Araştırma Makalesi
Research Article

Evaluation of the Frequency of Kidney Injury in the PACU: A Prospective Observational Study

AMELİYAT SONRASI YOĞUN BAKIM ÜNİTESİNDE (PACU) BÖBREK HASARI SIKLIĞININ DEĞERLENDİRİLMESİ: PROSPEKTİF GÖZLEMSEL BİR ÇALIŞMA

Farid HAJİLİ[1], Volkan HANCI[1], Şule ÖZBİLGİN[1] , Erol GÖKEL[1], Pınar AYVAT[2], Dilek ÖMÜR[1]

[1]Dokuz Eylul University, Department of Anesthesiology and Intensive Care, Izmir, Türkiye.
[2]Demokrasi University, School of Medicine,Department of Anesthesiology and Intensive Care, Izmir, Türkiye

ABSTRACT

In the study, the frequency of postoperative acute kidney injury (AKI), factors associated with AKI, and the effect of AKI on outcomes in surgical cases treated in the Postoperative intensive care unit (PACU) in the postoperative period were investigated.

Material and Method: The study is a prospective and observational study. Surgical cases treated in the PACU in the postoperative period were included in our study. Demographic characteristics of the patients, characteristics of the operation and anesthesia, Charlson Comorbidity Index (CCI) values, American Society of Anesthesiologist (ASA) risk classes, preoperative biochemistry results and preoperative hemogram results were recorded. Patients' AKI was assessed using the Risk, Injury, Failure, Loss of Function, and End-Stage Renal Disease (RIFLE) and Acute Kidney Injury Network criteria(AKIN).

Results: 583 postoperative cases were examined. The frequency of AKI in PACU was 17.7%. Age, preoperative CCI, BUN, GFR values, preoperative peptic ulcer history, preoperative calcium, total bilirubin levels and the urgency of operation were the preoperative reasons for AKI. Intraoperative use of blood and colloid also affected postoperative AKI. There was a relationship between AKI and the amount of crystalloid and FFP used in PACU. In patients with AKI, the frequency of inotropic use in PACU, the frequency of the use of IMV and the duration, cardiac complication, arrhythmia, respiratory system complications, sepsis and mortality rate were higher compared to patients without AKI ($p < 0.05$).

Conclusion: In the postoperative period, the frequency of AKI was found to be 17.7% in patients treated in PACU. It was determined that there was a relationship between age, CCI, BUN, GFR, calcium, bilirubin values and the urgency of the operation and postoperative AKI. The development of AKI in the postoperative period is associated with increased morbidity and mortality.

Keywords: Acute Kidney Injury, Postoperative, PACU, Critical Care

Farid HAJİLİ
Dokuz Eylul University, Department of Anesthesiology and Intensive Care, Izmir, Türkiye.
E-posta: farid.hacili@mail.ru
https://orcid.org/ 0000-0002-7737-8007

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ÖZ

Amaç: Bu çalışmada postoperatif yoğun bakım ünitesinde tedavi edilen cerrahi olgularda postoperatif dönemde, postoperatif akut böbrek hasarı (ABH) sıklığı, ABH ile ilişkili faktörler ve ABH'nin sonuçlar üzerine etkisi araştırılmıştır.

Gereç ve Yöntem: Bu çalışma prospektif ve gözlemsel bir çalışmadır. Çalışmamıza postoperatif dönemde PACU'da tedavi edilen cerrahi vakalar dahil edilmiştir. Hastaların demografik özellikleri, ameliyat ve anestezi özellikleri, Charlson Komorbidite İndeksi (CCI) değerleri, Amerikan Anesteziyoloji Derneği (ASA) risk sınıfları, ameliyat öncesi biyokimya sonuçları ve ameliyat öncesi hemogram sonuçları kaydedildi. Hastaların AKI'si Risk, Yaralanma, Başarısızlık, Fonksiyon Kaybı ve Son Dönem Böbrek Hastalığı (RIFLE) ve Akut Böbrek Hasarı Ağı (AKIN) kriterleri kullanılarak değerlendirildi.

