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Acute Kidney Injury After Hip Replacement Surgery Under Spinal Anesthesia in the Elderly: A Retrospective Analysis

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Abstract

Introduction: The elderly are particularly prone to perioperative organ dysfunction due to various procedure-related or anesthetic issues. We aimed to assess the retrospective data of the subjects who underwent total hip replacement surgery under spinal anesthesia within the scope of acute kidney injury (AKI) occurrence.

Methods: Data from 130 patients were evaluated. Bupivacaine mixtures were preferred for providing adequate anesthesia. The sample population was split into two groups according to AKI development, considering the Kidney Disease Improving Global Outcomes (KDIGO) criteria. Demographic features, intraoperative hemodynamical recordings, and other perioperative biochemical and clinical parameters of the groups were compared. Length of hospitalization (LOH), intensive care unit stay (ICUS), in-hospital mortality, and one-year mortality were established as outcome variables.

Results: AKI was observed in 9.2% (n=12) of our sample population. In the entire set of data, baseline renal function was the only discriminating factor between the AKI (-) and AKI (+) groups. The initial glomerular filtration rate (GFR) was significantly lower in the latter (ml/min/m^2, 71 [30] vs. 37 [34.7], p<0.001). A GFR of 55 ml/min/m^2 was determined as a cutoff value for estimating AKI occurrence (AUC:0.88, p<0.001) with 83.3% sensitivity and 76.3% specificity. AKI was associated with increased LOH (days, 3 [2] vs. 4 [9.5], p=0.038) and ICUS (days, 0.5 [3] vs. 3.5 [10.3], p=0.005).

Discussion and Conclusion: Baseline renal function was the only parameter closely related to AKI development in our sample population. AKI led to prolonged ICUS and hospitalization.

Keywords: Acute kidney injury; Bupivacaine; Geriatrics; Intraoperative monitoring; Spinal anesthesia; Total hip replacement.

Spinal anesthesia (SA) is the preferred method for orthopedic lower limb surgery due to its beneficial effects on perioperative hemodynamical status, cardiac and respiratory physiology, and enhanced recovery[1,2]. However, the method itself may lead to a sudden decline in blood pressure due to excessive sympathetic blockade[2-4]. Perioperative hypotension is a cardinal concern for the elderly, who constitute the vast majority of patients undergoing this type of surgery. The risk of hypotension-mediated critical end-organ damage is particularly evident in these patients due to the frequent presence of comorbid clinical conditions and diminished vascular autoregulation function[4-7]. Thereby, various alterations of SA were tested to reduce the rate of hypotension during orthopedic surgery. The main attempts at modifications can be listed as unilateral

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SA, continuous or low-speed intrathecal injection of anesthetics, combination of different agents, puncture with specific needles, and utilization of hypobaric mixtures of local anesthetics[1,8-11]. Aside from the decreased rate of hypotension, the utilization of hypobaric solutions may be timesaving during patient preparation and offer a rapid mobilization phase after surgery[9,10,12-14].

The consequences of perioperative monitoring output have frequently been investigated in the literature. Nevertheless, the relationship between the duration and extent of intraoperative hypotension and the occurrence of adverse clinical events remains a matter of debate. This is mostly due to the wide range of event definitions and heterogeneity of the study designs[15-18]. Acute Kidney Injury (AKI) is a relatively common event in the surgical population with an observed estimated frequency of 2-18% during hospital admissions[19]. The principal conditions resulting in impaired renal blood flow during surgery are reduced mean arterial pressure and unpreserved cardiac output[6,19,20]. AKI was also identified as a risk factor for early postoperative and long-term morbidity and mortality[20].

In this retrospective study, the subject data of those who had undergone total hip replacement (THR) surgery under SA were analyzed. We sought to evaluate the impact of patient demographics, baseline laboratory findings, the baricity of local anesthetics used for SA, perioperative hemodynamical recordings, and several other clinical conditions on postoperative AKI development, which was postulated as a surrogate endpoint indicating organ hypoperfusion. The clinical outcomes between the AKI (+) and AKI (-) groups were also compared.

