytes, Hb, and Hct values.

DISCUSSION

The incidence of AKI in postoperative intensive care patients varies between 10% and 56%.[9,10] The AKI rate of 21.9% in our postoperative intensive care patients is consistent with this reported range.

Risk indices [Simple Postoperative AKI Risk (SPARK) index, AKI prediction model] were used to predict the risk of developing AKI in non-cardiac surgeries in the postoperative period.[11,12] These predictive models can be used to identify high-risk postoperative patients and provide a scientific and effective basis for clinicians to identify AKI early. Seven parameters are used in the AKI prediction model used in intensive care: advanced age, emergency surgery, increased baseline creatinine level, chronic kidney disease, nephrotoxic drug use, diuretic use, and Sequential Organ Failure Assessment (SOFA) score. In our study, age, emergency surgery, use of diuretics, and use of contrast agents from nephrotoxic drugs were associated with AKI.

Although there is no definite consensus that blood loss is associated with the risk of AKI, it was shown in a study conducted on liver transplant recipients that each 1 liter of perioperative blood loss significantly increased the risk of continuous renal replacement therapy.[13] Although we do not know the amount of intraoperative blood loss in our patients, the rate of AKI was higher in patients who needed ES in the postoperative period.

A study involving 893 postoperative orthopedic surgery patients concluded that patients with risk factors for AKI should be followed up in the postoperative period. In the same study, DM was found to be associated with the incidence of AKI.[14] 58.9% of our patients were orthopedic patients, and AKI was more common in our patients with DM.

Table 3. Intensive care status of patients

	AKI (n=42)	Non-AKI (n=150)	Total (n=192)	P
Intensive care hospital stay (days), median (min-max)	5 (1-80)	3 (1-30)	3 (1-80)	<0.001#
Intensive care exit, service/exitus, n (%)	28 (66.7)/ 14 (33.3)	141(94)/ 9(6)	169 (88)/ 23 (12)	<0.001*
Dialysis, yes/no, n (%)	10 (23.8)/ 32 (76.2)	0 (0)/ 150 (100)	10 (5.2)/ 182 (94.8)	<0.001*
Need for mechanical ventilation, yes/no, n (%)	15 (35.7/ 27 (64.3)	22 (14.7)/ 128 (85.3)	37 (19.3)/ 155 (80.7)	<0.001*
Mechanical ventilation length of stay, median (min-max)	0 (0-61)	0 (0-10)	0(0-61)	0.001#
APACHE II, median (min-max)	10.50 (4-26)	6 (4-22)	6 (4-26)	<0.001#

Data are given as the number of patients (%), and median (minimum-maximum). #Mann Whitney U, *Chi-Square

Table 4. Biochemical values of patients

	AKI (n=42)	Non-AKI (n=150)	Total (n=192)	P
Creatinine mg/dl, entry, median (min-max)	1.05 (0.33-5.18)	0.74 (0.21-2.62)	0.78 (0.21-5.18)	<0.001
Creatinine, mg/dl, highest, median (Min-Max)	1.95 (1.10-8.22)	0.80 (0.21-2.62)	0.89 (0.21-8.22)	<0.001
Na, mEq/L, median (Min-Max)	139 (122-155)	138 (128-198)	138.5 (122-198)	0.715
Wbc, ($\times 10^3/\mu L$), median (Min-Max)	11.61 (4.63- 30.20)	11.24 (2.65-37.21)	11.32 (2.65-37.21)	0.841
Hb, gr/dl, median, IQR:	10.40 (7-15.10)	10.95 (3.32-16.60)	10.9 (3.32-1.60)	0.084
Hct,%, median, IQR:	31.4 (21.30-48.50)	34.15 (22.60-50)	34 (21.3-50)	0.155

Data are given as the number of patients (%), and median (minimum-maximum). #Mann Whitney U, *Chi-Square, Na: Sodium, Wbc: White blood cell count, Hb: Haemoglobin, Hct: Hematocrit

In the perioperative period, oliguria is common and is not always accompanied by an increase in creatinine. It can be seen physiologically with the effect of pain, nausea, and increased ADH in response to surgery.[15,16] Although some studies suggest that intraoperative oliguria and the incidence of postoperative AKI are unrelated, it was suggested that intraoperative oliguria, especially in cardiac and intra-abdominal surgeries, and vasopressor therapy initiated intraoperatively were associated with the incidence of postoperative AKI.[17-19] One of the limitations of our study was that it was retrospective, so we could not record the data of our patient's intraoperative period.