Bulgular: Çalışmamızda postoperatif erken dönemde böbrek hasarlanması sıklığı %17,7 olarak belirlendi. Yaş, preoperatif CCI, BUN, GFR, kalsiyum, total bilüribün değerleri, preoperatif peptik ulkus öyküsü, operasyonun aciliyeti, intraoperatif kan ve kolloid kullanım sıklığı, PACU'da kristaloid ve TDP miktarı, PACU'da kolloid kullanımı sıklığı ile postoperatif akut böbrek hasarı arasında ilişki bulunduğu belirlenmiştir ($p<0,05$). Postoperatif böbrek hasarı gelişen olgularda PACU'da inotrop kullanım sıklığı, invaziv mekanik ventilatör kullanım sıklığı ve süresi, PACU yatış süresinin arttığı, kardiyak komplikasyon, aritmi, atrial fibrilasyon, solunum sistemi komplikasyonları, sepsis, nörolojik komplikasyonlar, postoperatif deliryum ve mortalite sıklığının yükseldiği belirlenmiştir ($p<0,05$).

Sonuç: Postoperatif yoğun bakım ünitesinde takip edilen olgularda erken dönemde böbrek hasarlanması sıklığı %17,7 olarak belirlenmiştir. Yaş, CCI, BUN, GFR, kalsiyum, bilirubin değerleri ve ameliyatın aciliyeti ile postoperatif AKI arasında ilişki olduğu tespit edilmiştir. Postoperatif dönemde AKI gelişimi artmış morbidite ve mortalite ile ilişkilidir.

Anahtar Kelimeler: Akut böbrek yetersizliği, Postoperatif, PACU, Yoğun Bakım

Acute kidney injury (AKI) is defined as the sudden loss of kidney functions in varying degrees, the excretion of nitrogenous wastes such as urea from the body and the deterioration of fluid/electrolyte balance. A decrease in glomerular filtration rate (GFR) and an increase in serum creatinine and blood urea nitrogen are also observed in AKI. For the grading of acute kidney injury, classifications such as "Risk, Injury, Failure, Loss, and End-stage (RIFLE)" and "Acute Kidney Injury Network (AKIN)" were created. Currently, these classifications are still used to determine the degree of kidney damage in patients (1-2).

It is very important to determine the perioperative risk factors for the early diagnosis and treatment of kidney damage that may occur in patients who will undergo surgery. Especially during major surgical procedures, AKI is one of the important risk factors for mortality and morbidity. Therefore, the effect of renal functions on surgical outcomes in the perioperative period is an important area of research. In patients who will undergo major surgery, pre-existing renal failure may occur with the effect of many factors (fluid treatments, anesthesia, etc.) in the perioperative period. Such factors may increase the risk of renal dysfunction and postoperative complications in postoperative patients (2-3).

In this prospective observational study, we aimed to evaluate the frequency of early postoperative kidney damage determined by RIFLE and AKIN criteria, the factors affecting the frequency of postoperative kidney damage, and the effects of postoperative kidney damage on outcomes, morbidity and mortality in surgical cases treated in postoperative intensive care unit (PACU).

MATERIALS AND METHOD

Our study was designed as a prospective, observational study. Ethics committee approval was obtained from the Non-Invasive Ethics Committee of Dokuz Eylül Univercity (Ethics Committee Decision dated 08.02.2021 and numbered 2021/04-25). Data collection was started after the approval of the ethics committee.

Inclusion Criteria: The study was carried out between 01.03.2021 and 28.02.2022. Patients over the age of 18 who were treated in the postoperative intensive care unit (PACU) of Dokuz Eylül Univercity Hospital Central Operating Room were included in the study. Written informed consent to participate in the study was obtained from all patients or their relatives.

Exclusion Criteria: Patients with a history of acute and chronic kidney disease before the operation, patients receiving or previously received renal replacement therapy, patients under the age of 18, patients whose records could not be reached, patients who did not give consent to participate in the study, patients who did not undergo surgery, and patients have positive COVID-19 tests, not included in the study.

Data Collection: The patients included in the study; Demographic characteristics, comorbidities, Charlson Comorbidity Index (CCI), American Society of Anesthesiology (ASA) risk class, preoperative biochemistry and hemogram results, anesthesia method, surgical characteristics were determined and recorded. Fresh frozen plasma (FFP), erythrocyte suspension (ES) and fluids (crystalloid/colloid) given intraoperatively were determined and recorded using intraoperative anesthesia follow-up registration forms.

