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The Effect of Sevoflurane and Desflurane on Low-flow Anesthesia in Acute Kidney Injury After Urological Surgery

Ürolojik Cerrahi Sonrasında Akut Böbrek Hasarında Düşük Akım Anestezide Sevofluran ve Desfluranın Etkisi

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ABSTRACT

Objective: Acute kidney injury (AKI) is associated with postoperative mortality and morbidity after noncardiac surgery. The present study is intended to evaluate the effect of sevoflurane (SEV) and desflurane (DES) on AKI in low-flow anesthesia, with a specific focus on urological surgeries known for their elevated risk of renal dysfunction.

Methods: This retrospective study included patients who underwent urological surgery lasting at least 2 hours under low-flow anesthesia (1 L min^{-1}) with SEV and DES between January 2021 and December 2022. Demographic data (age, body mass index, gender), American Anesthesiology Association physical classification (ASA), and history of comorbidities such as hypertension and diabetes mellitus, were evaluated. Additionaly, preoperative and 48th postoperative renal function parameters and operative characteristics, were examined.

Results: The study encompassed data from a total of 99 patients. The patients were divided into two groups: Group SEV (n=51) and Group DES (n=48). In terms of demographic data, operative characteristics, or preoperative laboratory results were no differences between the groups. Intraoperative heart rate, mean blood pressure, and bispectral index were similar in both groups. Urea, creatinine, and glomerular filtration rate values at the postoperative 48th hour were similar between the groups. The occurrence of AKI was not significantly different between Group SEV (n=12) and Group DES (n=12) (p=0.630).

Conclusion: Compared to desflurane, sevoflurane had a similar effect on the development of AKI in urological surgeries under low-flow anesthesia.

Keywords: Acute kidney injury, desflurane, sevoflurane

ÖZ

Amaç: Akut böbrek hasarı (ABH), nonkardiyak cerrahi sonrası postoperatif mortalite ve morbidite ile ilişkilendirilmektedir. Bu çalışmada, özellikle renal fonksiyon bozukluğu yönünden artmış risk teşkil eden ürolojik cerrahilerde sevofluran (SEV) ve desfluranın (DES) düşük akım anestezide ABH üzerine etkisini değerlendirmeyi amaçladık.

Yöntem: Bu retrospektif çalışmaya Ocak 2021- Aralık 2022 arasında sevoflurane ve desfluran ile düşük akım anestezi (1 L dk^{-1}) altında, en az 2 saat süren ürolojik cerrahi geçiren hastalar alındı. Hastaların cinsiyet, yaş, vücut kitle indeksi, ASA skoru, hipertansiyon ve diyabetes mellitus gibi komorbidite öyküsünü içeren demografik veriler incelendi. Preoperatif ve postoperatif 48. saat renal fonksiyon parametreleri ve operasyon özellikleri tarandı.

Bulgular: Çalışmaya toplam 99 hastanın verileri dahil edildi. Hastalar Grup SEV (n=51) ve Grup DES (n=48) olmak üzere iki gruba ayrıldı. Gruplar arası demografik veriler, cerrahi operasyon ve preoperatif laboratuvar değerleri arasında fark yoktu. İntraoperatif kalp atım hızı, ortalama kan basıncı ve bispektral indeks değerlerinde gruplar arası fark yoktu. Postoperatif 48. saatte bakılan üre, kreatinin ve glomerüler filitrasyon hızı değerleri gruplar arası benzerdi. Akut böbrek hasarı yönünden gruplar arasında fark yoktu (Grup SEV: 12, Grup DES: 12, p=0,630).

Sonuç: Desfluran ile karşılaştırıldığında, düşük akım sevofluran anestezisinin, ürolojik cerrahilerde ABH gelişimi yönünden benzer etkiye sahip olduğu gözlendi.

Anahtar sözcükler: Akut böbrek hasarı, desfluran, sevofluran

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INTRODUCTION

Acute kidney injury (AKI) is a common complication that occurs following noncardiac surgeries, with reported incidence rates ranging from 6% to 39%. It increases morbidity and mortality, and even mild AKI is associated with increased perioperative and long-term mortality. In addition, it causes longer stays in the intensive care unit and hospital, leading to increased healthcare costs. Furthermore, AKI is a common component of multiorgan dysfunction, which can be caused by failures of other major organ systems. Therefore, it is a common complication that worsens postoperative complications (1-3).