Materials and Methods

Study Qualifications and Patient Selection

This study was conducted in a tertiary multidisciplinary center performing over 2,000 surgical procedures under SA, of which orthopedic surgery constituted roughly 50%. Among SA cases between January 2019 and January 2020, the digital and printed log files of 204 American Society of Anesthesiologists (ASA) I-IV patients over the age of 65 who underwent elective THR surgery were examined for inclusion eligibility. The frequency of ASA classes of the study population from Class I to Class IV were 4.6%, 34.6%, 59.2%, and 1.5%, respectively. Seventy-four patients were excluded due to missing data, end-stage renal disease (glomerular filtration rate [GFR]<15ml/min or routine dialysis treatment) or having an extreme initial systolic blood pressure (SBP<90mmHg or>180mmHg). The calculated size for observing AKI in our sample population was 119 patients when an incidence of 15% was estimated by taking the alfa error as 0.05 and beta error as 0.2. After executing the abovementioned exclusions, the ultimate sample population was comprised of 130 subjects in our study. The ethical approval was provided by the local committee of Istanbul Haseki Training and Research Hospital (2020/209, Date of approval: 25.11.2020). Hence, the study was accepted to follow the global ethical standards stated in the most recent version of the Declaration of Helsinki. Permission to use the data presented in this study was granted by Kanuni Sultan Suleyman Training and Research Hospital.

Demographic and Baseline Clinical Features of the Study Population

ASA-class and comorbid diseases were recorded from patient identification forms. Clinical conditions of interest were hypertension, diabetes mellitus, atherosclerotic cardiac or peripheral vascular disease, previous stroke or transient ischemic attack, history of heart failure, presence of left-ventricular systolic dysfunction (left-ventricular ejection fraction ≤40%), chronic pulmonary diseases, thyroid disorders, and neurocognitive disorders. Body mass index (BMI) was calculated using the Du Bois method[21]. Preoperative creatinine and hemoglobin levels were noted. The estimated glomerular filtration rate (eGFR) was calculated using the CKD-EPI formula.

Anesthesia Technique and Perioperative Recordings

Following the institutional algorithms, the patients were invariably premedicated with 0.01-0.03mg/kg midazolam and 0.5mcg/kg fentanyl before the initiation of anesthesia. At the operation table, a 500ml balanced electrolyte solution was rapidly infused before puncture. In the facility where this study was conducted, 15mg (3ml) of the hyperbaric bupivacaine 0.5% solution in the readily available form (density at 37°C: 1.0236) is used when hyperbaric SA is chosen. If the hypobaric mixture is preferred, 1.25ml of distilled water and 37.5mcg fentanyl (0.75ml) are added to 10mg (2ml) of isobaric bupivacaine 0.5% solution (density at 37°C: 0.9965)[22]. In the entire sample population, the subarachnoid space was punctured with a 25-gauge Quincke (Vygon®, Ecouen, France) needle using a midline approach at the level of L3-4 or L4-5 intervertebral space. The tip of the needle was caudally directed to avoid proximal dissemination. When the hyperbaric solution was preferred, the anesthetic solution was administered while the patient was lying in the lateral position with the diseased site facing downward. Then, patients were stabilized in the same position for approximately 10 minutes until an adequate motor blockade was achieved (Bromage scale 2 or 3)[23]. Eventually, they were flipped over to bring the side of interest to the surgical zone. While collecting the data, the procedure time and the mixture used for SA were recorded from the anesthesia log files. Ephedrine (6mg bolus injection) and atropine (1mg bolus injection) used in the operation room were noted. Intraoperative red blood cell transfusion was also stated. Noninvasive blood pressure measurement recordings at baseline and every 10 minutes for an hour were enlisted. In addition to time-log-based comparisons for SBP, diastolic (DBP), and mean (MBP) arterial blood pressure, the average of pressure measurements, the difference between maximum and minimum values, percent decrease with reference to baseline, and change in blood pressure between baseline and 10th minute measurement were calculated. Baseline and 10-minute-apart intraoperative measurements in the first hour, minimum and average values of heart rate, and average and minimum values for pulse oximetry measurements were recorded. The presence of postoperative significant anemia was noted, which had been described as a hemoglobin value of 8g/dl or lower.