Hemoglobin levels, serum creatinine level, urine output amount, renal replacement therapy requirement were determined and recorded on the postoperative 1st day. Patient data were obtained by examining preoperative and peroperative anesthesia patient data record forms, postoperative intensive care patient data record forms and hospital data record automation systems.

Scoring: With these collected data, patients were classified as risk (R), injury (I) and failure (F) using RIFLE criteria (2–4). Acute Kidney Injury Network (AKIN) classification (5-6) were also evaluated.

Early postoperative complications: We recorded early postoperative complications that occurred during the patients' stay in the PACU unit. Rigid objectives were set to define every individual complication in an attempt to avoid any observer bias. Complications were categorised as including in-hospital mortality, wound infections (inflammation/purulent drainage, positive swab culture), pneumonia (shadowing on chest X-ray, purulent sputum ± positive sputum culture), pulmonary complications (pneumonia, pneumothorax, pulmonary embolism, hypoxia, atelectasis), sepsis (positive culture with a change of 2 points in SOFA score), myocardial infarction (MI), preoperative non-existent atrial fibrillation (AF), cardiac arrhythmia (any arrhythmia non-existent preoperatively), urinary system complications (urinary retention, oliguria, acute renal failure), postoperative bleeding, postoperative delirium (7). Postoperative length of stay in the intensive care unit and status of discharge were recorded as discharge or mortality.

Statistical Analysis: In the analysis of the study, SPSS 24.0 was used. Variables with continuous values were expressed as mean ± standard deviation, and variables with frequency were expressed as frequency (n) and percentage (%). The normal test assumptions of continuous variables were analysed by Kolmogorov Smirnov and Shapiro-Wilk tests. Continuous data were analysed using t-test, one-way ANOVA test, Mann-Whitney U test, Kruskal-Wallis test, depending on the number of groups and normality test results. For group comparisons of frequency variables, Pearson's chi-square and Fisher's exact chi-square tests were used. The correlation analyses were performed using Pearson's correlation analysis test. Statistically significant p value less than 0.05 was considered statistically significant.

RESULTS

A total of 1152 patients treated in the PACU unit of Dokuz Eylül Univercity Hospital were included in the

study. 569 patients were excluded from the study because 67 patients had preoperative chronic renal failure, 32 patients had preoperative acute renal failure, 302 patients refused to participate in the study, 142 patients had missing data and 26 patients were under 18 years of age. Consequently, the data of 583 patients have been analysed.

Of the patients, 295 (50.6%) were male and 288 (49.4%) were female. Mean age was 65.14±17.00 years and mean weight was 73.89±10.79 kg. 171 (29.3%) of the cases were smokers and most common co-morbidity was HT (58.3%). The average CCI value was 4.11±2.17.

The cases were mostly in the risk group of ASA II (50.9%) and ASA III (45.8%). 381 (65.4%) cases were operated under elective conditions, 202 (34.6%) were operated under emergent conditions. General anesthesia was applied to 568 (97.4%) of them and regional anesthesia was applied to 15(2.6%). The anesthesia periods of the cases were average 215.92±142.33 minutes.

The urine volume of the patients at the arrival of PACU was 764.57±616.52 mL, postop 6th hour urine volume was 557.85±334.70 mL, postop 12th hour urine volume was 1091.09±510.64 mL, postop 24th hour urine volume was 1856.19±753.38 mL. The average BUN value of the patients was 20.32±19.26 mg/dL, Cr value was 0.84±0.40 mg/dL, and GFR value was 85.10±25.42. The average length of stay in PACU was 25.17±21.48 hours. 4 (0.7%) of the cases were dead. The average hospital stay of the patients was 13.80±11.73 days.

According to RIFLE and AKIN criteria, various levels of renal damage were detected in 103 (17.7%) patients. According to RIFLE classification, 64 (11.0%) cases were "R", 29 (5.0%) were "I", 10 (1.7%) were "F" however, when evaluated according to AKIN classification, 66 (11.3%) were in Phase I, 27 (4.6%) were in Phase II, and 10(1.7%) were in Phase III.