Different inhalation anesthetics have varying effects on systemic circulation or renal perfusion (4). In animal studies, sevoflurane (SEV) is associated with compound A nephrotoxicity resulting from its interaction with carbon dioxide absorbents (5,6). In previous studies, it has been reported that compound A concentration would increase with low-flow rate; thereby, the risk of nephrotoxicity would increase in a concentration and time-dependent manner (7-9). However, the impact of SEV on the kidney during low-flow anesthesia remains debatable, as human studies in this area are limited. Urological surgeries constitute a risky group of surgeries in terms of renal failure due to preoperative renal dysfunction and possible tissue loss after surgery. But, little is known about the effect of anesthesia on the development of AKI, especially after urological surgery.

Therefore, in our study aims to examine the influence of SEV and desflurane (DES) on short-term AKI in patients undergoing urological surgery under low-flow anesthesia.

MATERIAL and METHODS

After receiving approval from the Eskisehir Osmangazi Hospital Ethics Committee (Decision number: 2023/17), a retrospective analysis was conducted on the data of 99 patients who underwent urological surgery between January 2021 and December 2022. The study included patients who underwent urological surgeries such as nephrectomy, cystectomy, and prostatectomy under general anesthesia for a minimum duration of 2 hours. Patients who received anesthesia techniques other than general anesthesia with sevoflurane (SEV) and desflurane (DES) were excluded from the study.

Demographic data (gender, age, body mass index (BMI)), ASA (American Society of Anesthesiologists) physical classification, and history of comorbidities including hypertension (HT) and diabetes mellitus (DM), were analyzed. Additionally, preoperative renal functions (urea, creatinine, and glomerular filtration rate (GFR)), operative characteristics, operative time, intraoperative hemodynamic values (heart rate, mean blood pressure), bispectral index (BIS) and postoperative renal functions (urea, creatinine, and GFR) were analyzed.

Creatinine change was calculated as the difference between postoperative and preoperative creatinine levels, with a threshold of ≥0 indicating a significant change. Preoperative GFR was divided into 5 categories: G1 (≥90 mL min^{-1} 1.73 m^{-2}), G2 (60–89), G3a (45–59), G3b (30–44), G4 (15–29), G5 (<15), and those in category 5 (<15) were excluded.

Primary Outcome

According to KDIGO (Kidney Disease: Improving Global Outcomes), an increase in creatinine is defined as 0.3 mg dL^{-1} or more within 48 hours, more than 1.5 times the baseline value within the first 7 days, or a urine volume of <0.5 mL kg^{-1} sa^{-1} in the last 6 hours (1). In this study, the criteria for acute kidney injury (AKI) were based on an increase in creatinine of 0.3 mg dL^{-1} or more within the 48-hour postoperative period.

General Anesthesia Procedure

After standard monitoring with electrocardiogram, pulse oximetry, capnography, invasive arterial blood pressure, and BIS (Covidien Deutschland GmbH, Neustadt, Germany), a routine general anesthesia protocol was performed. In the anesthesia protocol, intravenous anesthetics (thiopental and propofol), muscle relaxants (rocuronium), and analgesics (remifentanil) were used for induction. The volatile anesthetics SEV (Sevorane®; AbbVie, North Chicago, IL, USA) or DES (Suprane; Baxter, Deerfield, IL, USA) were used for maintenance, and groups were designated as Group SEV and Group DES according to the volatile agent used. In both groups, anesthesia maintenance was started with a mixture of 50% O_2 + 50% air and 6–8% desflurane or %2-3 sevoflurane in a 4 L min^{-1} fresh gas flow (FGF). When the BIS value reached 40–60 (after a mean duration of 10 min), FGF set to 1 L min^{-1}.

A remifentanil infusion (0.1–0.2 µg kg^{-1}) was administered within 20% of the preoperative values. Patients were mechanically ventilated with tidal volume 6-8 mL kg^{-1}, I:E ratio: 1:2 and the respiratory rate was adjusted so that the $EtCO_2$ value was between 30-40 mmHg and a fresh gas flow of 1 L min^{-1} of air/O_2 combination. In case of hypotension, defined as a systolic blood pressure decrease <65 mmHg, firstly volume replacement and ephedrine 5-10 mg was administered for treatment. Postoperatively, all patients were administered paracetamol (1 g) and tramadol (1 mg kg^{-1}) for postoperative analgesia and then were extubated and then to the postanesthesia care unit. Dräger Perseus® A500 closed-circuit system anesthesia devices with carbon dioxide absorbent (KNGSORB, Kingmedikal Ltd. Şti, İzmir, Türkiye) are used in our clinic, which contains CaOH and NaOH.