Definition of AKI and Outcome Variables

AKI was identified with the previously validated definition: a 1.5-fold increase in serum creatinine as compared to baseline, or >0.3 mg/dl increase within 48 hours, or urine output <0.5 ml/kg/h for 6 h in the postoperative period.[24] Critical care unit stay (ICUS), length of hospitalization (LOH), in-hospital mortality, and one-year mortality were determined as outcome variables comparable between AKI (+) and AKI (-) patients.

Statistical Analysis

The data were presented as mean±standard deviation and median (interquartile range) for continuous variables with or without normal distribution, respectively. Categorical variables were expressed as percentages (number of cases). The normality of continuous variables was assessed using the Shapiro-Wilk test. According to the condition of following a normal distribution, Unpaired-t and Mann-Whitney-U tests for independent samples were used

Table 1. Demographic and baseline clinical features of the patients with and without postoperative acute kidney injury (AKI).

	Overall (n=130)	AKI (-) (n=118)	AKI (+) (n=12)	p
Demographic characteristics				
Age, years; Median (IQR)[a]	81 (11)	80 (11.3)	82.5 (7.5)	0.260
Gender, female; % (n)[b]	69.2 (90)	68.6 (81)	75 (9)	0.649
BMI, kg/m2; Mean±SD[c]	27.0±4.9	27.2±5.0	25.3±3.7	0.188
ASA score; Median (IQR) [a]	3 (1)	3 (1)	3 (0)	0.174
Hypobaric bupivacaine use, % (n)[b]	80.8 (105)	80.5 (95)	83.3 (10)	0.813
ASCVD; % (n) [b]	25.4 (33)	24.6 (29)	33.3 (4)	0.507
Stroke or TIA; % (n) [b]	7.7 (10)	7.6 (9)	8.3 (1)	0.930
History of heart failure; % (n) [b]	16.9 (22)	17.8 (21)	8.3 (1)	0.405
LV systolic dysfunction; % (n) [b]	6.9 (9)	6.8 (8)	8.3 (1)	0.840
CPD; % (n) [b]	20 (26)	21.2 (25)	8.3 (1)	0.289
Thyroid disorder; % (n) [b]	5.4 (7)	5.9 (7)	0 (0)	0.386
Neurocognitive disorder; % (n) [b]	13.8 (18)	13.6 (16)	16.7 (2)	0.767
Hypertension; % (n) [b]	53.8 (70)	55.1 (65)	41.7 (5)	0.374
Diabetes mellitus; % (n) [b]	18.5 (24)	17.8 (21)	25 (3)	0.540
Baseline laboratory findings				
Hemoglobin, g/dl; Mean±SD [c]	11.9±1.7	11.9±1.7	11.8±1.7	0.881
Creatinine, mg/dl; Median (IQR) [a]	0.89 (0.42)	0.84 (0.40)	1.31 (1.58)	<0.001
eGFR, ml/min/1.73 m^2; Median (IQR) [a]	69 (33)	71 (30)	37 (34.7)	<0.001

[a]Mann-Whitney U test was used for comparison. [b]Chi-square test was used for comparison. [c]Unpaired-t test was used for comparison. ASCVD: atherosclerotic cardiovascular disease; BMI: body mass index; CPD: chronic pulmonary disease; eGFR: estimated glomerular filtration rate; IQR: interquartile range; TIA: transient ischemic attack.