The incidence of kidney injury was analysed according to the departments. In subgroup analysis, the incidence of kidney injury was found to be statistically significantly different between departments ($p<0.05$, chi-square test) (Table 1)

Table 1. Frequency of kidney damage according to surgical departments of the cases (n, %)

Acute Kidney Injury	None	Presence
General Surgery (n=241)	188(78.0%)	53(22.0%)
Orthopedics (n=153)	122(79.6%)	31(20.4%)
Interventional Radiology (n=3)	2(66.7%)	1(33.3%)
Plastic Reconstructive Surgery (n=20)	17(85.0%)	3(15.0%)
Ear, Nose and Throat Surgery (n=26)	23(88.5%)	3(11.5%)
Neurosurgery (n=88)	78(88.6%)	10(11.4%)
Urology (n=29)	28(96.6%)	1(3.4%)
Thoracic Surgery (n=1)	0 (0%)	1(100%)
Ophthalmic Surgery (n=6)	6(100%)	0 (0%)
Obstetrics and Gynecology (n=16)	16(100%)	0 (0%)

According to subgroup analysis, statistically significant difference was found in the incidence of kidney injury according to the types of surgery ($p<0.05$, chi-square test) (Table 2).

Table 2. Frequency of kidney damage according to the type of surgery (n, %)

Acute Kidney Injury	None	Presence
Femur Fracture Surgery	69(72.6%)	26(27.4%)
Major Abdominal Surgery	123(75.0%)	41(25.0%)
Hepatobiliary Surgery	32(82.1%)	7(17.9%)
Intracranial Surgery	51(82.3%)	11(17.7%)
Major Head and Neck Surgery	20(83.3%)	4(16.7%)
Other Orthopedic Surgeries	27(87.1%)	4(12.9%)
Hernia Repair Surgery	7(87.5%)	1(12.5%)
Plastic Reconstructive Surgery	16(88.9%)	2(11.1%)
Gastrointestinal System Surgery	21(91.3%)	2(8.7%)
Amputation	16(94%)	1(5.4%)
Urological Surgery	27(96.4%)	1(3.6%)
Spinal Surgery	35(100.0%)	0(0%)
Gynecological Obstetric Surgery	13(100.0%)	0(0%)
Ophthalmic Surgery	6(100.0%)	0(0%)
Other Surgery	17(85%)	3(15.0%)

The association between comorbidities (DM, HT, CHF, CAD, asthma, COPD, OSAS, CKD, CVO, hypothyroidism, hyperthyroidism, malignancy) preoperatively was not statistically significant with AKI determined by RIFLE and AKIN scoring in the postoperative period (p>0.05, chi-square test). However, the frequency of renal injury determined by RIFLE was statistically higher in patients with a history of peptic ulcer (p=0.001, chi-square test). In the risk factor analysis of patients with postoperative kidney injury, there was a correlation between BUN, calcium, bilirubin values and calculated CCI and GFR. There were positive correlations between age, BUN, bilirubin and CCI values and negative correlations between GFR and calcium values (Table 3).

Table 3. CCI, age, and preoperative BUN, GFR, Ca, total bilirubin values (mean±SD) of patients with and without postoperative kidney damage

Acute Kidney Injury	CCI	Age	BUN	GFR	Ca	Bilirubin
None (n=480)	4.01±2.18	64.04±17.04	19.16±9.39	85.88±24.10	8.82±0.92	0.92±0.94
Presence (n=103)	4.55±2.10	70.31±15.91	21.42±12,45	80,31±24,28	8,37±1,04	1,81±2,68
p*	**0,021**	**<0,001**	**0,038**	**0,034**	**<0,001**	**<0,001**
p**	**0,023**	**0,001**	**0,038**	**0,034**	**<0,001**	**<0,001**
Coorelation Coefficient (r)	0.095	0.141	0,086	-0,088	-0,186	0,236

*: Student t test

**: Pearson correlation analysis

The urgency of the operation, intraoperative ES and colloid administration affected the postoperative kidney damage. However, crystalloid given in the intraoperative period, colloid, FFP, the amount of ES, the amount of urine

output and the duration of anesthesia did not affect the postoperative insufficiency. The amount of crystalloid and FFP given in the postoperative period, the use of inotropes, the use of invasive mechanical ventilators (IMV), affected renal failure (p<0.05) (Table 4,5).