Statistical Analysis

The conformity of continuous variables to a normal distribution among the groups was evaluated using the Shapiro–Wilk normality test. In addition, the Mann–Whitney U test was performed for intergroup comparison of the continuous variables. An analysis of variance was used to compare repeated measures of the continuous variables between the groups. Furthermore, chi-square analysis was used to compare categorical variables between the groups. Pearson's, Yates', and Fisher's exact tests and the exact test methods obtained using Monte Carlo simulation were applied in the chi-square analyses. The $p<0.05$ was set as the significance level. All analyses were performed using IBM SPSS Statistics Version 25 (IBM Corp Armonk, NY).

RESULTS

In this study, we conducted an analysis of 99 patients who underwent urological surgery. The groups exhibited no significant differences demographic data, including age, BMI, gender, ASA score, presence of comorbidities (DM and HT), or operative characteristics and preoperative laboratory values (hemoglobin, urea, creatinine, and GFR). Additionally, there was no significant difference in the distribution of preoperative GFR categories (G1, G2, G3a, G3b, and G4) between the groups (p=0.593) (Table I, II).

There was a statistical difference between the groups in terms of operative time (Group SEV=225.78 ± 88.26 and Group DES=258,13 ± 108,93) (p=0.047) (Table I). However, urea, creatinine, and GFR values at the postoperative 48th hour were similar between the groups (Table II) (Figure 1). There was no difference between the groups in terms of AKI (Group SEV=12, Group DES=12, p=0.630).

Intraoperative heart rate, mean blood pressure, and BIS were not different between the two groups (p=0.07, p=0.213, and p=0.287, respectively) (Figures 2, 3, 4). Additionally, there was no statistical difference between the groups in terms of

Table I: Baseline, Demographic and Surgical Characteristics [Mean ± SD and Number (%)]

	Sevoflurane (n = 51)	Desflurane (n = 48)	p
Age	60.18 ± 12.86	61.69 ± 9.51	0.989
BMI	27.71± 5.16	27.36 ± 4.11	0.809
Gender (M/F)	38/13	36/12	1.000
ASA			
I	3 (5.8)	1 (2.0)	0.343
II	33 (64.7)	37 (77.0)	
III	15 (29.4)	10 (20.8)	
Comorbidity			
DM	8 (15.6)	10 (20.8)	0.687
HT	21 (41.1)	19 (39.5)	1.000
Preoperative Hb (gr dL^{-1})	14.20 ± 2.23	13.95 ± 2.06	0.415
Surgical operation			
Radical prostatectomy	10 (19.6)	9 (18.7)	0.443
Radical cystectomy	9 (17.6)	13 (27.0)	
Partial nephrectomy	19 (37.2)	10 (20.8)	
Radical nephrectomy	7 (13.7)	4 (8.3)	
Prostatectomy	3 (5.8)	6 (12.5)	
Nephroureterectomy	2 (3.9)	4 (8.3)	
Nephrectomy	0 (0)	1 (2.0)	
Pyeloplasty	1 (1.9)	1 (2.0)	
Operative time (minute)	225.78 ± 88.26	258.13 ± 108.93	0.047
Complication	10 (19.6)	7 (14.5)	0.803
Fever	1 (2)	0 (0)	
Urinary tract infection	0 (0)	1 (2.1)	
Ileus	1 (2)	0 (0)	
Myocardial infarction	0 (0)	1 (2.1)	
Pulmonary embolism	1 (2)	0 (0)	
Need for intensive care	7 (13.7)	5 (10.4)	

SD: Standard deviation; **BMI:** Body mass index; **ASA:** American Society of Anesthesiologists; **DM:** Diabetes mellitus; **HT:** Hypertension; **Hb:** Hemoglobin.