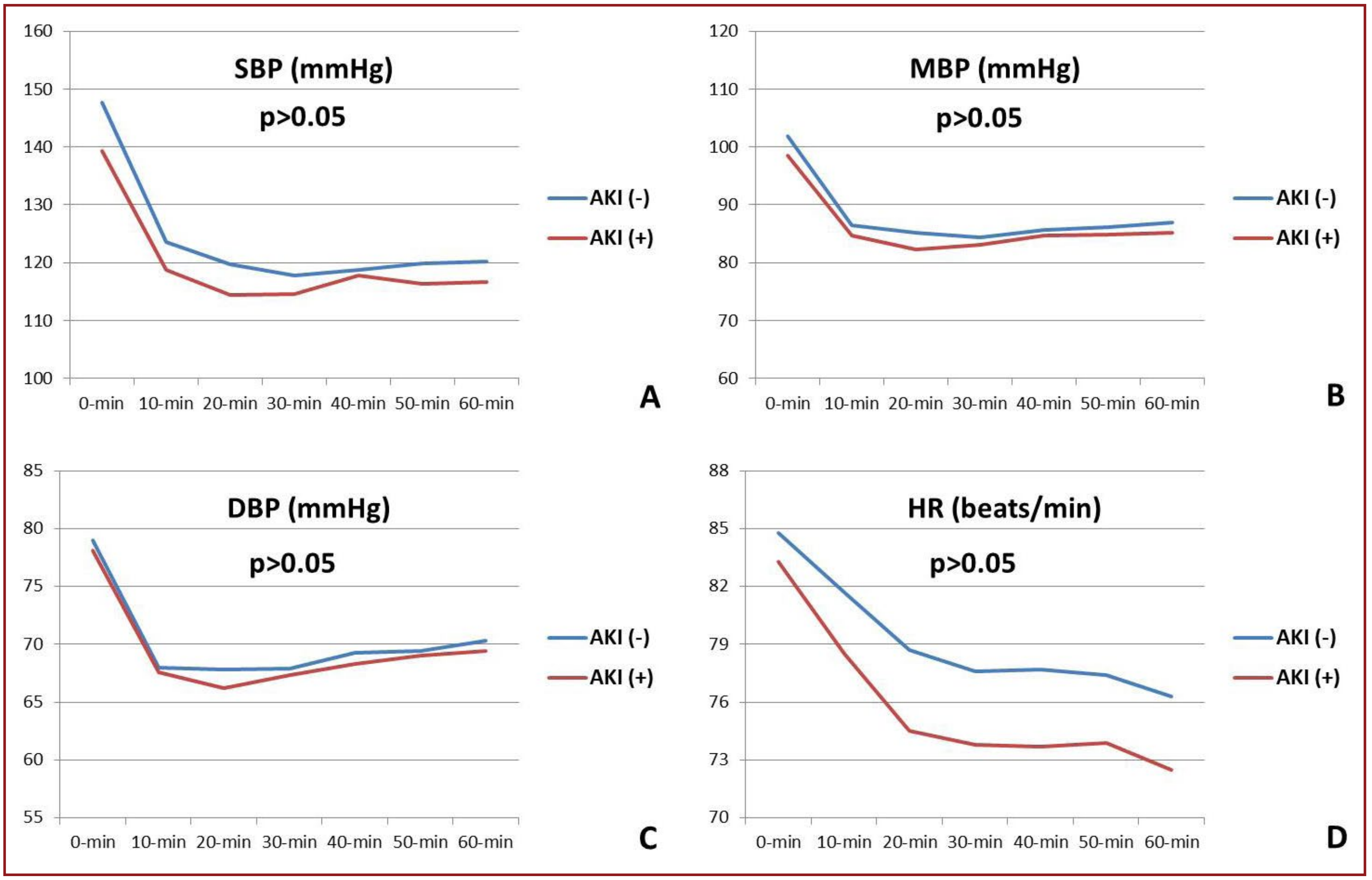

Figure 1. The line charts representing the course of intraoperative hemodynamic recordings with 10-min intervals **(a-d)**. Mean values for the measurements at the first 60 minutes were displayed.

AKI: acute kidney injury; DBP: diastolic blood pressure; HR: heart rate; MBP: mean blood pressure; SBP: systolic blood pressure.

for distinguishing the variables. Categorical variables were compared with the Chi-square test.

ROC analysis was performed to determine the sensitivity and specificity of the baseline GFR for predicting AKI. Statistical Package for the Social Sciences (SPSS version 22.0, SPSS Inc., Chicago, IL, USA) was used for these assessments.

Results

The study population comprised 130 patients with a median age of 81 (11); 69.2% (n=90) of the subjects were female. The median ASA score of the population was 3 (1). Hypobaric bupivacaine mixture was used in 80.8% (n=105) of the cases.