Table 4. Examination of factors associated with postoperative kidney injury

Peroperative Parameters		**Patients without acute kidney injury (n=480)**	**Patients with acute kidney injury (n=103)**	**p**
The urgency of the operation	Urgent (n=202)	150(74.3%)	52(25.7%)	**< 0.001***
	Elective (n=381)	330(86.6%)	51(13.4%)	
Intraoperative use of ES	No(n=487)	411(84.4%)	76(15.6%)	**0.003***
	Yes(n=96)	69(71.9%)	27(28.1%)	
Intraoperative use of colloid	No(n=295)	253 (85.8%)	42 (14.2%)	**0.028***
	Yes(n=288)	227 (78.8%)	61 (21.2%)	
Postoperative parameters		**Patients without acute kidney injury (Mean±SD)**	**Patients with acute kidney injury** (Mean±SD)	**p**
Amount of crystalloid used in PACU		2462.30±1314.17	3278.44±1544.36	**<0.001****
Amount of colloid used in PACU		700.00±447.21	1312.50±1179.24	0.315**
Amount of ES used in PACU		322.36±128.76	333.33±123.09	0.796**
Amount of FFP used in PACU		345.83±121.46	500.00±0.00	**0.001****
Amount of PLT used in PACU		250±0.00	250.00±0.00	1**
Amount of inotrope used in PACU		13.25±15.46	31.12±40.08	**<0.001****
Urine output in PACU for 6 hours		597.62±332.38	372.52±279.76	**<0.001****
Urine output in PACU for 12 hours		1180,33±481.25	740,67±472.41	**<0.001****
Urine output in PACU for 24 hours		2015.54±655.20	1380.73±829.06	**<0.001****
Serum BUN level in PACU		18.31±17.90	29.30±22.44	**<0.001****
Serum Cr level in PACU		0.74±0.25	1.26±0.61	**<0.001****
Serum GFR level in PACU		90.85±21.61	59.64±25.48	**<0.001****

*: Chi square test , **: Student t test

The occurrence of postoperative AKI had a weaker positive correlation with the duration of IMV and PACU stay in the postoperative period (p<0.05) (Table 5).

Table 5. The relation between postoperative renal failure and intraoperative frequency and duration of NIMV and IMV use, length of stay in PACU and hospital (mean±S

	Patients without acute kidney injury (n=480)	**Patients with acute kidney injury (n=103)**	**p**	Coorelation Coefficient (r)
Frequency of inotropic use (n, %)	12 (2.5%)	17 (16.5%)	**<0.001***	---
Inotrope usage time (hours)	20.33±17.62	22.35±16.53	0.499**	---
Amount of inotropic use (mg)	13.25±15.46	31.12±40.08	0.073**	---
Frequency of NIMV use (n, %)	31 (6.5%)	8 (7.8%)	0.630*	---
NIMV usage time (hours)	7.29±5.83	8.62±9.54	0.959**	---
Frequency of IMV use (n, %)	417 (86.9%)	97 (94.2%)	**0.037***	---
IMV usage time (hours)	12.40±14.92	23.49±28.08	**<0.001****	0.233***
Length of stay in PACU (hours)	23.09±18.92	34.87±28.92	**<0.001****	0.209***
Length of stay in hospital (days)	13.75±11.90	14.07±10.97	0.797**	---

*: Chi square test , **: Student t test , ***: p<0,001; Pearson correlation analysis

When the postoperative complications that occurred during postoperative hospital follow-up were analysed, there was a statistically significant association between the presence of AKI, cardiac complications, arrhythmia, respiratory system complications and sepsis and the frequency of mortality ($p<0.05$) (Table 6).