Table II: AKI and Perioperative Laboratory Values [mean ± SD and number (%)]

	Sevoflurane (n=51)	Desflurane (n=48)	p
AKI	12 (23.1)	12 (25.0)	0.630
Creatinine variance	0.23 ± 0.24	0.30 ± 0.25	0.171
Preoperative urea	15.11 ± 4.29	16.74 ± 8.42	0.449
Preoperative creatinine	0.92 ± 0.23	1.08 ± 0.51	0.116
Preoperative GFR category G1 (≥90 mL min^{-1} 1.73 m^{-2}) G2 (60–89) G3 (45–59) G3b (30–44) G4 (15–29)	 23 (45.0) 22 (43.1) 4 (7.8) 2 (3.9) 0 (0)	 19 (39.5) 19 (39.5) 4 (8.3) 4 (8.3) 2 (4.1)	0.593
Postoperative urea	13.79 ± 5.11	14.86 ± 7.61	0.413
Postoperative creatinine	1.06 ± 0.36	1.24 ± 0.55	0.075
Postoperative GFR	72.93 ± 19.56	66.07 ± 21.79	0.132
Preoperative lactate	1.20 ± 0.61	1.00 ± 0.51	0.050
Postoperative lactate	1.48 ± 0.78	1.66 ± 0.85	0.156

AKI: Acute kidney injury; **SD:** Standard deviation; **GFR:** Glomerular filtration rate.

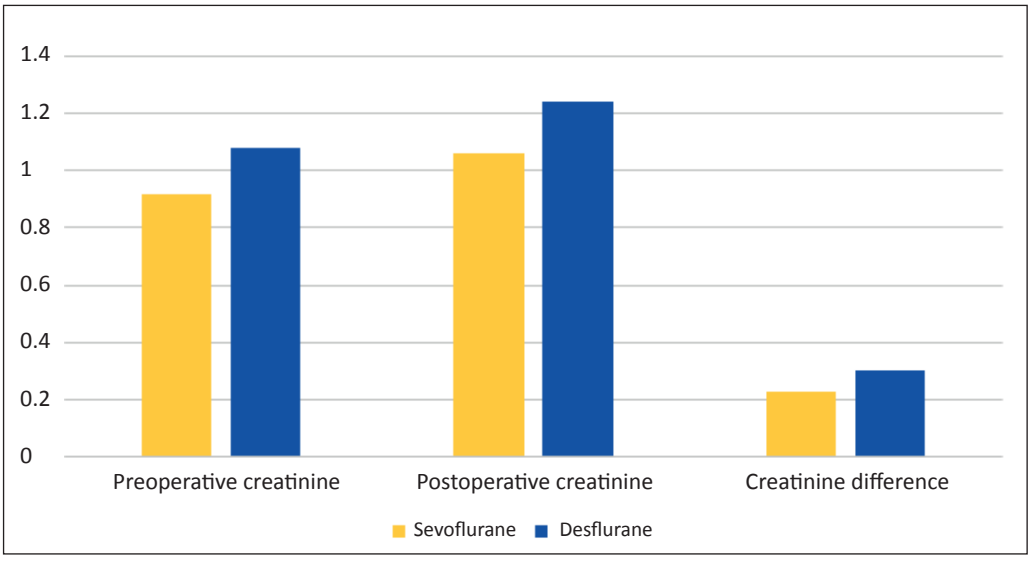

Figure 1: Perioperative creatinine values.

preoperative and postoperative lactate levels (p=0.050, and p=0.156, respectively).

Other postoperative complications observed included fever, urinary tract infection, myocardial infarction, pulmonary embolism, ileus, and the need for intensive care. However, there was no significant difference between the groups in terms of these complications (p=0.803) (Table I).

DISCUSSION

In this retrospective study, we evaluated the association between SEV and DES inhalation anesthetics under low-flow anesthesia and the incidence of postoperative AKI in patients undergoing urological surgery. The incidence of AKI in the early postoperative period was found to be 24.2% among the patients. Importantly, there were no significant differences in predictive factors and the incidence of AKI between the SEV and DES groups.

Concerns regarding organ toxicity associated with the metabolites of inhalation anesthetics exist, although DES is known to be highly stable and less bio transformed compared to other halogenated inhalation anesthetics. Previous studies have shown better hepatic and renal function in DES compared to SEV when administered at an equivalent dose of 1 minimum alveolar concentration (MAC) desflurane undergoing right hepatectomy in living donors (5). It has been shown that