Postoperative Recovery (ERAS) guidelines cover surgical and anesthetic preoperative, perioperative, and postoperative care. The instructions in this guide cover all postoperative patients, including patients in the post-anesthesia intensive care unit. It was shown that protocols including early mobilization, nutrition, fluid status, and pain control of patients reduce the ICU length of stay and complications and improve surgical outcomes.[20] However, some studies have reported that the restrictive fluid therapy approach in these protocols increases the risk of AKI.[21,22] We do not have a restrictive protocol for fluid therapy. However, since our study was retrospective, we could not evaluate the amount of fluid given.

In a prospective study performed on 1200 postoperative patients excluding cardiovascular surgery, AKI was found to be associated with increased morbidity and mortality.[23] In a study conducted on general surgery patients, mortality increased eight times in those with perioperative AKI.[24] In another study conducted with general surgery patients, 30-day mortality was found as 1.9% in those who did not develop AKI, while it was 31% in patients with AKI.[25] While our overall mortality rate was 6% in patients who did not develop AKI, it was 33.3% in those who did. The reason for the high mortality rate in our patients who did not develop AKI may be due to different surgical groups, and different factors may be effective in mortality.

The limitations of our study are the inclusion of different surgical groups, being a retrospective study and not including the intraoperative period.

CONCLUSION

In the study we conducted in the intensive care unit, it was found that AKI developed in approximately one-fifth of the patients who were followed up in the postoperative intensive care unit after non-cardiac surgery. Our patients who developed AKI had higher mortality, longer intensive care unit stays, and higher mechanical ventilation (MV) needs. It was observed that the AKI development rate was higher after emergency operations. Hence, we think that the evaluation of risk factors that may cause the development of AKI and trying to correct them may be effective in preventing the development of acute kidney injury.However, for the management of postoperative AKI in the intensive care unit, multicentre studies involving the intraoperative period in the same surgical group are needed.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of Afyonkarahisar Health Sciences University Faculty of Medicine Ethics Committee (Date: 04.11.2022, Decision No: 14).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Boyer N, Eldridge J, Prowle JR, Forni LG. Postoperative acute kidney injury. *Clin J Am Soc Nephrol.* 2022;17(10):1535-1545. doi:10.2215/CJN.16541221
2. Prowle JR, Forni LG, Bell M, et al. Postoperative acute kidney injury in adult non-cardiac surgery: joint consensus report of the acute disease quality initiative and perioperative quality initiative. *Nat Rev Nephrol.* 2021;17(9):605-618. doi:10.1038/s41581-021-00418-2
3. Lee HJ, Bae J, Kwon Y, et al. General anesthetic agents and renal function after nephrectomy. *J Clin Med.* 2019;8(10):1530. doi:10.3390/jcm8101530
4. Nash DM, Mustafa RA, McArthur E, et al. Combined general and neuraxial anesthesia versus general anesthesia: a population-based cohort study. *Can J Anaesth.* 2015;62(4):356-368.
5. Goren O, Matot I. Perioperative acute kidney injury. *Br J Anaesth.* 2015;115 Suppl 2:ii3-ii14. doi:10.1093/bja/aev380
6. Ostermann M, Bellomo R, Burdmann EA, et al. Controversies in acute kidney injury:Conclusion from a kidney disease: improving global outcomes (KDIGO) conference. *Kidney Int.* 2020;98(2):294-309. doi:10.1016/j.kint.2020.04.020
7. Abelha FJ, Botelho M, Fernandes V, Barros H. Determinants of postoperative acute kidney injury. *Crit Care.* 2009;13(3):R79.
8. Lone Z, Zhang A, Benidir T, et al. The role of enhanced recovery after surgery protocols in the development of acute kidney injury following radical cystectomy. *Urol Oncol.* 2022;40(10):453.e1-453.e7. doi:10.1016/j.urolonc.2022.07.004
9. Park S, Cho H, Park S, et al. Simple postoperative AKI risk (SPARK) classification before noncardiac surgery: a prediction index development study with external validation. *J Am Soc Nephrol.* 2019;30(1):170-181. doi:10.1681/ASN.2018070757
10. Zhang Y, Zhang X, Xi X, Dong W, Zhao Z, Chen S. Development and validation of AKI prediction model in postoperative critically ill patients:a multicenter cohort study. *Am J Transl Res.* 2022;14(8):5883-5895.