AKI was observed in 12 (9.2%) patients. Among all demographic and preoperative laboratory features, baseline renal function was the only discriminative variable between the groups (Table 1). Baseline creatinine level was higher (mg/dl, 0.84 [0.40] vs. 1.31 [1.58]; p<0.001) and eGFR was significantly lower in the AKI (+) group (ml/min/1.73 m^2, 71 [30] vs. 37 [34.7]; p<0.001). None of the time-based comparisons between the intraoperative hemodynamic recordings of the AKI (-) and AKI (+) groups revealed statistical significance (Fig. 1). Variables derived from these recordings, procedure time, transfusion need, and the rates of ephedrine and atropine use were also comparable among the groups (Table 2).

According to the ROC analysis (Fig. 2), there was a strong association between baseline GFR and AKI occurrence (AUC: 0.88, p<0.001). When 55 ml/min/m^2 was accepted as the cut-off level, the sensitivity of GFR for estimating AKI was 83.3%, and the specificity was 76.3%.

As an additional analysis, the relationship of AKI with LOH and ICUS as well as in-hospital and one-year mortality rates was sought. AKI (+) patients had significantly longer LOH and ICUS (Table 3).

Table 2. Hemodynamical recordings and other intraoperative features of the patients with and without postoperative acute kidney injury.

	AKI (-) (n=118)	AKI (+) (n=12)	p
Intraoperative features			
Procedure time, mins; Median (IQR) [a]	90 (40)	95 (35)	0.713
Atropine use; % (n) [b]	6.8 (8)	8.3 (1)	0.840
Ephedrine use; % (n) [b]	23.7 (28)	33.3 (4)	0.462
Perioperative RBC transfusion; % (n) [b]	8.5 (10)	8.7 (1)	0.987
Postoperative significant anemia; % (n) [b]	32.2 (38)	50 (6)	0.215
Parameters related to perioperative hemodynamical recordings			
SBPaverage, mmHg; Mean±SD [c]	123.9±17.5	119.6±22.2	0.439
SBPminimum, mmHg; Mean±SD [c]	107.8±20.0	107.3±24.7	0.923
ΔSBP, mmHg; Median (IQR) [a]	42 (36.3)	31.5 (29)	0.258
ΔSBP0-10min, mmHg; Median (IQR) [a]	21 (28.5)	22.5 (20.8)	0.945
SBPreduction, %; Median (IQR) [a]	25 (20.2)	19 (23.1)	0.243
MBPaverage, mmHg; Mean±SD [c]	88.1±11.6	86.1±15.4	0.593
MBPminimum, mmHg; Mean±SD [c]	77.8±13.5	77.4±17.4	0.930
ΔMBP, mmHg; Median (IQR) [a]	24 (16.3)	21 (14)	0.376
ΔMBP0-10min, mmHg; Median (IQR) [a]	14.7 (19.3)	14.2 (14.2)	0.875
MBPreduction, %; Median (IQR) [a]	23.4 (16.6)	19.2 (17.8)	0.276
DBPaverage, mmHg; Mean±SD [c]	70.2±10.0	69.4±14.1	0.788
DBPminimum, mmHg; Mean±SD [c]	61.5±11.1	60.7±15.5	0.818
ΔDBP, mmHg; Median (IQR) [a]	20 (17)	20 (5.8)	0.910
ΔDBP0-10min, mmHg; Median (IQR) [a]	10 (14.3)	11 (9.8)	0.532
DBPreduction, %; Median (IQR) [a]	21.8 (18.8)	17.9 (19.8)	0.410
HRminimum, beats/min; Median (IQR) [a]	70 (17)	68 (18)	0.579
HRaverage, beats/min; Median (IQR) [a]	77.4 (18.9)	73.2 (27.1)	0.533
SaO_2minimum, %; Median (IQR) [a]	96 (3)	97 (7)	0.588
SaO_2average, %; Median (IQR) [a]	98.7 (2.1)	97.7 (4.1)	0.146

[a]Mann-Whitney U test was used for comparison. [b] Chi-square test was used for comparison. [c] Unpaired-t test was used for comparison. HR: heart rate; IQR: interquartile range; MBP: mean blood pressure; RBC: packed red blood cells; SaO_2, arterial oxygen saturation in pulse oximetry; SBP: systolic blood pressure.