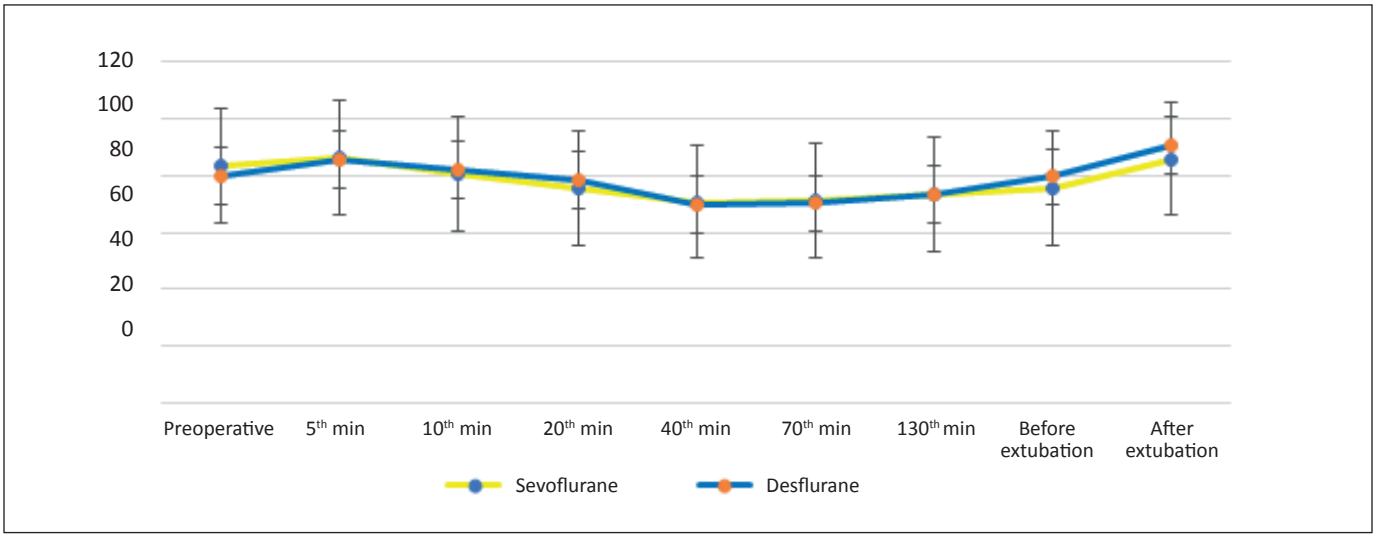

Figure 2: Perioperative heart rate values.

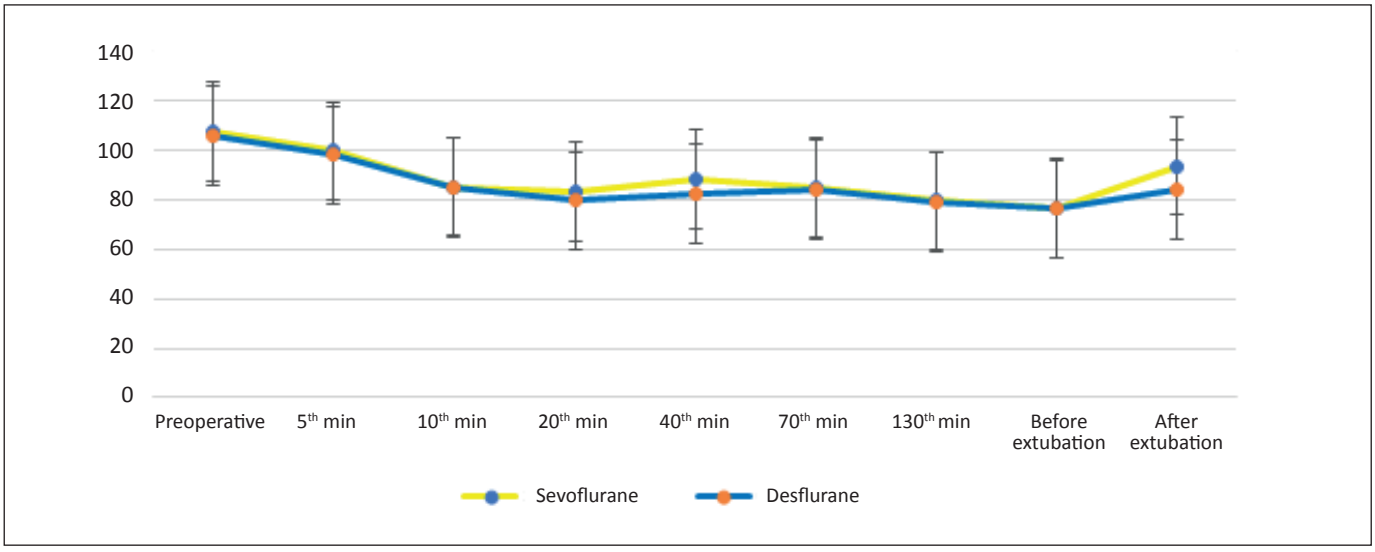

Figure 3: Perioperative mean arterial blood pressure values.