11. Kim JM, Jo YY, Na SW, et al. The predictors for continuous renal replacement therapy in liver transplant recipients. *Transplant Proc.* 2014;46(1):184-191. doi:10.1016/j.transproceed.2013.07.075
12. Kateros K, Doulgerakis C, Galanakos SP, Sakellariou VI, Papadakis SA, Macheras GA. Analysis of kidney dysfunction in orthopaedic patients. *BMC Nephrol.* 2012;13:101. doi:10.1186/1471-2369-13-101
13. Zarbock A, Koyner JL, Hoste EAJ, Kellum JA. Update on perioperative acute kidney injury. *Anesth Analg.* 2018;127(5):1236-1245. doi:10.1213/ANE.0000000000003741
14. Puckett JR, Pickering JW, Palmer SC, et al. Low versus standard urine output targets in patients undergoing major abdominal surgery:a randomized noninferiority trial. *Ann Surg.* 2017;265(5):874-881. doi:10.1097/SLA.0000000000002044
15. Priyanka P, Zarbock A, Izawa J, Gleason TG, Renfurm RW, Kellum JA. The impact of acute kidney injury by serum creatinine or urine output criteria on major adverse kidney events in cardiac surgery patients. *J Thorac Cardiovasc Surg.* 2021;162(1):143-151. e7. doi:10.1016/j.jtcvs.2019.11.137
16. Mizota T, Yamamoto Y, Hamada M, Matsukawa S, Shimizu S, Kai S. Intraoperative oliguria predicts acute kidney injury after major abdominal surgery. *Br J Anaesth.* 2017;119(6):1127-1134. doi:10.1093/bja/aex255
17. Ariyarathna D, Bhonsle A, Nim J, et al. Intraoperative vasopressor use and early postoperative acute kidney injury in elderly patients undergoing elective noncardiac surgery. *Ren Fail.* 2022;44(1):648-659. doi:10.1080/0886022X.2022.2061997
18. Cavallaro P, Bordeianou L. Implementation of an ERAS Pathway in Colorectal Surgery. *Clin Colon Rectal Surg.* 2019;32(2):102-108. doi:10.1055/s-0038-1676474
19. Myles PS, Bellomo R, Corcoran T, et al. Restrictive versus liberal fluid therapy for major abdominal surgery. *N Engl J Med.* 2018;378(24):2263-2274. doi:10.1056/NEJMoa1801601
20. Shen W, Wu Z, Wang Y, Sun Y, Wu A. Impact of enhanced recovery after surgery (ERAS) protocol versus standard of care on postoperative acute kidney injury (AKI):A meta-analysis. *PLoS One.* 2021;16(5):e0251476. doi:10.1371/journal.pone.0251476
21. Biteker M, Dayan A, Tekkesin AI, et al. Incidence, risk factors, andoutcomes of perioperativeacutekidneyinjury in non-cardiacandnonvascularsurgery. *Am J Surg.* 2014;207:53-59.
22. Kheterpal S, Tremper KK, Heung M, et al. Development and validation of an acute kidney injury risk index for patients undergoing general surgery: results from a national data set. *Anesthesiology.* 2009;110(3):505-515. doi:10.1097/ALN.0b013e3181979440
23. Kim M, Brady JE, Li G. Variations in the risk of acute kidney injury across intraabdominal surgery procedures. *Anesth Analg.* 2014;119(5):1121-1132. doi:10.1213/ANE.0000000000000425
24. Boyer N, Eldridge J, Prowle JR, Forni LG. Postoperative acute kidney injury. *Clin J Am Soc Nephrol.* 2022;17(10):1535-1545.
25. Prowle JR, Forni LG, Bell M, et al. Postoperative acute kidney injury in adult non-cardiac surgery: joint consensus report of the acute disease quality initiative and perioperative quality initiative. *Nat Rev Nephrol.* 2021;17:605-618.
26. Lee HJ, Bae J, Kwon Y, et al. General anesthetic agents and renal function after nephrectomy. *J Clin Med.* 2019;8(10):1530.
27. Nash DM, Mustafa RA, McArthur E, et al. Combined general and neuraxial anesthesia versus general anesthesia: a population-based cohort study. *Can J Anaesth.* 2015;62 (4):356-368.
28. Prowle JR, Forni LG, Bell M, et al. Postoperative acute kidney injury in adult non-cardiac surgery: joint consensus report of the acute disease quality initiative and perioperative quality initiative. *Nat Rev Nephrol.* 2021;17(9):605-618.