Table 6. The relationship between the presence of postoperative kidney injury and postoperative complications

Postoperative Complications	Patients without acute kidney injury (n=480)	Patients with acute kidney injury (n=103)	All patients (n=583)	p
Mortality	18 (3.8%)	21 (20.4%)	39 (6.7%)	**<0.001***
Cardiac complications	22 (4.6%)	19 (18.4%)	41 (7%)	**<0.001***
Myocardial infarction	1 (0.2%)	0 (0%)	1 (0.2%)	0.823**
Arrhythmia	6 (1.3%)	9 (8.7%)	15 (2.6%)	**<0.001***
Atrial Fibrillation	4(0.8%)	3(2.9%)	7 (1.2%)	0.109**
Respiratory System Complications	35 (7.3%)	24 (23.3%)	59 (10.1%)	**<0.001***
Sepsis	0(0%)	3(2.9%)	3 (0.5%)	**0.005****
Postoperative bleeding	4(0.8%)	0(0%)	4 (0.7%)	0.458**
Neurological complication	4(0.8%)	3(2.9%)	7(1.2%)	0.109**
Postoperative delirium	3(0.6%)	2(1.9%)	5(0.9%)	0.215**

*: Chi square test

**: Fisher's exact test

DISCUSSION

The purpose of the present study involving 583 postoperative patients without previous renal injury was to evaluate the effects of AKI on outcomes, the frequency of early postoperative AKI and the factors affecting it. We found that the frequency of early AKI in PACU was 17,7%. Age, preoperative CCI, BUN, GFR values, preoperative peptic ulcer (PU) history, preoperative calcium, total bilirubin levels and the urgency of operation were the preoperative reasons for AKI. Intraoperative use of blood and colloid (regardless of amount) also affected postoperative AKI. There was a relationship between AKI and the amount of crystalloid and FFP used in PACU. In patients with AKI, the frequency of inotropic use in PACU, the frequency of the use of IMV and the duration, cardiac complication, arrhythmia, respiratory system complications, sepsis and mortality rate were higher compared to patients without AKI.

In general, studies have reported the risk of developing postoperative AKI at different rates in different operations. In a study in which 258 patients were evaluated after major abdominal surgery, 12.0% of the cases developed kidney damage, however, the cases did not reach higher than Stage 1 in the AKIN scoring system (8). In another study, which examined 703 major abdominal surgery patients retrospectively, it was reported that postoperative AKI was detected in 17.4% of the cases. When the distribution of these cases according to AKIN scoring was examined, the researchers found that 67.2% of the cases were identified as stage 1; 21.3% as stage 2 and 11.5% as stage 3 (9). In another study, in which 47 patients had primary ovarian cancer and peritoneal metastases and who were given SRC-HIPEC, the incidence of postoperative AKI was 40.4% (10). In a study including 239 cases who underwent prospective emergency laparotomy in the UK, it was reported that 39.7% of the cases had AKI (11). In our study, the incidence of AKI in the first 24 hours postoperatively was 25% in our patients who underwent major abdominal surgery and who were followed up in our PACU unit after surgery. Previous studies included all surgical patients in the postoperative period. However, our study included high-risk patients who were followed up in PACU. For this reason, we thought that the rate of kidney damage in our study was higher than in previous studies.

In a retrospective study of 365 patients who underwent intracranial aneurysm clipping surgery, the incidence of postoperative AKI was 18.63% and according

to the stages of AKIN, 92.65% of the cases were reported as stage 1; 5.88% as stage 2, and 1.47% as stage 3 (12). Similar to this study, the incidence of AKI was 17.7% in our study in patients followed up in the PACU unit after intracranial interventions.

In a study including 2692 patients who underwent hepatectomy, postoperative AKI incidence was found to be 16% (13). Likewise, in a study retrospective analysis of 457 patients who underwent hepatectomy, the incidence of postoperative AKI was found to be 15% (14). Another study including 446 patients who underwent partial hepatectomy found a 17.9% incidence of postoperative AKI (15). Postoperative renal injury was found in 7.6% of cases in another study in which 131 patients were prospectively evaluated after hepatobiliary surgery (16). Patients who underwent hepatectomy were evaluated in 146 patients and the incidence of postoperative AKI was found to be 21% (17). Furthermore, another study in which risk factors for postoperative AKI were analysed, 3616 patients including hepatectomy and pancreatectomy operations were evaluated and the postoperative AKI incidence was found to be 6.6% (18). Similar to these studies, in our study, postoperative kidney injury incidence was found to be 17.9% in our patients who were followed up in our postoperative PACU unit after hepatobiliary surgery.