the immune modulatory activity of inhalation anesthetics is related to the trifluorocarbon molecules in their structure, and renal protection is related to lipid solubility. However, it has been reported that DES has similar protective effects with SEV on ischemic reperfusion injury in recipients of living donor kidney transplants, although its lipid solubility is lower (10). In our study, equivalent depths of anesthesia were achieved with BIS monitoring. However, no difference was found in terms of postoperative renal function tests or the incidence of AKI between the SEV and DES groups.

The nephrotoxicity associated with compound A is depends on the dose, concentration, and exposure time. Compound A in the anesthesia circuit will increase as the FGF decreases, so there are ongoing discussions about whether exposure to compound A will increase in low-flow anesthesia. To minimize exposure to compound A, the Food and Drug Administration does not recommend exceeding 2 MAC hours at flow rates of 1–2 L min^{-1} or even a FGF rate of <1 L min^{-1} in patients that are administered SEV. However, studies have shown that long-term (≥10 hours) low-flow SEV anesthesia has similar effects on renal and hepatic functions compared to high-flow SEV and low-flow isoflurane anesthesia in patients undergoing head and neck tumor surgery (11,12). Additionally, low FGF with long anesthesia duration has been reported to have similar effects on hepatorenal functions between isoflurane and SEV in orthopedic surgeries, even in patients with renal disease (13). Even in patients with pre-existing renal disease, the effects of low-flow SEV and isoflurane were reported to be similar on renal function (14). Reducing FGF during inha-

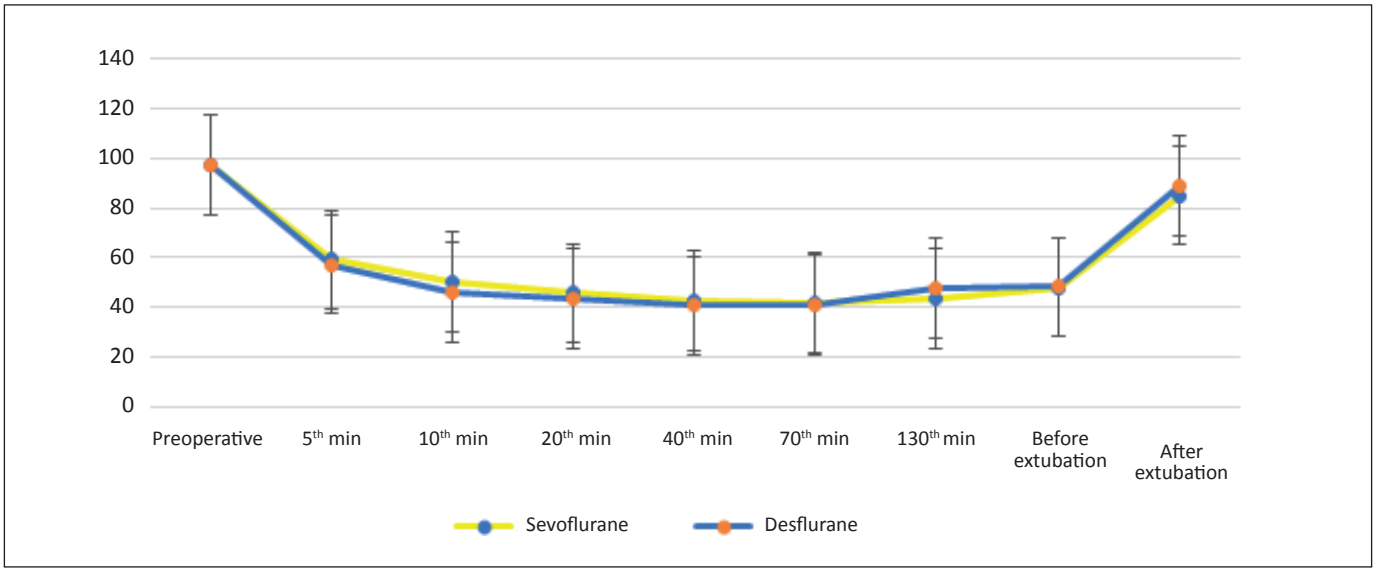

Figure 4: Perioperative bispectral index values.

lation anesthesia can reduce costs and have environmental benefits (15).