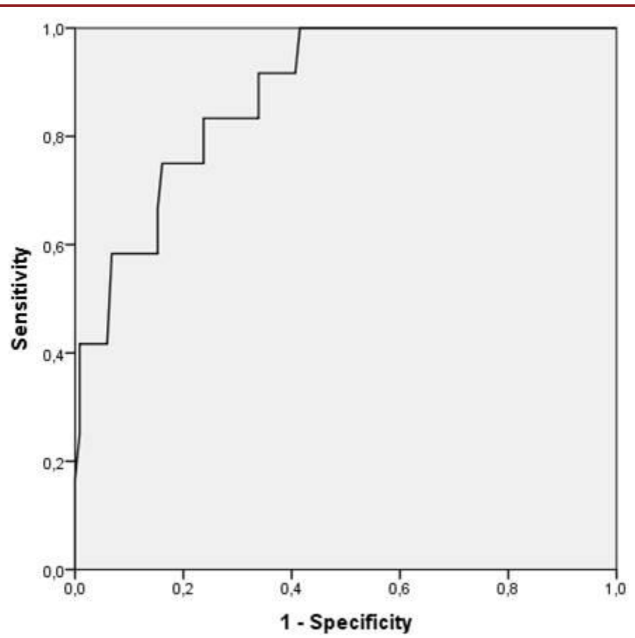

Figure 2. The ROC curve representing the performance of eGFR for predicting acute kidney injury (AUC: 0.88, p<0.001).

Table 3. Comparison of outcome variables associated with AKI occurrence.

	AKI (-) (n=118)	AKI (+) (n=12)	p
LOH, days; Median (IQR) [a]	3 (2)	4 (9.5)	0.038
ICUS, days; Median (IQR) [a]	0.5 (3)	3.5 (10.3)	0.005
In-hospital mortality; % (n) [b]	4.2 (5)	16.7 (2)	0.069
One-year mortality; % (n) [b]	17.8 (21)	16.7 (2)	0.922

[a] Mann-Whitney U test was used for comparison. [b] Chi-square test was used for comparison. AKI: acute kidney injury; ICUS: intensive care unit stay; IQR: interquartile range; LOH: length of hospitalization.

Discussion

With the aging population, lower limb joint replacement surgery has become a major health issue due to its high incidence and remarkable operation-related morbidity and mortality[25]. Individuals subjected to this risk commonly have chronic comorbid conditions, which may lead to a vulnerable state for the occurrence of short- and long-term serious adverse events associated with critical end-organ damage[6]. Considering the diminished functional reserve and autoregulation responses of the organ systems in the elderly, even slight hemodynamic fluctuations may set the ground for the development of these events[6,7]. Since reducing the risk of postoperative complications is the main objective of perioperative medicine, anesthetic management during this major surgery has involved safer methods over time, which should have resulted in less alteration of hemodynamics[4,5,26].

Neuraxial techniques also exert several favorable features, such as reduced postoperative bleeding, thromboembolic complications, nausea, and vomiting, compared to general anesthesia. However, SA is also associated with an increased risk of severe and/or persistent hypotension by hindering cardiovascular adaptation to volume alterations[27]. This instance was reported to occur in 25–69% of SA cases, posing particular significance to geriatric patients[4]. Thus, rapid counteraction with volume loading and vasopressors is of critical importance in this population. Additionally, hydration with colloid or crystalloid solutions before the procedure, reducing the dose of local anesthetic, and attempts to limit the distribution of the drug can be counted as the main preventive measures[2,4,8,13,27]. SA consuming lower doses of local anesthetics came to the forefront, which hypothetically offered a better profile by this means, mainly by reducing the extent of sympathetic blockade[4,8,10]. The hypobaric anesthetic mixture was abundantly used in our population due to the above-mentioned concerns in addition to standard protocols such as preoperative volume repletion. Comparing the perioperative hemodynamic output and postoperative outcomes of the patients receiving the hyperbaric and hypobaric solutions was not a matter of investigation in our study. Nevertheless, from the perspective of AKI development, the baricity of the anesthetic mixture was not a discriminating factor.