The incidence of postoperative AKI was found to be 0.9% in a retrospective study including 4722 cases who underwent bariatric surgery (19). A study including 536 cases who underwent radical gastrectomy showed that the incidence of postoperative AKI was 6.9% (20). The incidence of AKI was found to be 14.4% in a retrospective study including 4718 subjects who underwent partial or total gastrectomy (21). Postoperative AKI incidence was found to be 35.3% in a study including 595 individuals who underwent oesophagectomy for oesophageal cancer (22). Retrospectively, in another study including 898 patients, postoperative renal injury incidence after gastrectomy was reported to be 11.9% (23). In our study, however, postoperative AKI incidence was found to be 8.7% in postoperative patients who were followed up and treated in the PACU unit after upper gastrointestinal system surgeries.

In a study including 486 patients who underwent thyroidectomy, postoperative AKI was found to be 4.9% (24). Postoperative AKI was evaluated with AKIN criteria in a study including 450 geriatric patients who underwent femur fracture surgery and AKI developed in 21.1% of the patients (25). The rate of postoperative AKI was found to be 28.4% in another retrospective study involving femur fracture patients over 65 years of age (26). The incidence of AKI was reported to be 19.2% in another study in which 500 patients operated for femur surgery were retrospectively evaluated (27). Another study in which 165 patients were prospectively evaluated in terms of the incidence of AKI and risk factors after femoral fracture surgery reported that 15.3% of the patients developed postoperative AKI and 1.8% of the patients needed renal replacement therapy (28). The incidence of AKI in the first 5 days postoperatively was found to be 11.9% in normal weight patients, 10.1% in underweight patients, 12.5% in the overweight group and 17.9% in obese patients in another study involving 13529 patients between 2005-2011 and investigating the incidence and risk factors of AKI after femoral fracture surgery (29). Patients aged ≥80 years who underwent surgery for femur fracture between 2015 and 2020 were evaluated in another retrospective study, and the incidence of AKI in the postsurgical term was found to be 9.8% (30). The development rate of AKI in the postoperative period was found to be 4.4% in another study conducted on 550 patients operated on for femur fracture (31). The incidence of postoperative AKI was 27.4% in patients who underwent femur fracture surgery in our study. The incidence of postoperative AKI in amputation cases was found to be 5.4% and the incidence of postoperative AKI after other orthopaedic surgeries was found to be 12.9% in our study.

The frequency of AKI varies according to many factors, such as the ethnic characteristics of the patients, the different postoperative follow-up periods, the country where the study was conducted, the year the study was conducted, and it is dispersed over a wide range in the literature analysis. These studies generally include all surgical patients in the postoperative period for the specific types of surgery such as orthopedic, intracranial etc. We considered that the reason for the difference between the previous studies and the rate of AKI in the present study

was that higher-risk patients were included in the study and therefore followed up in the PACU.