The use of prolonged SEV anesthesia in low-flow anesthesia has been reported to be safe in some studies, even when baralyme is used instead of the CO_2 absorbent, which maximizes exposure to compound A (16). Although there were a variety of operative times in our study, all surgeries lasted longer than 2 hours. With the use of the CO_2 absorbent, FGF was applied at 1 L min^{-1}, and no difference was found between the groups in terms of AKI. This suggests that the low-flow anesthesia technique with SEV using the CO_2 absorbent did not lead to a higher incidence of AKI compared to DES anesthesia in the context of urological surgeries.

A number of risk factors have been identified for renal dysfunction, which can be related to both surgery and anesthesia (17). Predictors for AKI include advanced age, male gender, hypoalbuminemia, ascites, active congestive heart failure, HT, DM, higher ASA physical status, intraperitoneal surgery, emergency surgery and renal failure (18,19). Compared to propofol anesthesia, SEV anesthesia decreased urine output and sodium excretion and was shown to increase plasma renin (20). In a study by Bang et al., where SEV was compared to propofol in colorectal surgery, SEV was associated with a modest increase in the incidence of AKI when RIFLE criteria were applied instead of AKIN (19). However, SEV anesthesia was not associated with increased mortality or admission to the intensive care unit, thus the clinical significance of these results remains unclear. The incidence of AKI in the SEV group was reported as 8.9% and 11.2% according to AKIN and RIFLE criteria, respectively (19).

Akut kidney injury is common occurrence among patients undergoing infrarenal abdominal aortic surgery. The AKIN criteria have demonstrated greater sensitivity and predictability in terms of mortality compared to the RIFLE criteria when in determining the incidence of AKI. Additionally, regardless of other postoperative complications and comorbidities, the presence of postoperative AKI, as defined by both criteria, was associated with higher 30-day overall mortality rates (21). According to the AKIN criteria, the incidence of AKI in our study was 18.5%. The higher incidence observed in our study may be attributed to the inclusion of patients with tissue loss, history of urinary tract surgery, or pre-existing renal dysfunction who were considered to be at a higher risk.

According to KDIGO, the female gender is defined as a risk factor in the development of AKI, whereas, in contrast, there are studies reporting that it is a protective factor in the development of hospital-associated AKI (22,23). Privratsky et al., in a study of patients undergoing noncardiac surgery, reported that younger women had lower rates of postoperative AKI than older women and men of all ages (1). However, in our study, no correlation was found between gender and AKI. The male gender was predominant due to the selected surgical population.

Perioperative hypotension has been linked to the development of AKI. Mechanisms that make the kidney more susceptible to ischemia and hypoxia during perioperative hypotension are held responsible in this regard. Additionally, perioperative kidney-protective strategies should take into account comorbidities such as preoperative renal insufficiency, diabetes, hypertension, and heart failure, as these factors can further increase the vulnerability of the kidney to hypotension-

induced damage. Although AKI is known to vary depending on both the severity and duration of hypotensive episodes, safe arterial pressure levels have not been defined (24). A recent consensus reported that an intraoperative mean blood presseure target of >60–70 mmHg was associated with a lower incidence of AKI in noncardiac surgery (25). In the study, risk factors such as intraoperative mean blood pressure values, preoperative renal failure, DM, and HT were similar between the groups.

Our study had several limitations that should be acknowledged. Firstly, the retrospective nature of the study limited our ability to gather data on all parameters that could potentially impact the results. One of these was the measurement of compound A level. Secondly, our study had a relatively short period, and the findings may not be easily generalized to other populations or surgical procedures.

CONCLUSION

In our study, we specifically selected a population undergoing urologic surgery, which presented a risk for renal failure due to the nature of the surgical procedures. We compared the effects of low-flow sevoflurane anesthesia to desflurane and found that sevoflurane had similar effects on postoperative renal functions and the development of AKI.

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AUTHOR CONTRIBUTIONS

Conception or design of the work: MO, GEK
Data collection: OY, SB
Data analysis and interpretation: MO, AO
Drafting the article: MO, GEK
Critical revision of the article: GEK, BBY
The author (MO, GEK, OY, SB, AO, BBY) reviewed the results and approved the final version of the manuscript.

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