29. Gündüz E ve Aydoğdu Titiz T. Biomarkers in the detection of acute renal injury associated with cardiac surgery. *GKDA Derg.* 2019;25(2):79-88.
30. Goren O, Matot I. Perioperative acute kidney injury. *Br J Anaesth.* 2015;115(2):3-14.
31. Ostermann M, Bellomo R, Burdmann EA, et al. Conference Participants. Controversies in acute kidney injury: Conclusion from a Kidney Disease: Improving Global Outcomes (KDIGO) Conference. *Kidney Int.* 2020;98(2):294-309.
32. Abelha FJ, Botelho M, Fernandes V, Barros H. Determinants of postoperative acute kidney injury. *Crit Care.* 2009;13(3):79.
33. Lone Z, Zhang A, Benidir T, et al. The role of enhanced recovery after surgery protocols in the development of acute kidney injury following radical cystectomy. *Urol Oncol.* 2022;40(10):453.
34. Park S, Cho H, Park S, et al. Simple postoperative AKI risk (SPARK) classification before non-cardiac surgery: a prediction index development study with external validation. *J Am Soc Nephrol.* 2019;30:170-181.
35. Zhang Y, Zhang X, Xi X, Dong W, Zhao Z, Chen S. Development and validation of AKI prediction model in postoperative critically ill patients:a multicenter cohort study. *Am J Transl Res.* 2022;14(8):5883-5895.
36. Kim JM, Jo YY, Na SW, et al. The predictors for continuous renal replacement therapy in liver transplant recipients. *Transplant Proc.* 2014;46(1):184-191.
37. Kateros K, Doulgerakis C, Galanakos SP, Sakellariou VI, Papadakis SA, Macheras GA. Analysis of kidney dysfunction in orthopaedic patients. *BMC Nephrol.* 2012;13:101.
38. Zarbock A, Koyner JL, Hoste EAJ, Kellum JA: update on perioperative acute kidney injury. *Anesth Analg.* 2018;127:1236-1245.
39. Puckett JR, Pickering JW, Palmer SC, et al. Low versus standard urine output targets in patients undergoing major abdominal surgery:A randomized noninferiority trial. *Ann Surg.* 2017;265:874-881.
40. Priyanka P, Zarbock A, Izawa J, Gleason TG, Renfurm RW, Kellum JA. The impact of acute kidney injury by serum creatinine or urine output criteria on major adverse kidney events in cardiac surgery patients. *J Thorac Cardiovasc Surg.* 2021;162:143-151.
41. Mizota T, Yamamoto Y, Hamada M, Matsukawa S, Shimizu S, Kai S:Intraoperative oliguria predicts acute kidney injury after major abdominal surgery. *Br J Anaesth.* 2017;119:1127-1134.
42. Ariyarathna D, Bhonsle A, Nim J, et al. Intraoperative vasopressor use and early postoperative acute kidney injury in elderly patients undergoing elective non-cardiac surgery. *Ren Fail.* 2022;44(1):648-659.
43. Cavallaro P, Bordeianou L. Implementation of an ERAS pathway in colorectal surgery. *Clin Colon Rectal Surg.* 2019;32(2):102-108.
44. Myles PS, Bellomo R, McCluskey S, et al. Restrictive versus liberal fluid therapy for major abdominal surgery. *New Engl J Med.* 2018;378:2263-2274.
45. Shen W, Wu Z, Wang Y, Sun Y, Wu A. Impact of enhanced recovery after surgery (ERAS) protocol versus standard of care on postoperative acute kidney injury (AKI): a meta-analysis. *PLoS One.* 2021;16(5):e0251476.
46. Biteker M, Dayan A, Tekkesin AI, et al. Incidence, risk factors, and outcomes of perioperative acute kidney injury in non-cardiac and nonvascular surgery. *Am J Surg.* 2014;207:53-59.
47. Kheterpal S, Tremper KK, Heung M, et al. Development and validation of an acute kidney injury risk index for patients undergoing general surgery:results from a national data set. *Anesthesiology.* 2009;110:505-515.
48. Kim M, Brady JE, Li G. Variations in the risk of acute kidney injury across intraabdominal surgery procedures. *Anesth Analg.* 2014;119:1121-1132.