A prospective study evaluating 258 patients after major abdominal surgery found that age and body mass index (BMI) were found to be risk factors for AKI. Hospitalisation in the critical care unit for more than 48 hours was found to be an independent risk factor in this study (8). In another retrospective study including 703 major abdominal surgery cases, hypertension was identified among the risk factors (9). In another study including 47 patients who underwent primary ovarian cancer operation, risk factors were found to be age, initial creatinine, initial GFR, preoperative albumin, number of preoperative carboplatin cycles, time interval between preoperative chemotherapy and operation and blood transfusion volume (10). In a study of 239 patients who underwent emergency laparotomy, age, serum lactate level, number of white blood cells, pre-operative systolic blood pressure and tachycardia were the risk factors (11). High-density lipoprotein (HDL), prothrombin time (PT), estimated glomerular filtration rate (eGFR), aneurysm larger than 10 mm and aneurysm rupture prior to surgery were found to be associated with AKI in a retrospective study of 365 patients who underwent intracranial aneurysm clipping surgery (12). In a study evaluating 2692 patients who underwent hepatectomy, age, female gender, BMI, diabetes, hypertension, haematocrit, duration of surgery, planned open procedure and pringle manoeuvre were factors increasing the risk of AKI (13). Another study in which 457 patients who underwent hepatectomy were analysed, advanced age, increased MELD score, major hepatectomy and extended operation duration were determined as risk factors (14). In a prospective study of 131 patients after hepatobiliary surgery, advanced age and elevated MELD-Na score were found to be important independent risk factors for the occurrence of AKI postoperatively (16). In another study in which 146 patients were prospectively evaluated after hepatobiliary surgery, increased intraoperative blood loss, age and pre-existing chronic kidney damage were independent risk factors (17). In a retrospective study evaluating 4722 patients, dehydration and infectious complications after bariatric surgery were determined as risk factors (19). Postoperative AKI risk was independently associated with age, BMI, hypertension, hyperlipidaemia, hyperlipidaemia and preoperative cystatin C in a study involving 536 patients undergoing radical gastrectomy (20). It was reported in a retrospective study including 4718 patients who underwent partial or total gastrectomy that male gender, hypertension, COPD, hypoalbuminemia, diuretic, vasopressor, contrast agent use and transfusion of ES were risk factors (21). In a study including 595 patients who underwent oesophagectomy, risk factors for AKI were reported as BMI, preoperative albumin level and angiotensin converting enzyme use (22). No relation was found between preoperative thyroid function and postoperative AKI in a study performed on 486 patients who underwent thyroidectomy. The risk factors associated with AKI in the same study were male gender, use of beta-blockers preoperatively, low albumin levels preoperatively and colloid use (24). In another study including hip fracture cases, older age, cardiac disease and postoperative transfusion were found to be related with AKI as a result of multivariate analysis (26). One study in which 500 patients who underwent surgery for hip fracture were evaluated found a higher risk of AKI in patients with chronic kidney disease and two or more concomitant comorbidities. The study reported that there was no association found between the type of operation and the occurrence of AKI (27). Another study including 13529 patients with hip fracture underlined that the postoperative risk of AKI increased in patients with obesity compared to patients with normal weight (29). According to another study conducted in 550 patients operated on for hip fracture, an estimated blood deficit of more than 766.5 ml and postoperative albumin levels less than 2.8 g/dl were emphasised as risk factors (31). We found a relationship between age, preoperative CCI, BUN, GFR values, preoperative history of PU, preoperative calcium, bilirubin levels, urgency of the operation, intraoperative use of blood and colloid, amount of crystalloid and FFP used in PACU and postoperative AKI.

In another study analysing risk factors for postoperative AKI, data of 3616 cases who had undergone a major abdominal surgery between 2016 and 2018 were analysed. It was reported that AKI incidence was 5.0% versus 7.8% in the TIVA versus inhalation groups, respectively. It has been highlighted that the risk of AKI

was significantly increased in the inhalation group (18). Nevertheless, no relation was found between the type of anaesthesia and the incidence of postoperative AKI in our study.

One study evaluating the relationship between calcium levels and AKI (32) found that a "U" shaped association was found to be present between calcium levels and AKI and both hypocalcaemia and hypercalcaemia were related with an elevated risk of AKI. In some other studies, it was found that high bilirubin levels were associated with AKI and high bilirubin levels were found to be another important risk parameter for the occurrence of AKI (33,34).

In our study, preoperative history of PU was found to be among the factors associated with AKI. In previous studies, similar to the findings of our study, AKI was emphasised in patients with a history of PU and especially in patients using long-term omeprazole (35,36).

Morbidity and mortality are reported to be increased in cases who develop postoperative AKI (9,14,15,25,27,28), hospital stay is prolonged (15,21,25,27,28), incidence of postoperative complications is increased (16), critical care unit hospitalisation rate, in-hospital mortality rate (21) and treatment costs are high (28). We found a statistically significant relationship between postoperative AKI and the frequency of cardiac complications, arrhythmia, respiratory system complications, sepsis and mortality rate. Consistent with previous reports, postoperative complication, morbidity and mortality rates increased significantly with the development of AKI.

As a result, we found that the incidence of early postoperative AKI was 17.7% in patients without previous renal injury who were managed in the intensive care unit in the immediate postoperative period. Age, preoperative CCI, BUN, GFR values, preoperative PU history, preoperative calcium, total bilirubin levels and urgency of the operation were correlated with postoperative AKI. Intraoperative blood and colloid use also affected postoperative AKI. There was a correlation between AKI and the amount of crystalloid and FFP used in PACU. The frequency of inotropic use in PACU, frequency and duration of IMV use, cardiac complications, arrhythmias, AF, respiratory system complications, sepsis and mortality rate were higher in patients with AKI than in patients without AKI.

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