Bupivacaine is a frequently used local anesthetic in SA due to its fewer cardiovascular side effects[3]. Both hypobaric and hyperbaric solutions have been determined to be effective and safe, with a relatively higher risk of bilateralization of the motor blockade in the former[8,10]. Wood et al.[28] reported a lower rate of intraoperative hypotension when the utilized amount of hyperbaric bupivacaine was <1.5 ml in their proximal femur fracture surgery series. Local anesthetics are mostly combined with opioids in this sense. Olofsson et al.[29] declared that the intrathecal bupivacaine–opioid combination provided a more stable hemodynamic course with fewer hypotensive episodes. Considering these facts, bupivacaine is the local anesthetic of choice for SA in our facility.

AKI is an underrecognized but remarkably frequent complication of major surgery, with a growing incidence considering the increased frequency of surgical procedures performed in the elderly who have several chronic comorbid conditions, including reduced renal functional reserve. Various risk factors were identified for AKI development, such as age, female gender, obesity, significant anemia, low mean arterial pressure, type of procedure, and anesthesia[19]. Orthopedic surgery was accepted to elicit high risk for AKI development for which age, hypertension, general anesthesia, and low intraoperative arterial pressure were identified as prominent predictors. Maintaining adequate blood volume and perfusion pressure were designated as key features for avoiding AKI[20,30]. Aside from hemodynamic stability, preventive measures such as prudent assessment of baseline renal function and risk of deterioration, strict glycemic control, discontinuation of angiotensin-converting enzyme inhibitors, and weighing the risk with benefits while using potentially nephrotoxic agents, mainly NSAIDs, are recommended[30,31].

Chronic kidney disease is a remarkably prevalent condition with estimated rates of 13.1% of the general population, and its association with postoperative AKI has been well demonstrated. It should also be emphasized that half of the patients with chronic kidney disease are over the age of 70[31]. However, the clinical significance of AKI is not only related to its reciprocal relationship with chronic kidney disease but also to yielding increased perioperative and long-term morbidity and mortality with increased costs[20]. In a cohort study that enrolled patients undergoing major surgery, a 30-day mortality rate of 31% was observed in patients suffering from AKI, while this rate was 1.9% in those without AKI. Of note, patients with a history of advanced-stage chronic kidney disease were excluded from this study[32].

Neuraxial anesthesia has promising effects on maintaining a favorable hemodynamic profile, and hence theoretically should be protective against AKI. However, AKI is still an issue of concern for this method. A large retrospective cohort comparing surgical patients who received general or non-general anesthesia revealed that the incidence and the unfavorable influence of AKI on prognosis were similar in both arms. Moreover, the assessment of perioperative renal function was poorer in the non-general anesthesia group. Ultimately, the authors underlined the necessity of a proper kidney function evaluation in this subset of patients[33].

AKI was observed in 9.2% of our sample population, and among all demographic and hemodynamic parameters, a lower eGFR value was designated as the only statistically significant distinguishing factor. An eGFR value of 55 ml/min/m^2 was identified as a cut-off value for predicting AKI, with considerable specificity and sensitivity rates. In line with the findings in the literature, AKI was associated with a longer hospital and ICU stay in our study. A higher in-hospital mortality rate was also anticipated in AKI (+) individuals, which revealed an apparent trend in group comparisons. Finally, one-year mortality was similar between the AKI (+) and AKI (-) groups.

It should be noted that certain limitations exist for this study. First, we should emphasize that blood pressure was monitored by the oscillometric method in all patients. These recordings may differ from intra-arterial ones in the case of notably reduced arterial elasticity. Additionally, cardiac output variation was not regarded for AKI occurrence. However, the impact of this drawback might be alleviated with comparable frequencies of cardiovascular disorders among groups. Undoubtedly, the above-mentioned retrospective findings should be verified in larger, prospective, multi-centered case series.

Conclusion

The baseline creatinine level and its clearance were the only factors distinguishing patients who had or had not developed AKI in our sample population. The remaining baseline clinical and laboratory features, perioperative hemodynamic recordings, and postoperative known risk factors for AKI were comparable among groups. Finally, AKI was coupled with longer hospital and critical care unit stays in this study.

Ethics Committee Approval: The ethical approval was provided by the local committee of Istanbul Haseki Training and Research Hospital (2020/209, Date of approval: 25.11.2020). Hence, the study was accepted to follow the global ethical standards stated in the most recent version of the Declaration of Helsinki. Permission to use the data presented in this study was granted by Kanuni Sultan Suleyman Training and Research Hospital.

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