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The effect of the prone position on intra-abdominal pressure and renal function

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ABSTRACT

Aims: Various surgical procedures are performed on patients in the prone position. Intra-abdominal pressure (IAP) refers to the pressure within the abdominal cavity between the internal organs and the abdominal wall. This study investigated the effect of the prone position-via increased IAP-on renal function.

Methods: This prospective observational study included patients aged 18-75 years with an American Society of Anesthesiologists (ASA) classification of I-III. 38 patients undergoing spinal surgery in the prone position and 37 patients undergoing colorectal surgery in the supine position were evaluated. Demographic characteristics, IAP, perioperative renal parameters, intraoperative blood loss, and postoperative course were assessed. IAP was measured by intravesical pressure monitoring.

Results: In patients undergoing lumbar surgery, IAP was significantly higher in the prone position (14 mmHg) compared with the supine position (11 mmHg; $p<0.05$). The incidence of class I intra-abdominal hypertension (IAH) was significantly higher in the prone position than in the supine position ($p<0.001$). A positive and significant correlation was found between body-mass index and IAP in both patients undergoing lumbar and colorectal surgery ($p<0.001$). Postoperative urea levels at 1, 24, and 48 hours were significantly higher in patients who underwent lumbar surgery ($p<0.05$). Among those undergoing colorectal surgery, patients with class I IAH had significantly higher intraoperative blood loss than those with normal IAP ($p<0.05$).

Conclusion: To prevent renal complications during surgery, patient positioning and fluid management should be monitored carefully. In addition, it should be noted that increased IAP can lead to greater intraoperative blood loss.

Keywords: Prone position, intra-abdominal hypertension, kidney function test

INTRODUCTION

Patient positioning for surgery is the joint responsibility of the anesthesiologist, surgeon, and nurses.[1] The optimal position should provide the best surgical access while being the most appropriate for the patient's tolerance.[1] In this context, the prone position is frequently preferred, particularly in procedures, such as spinal surgery.[1] Depending on the selected surgical position, especially in the prone position, an increase in intra-abdominal pressure (IAP) and associated complications can occur.[1,2]

IAP refers to the steady pressure within the abdominal cavity resulting from the interaction between the abdominal wall and internal organs.[2] While values up to 5 mmHg are considered physiologically normal in adults, IAP can rise to 10 mmHg or higher because of conditions, such as obesity.[2] Intra-abdominal hypertension (IAH) is defined as a sustained pathological elevation of IAP greater than 12 mmHg in three consecutive measurements.[3] In cases where IAP is consistently 20 mmHg or higher, abdominal compartment syndrome (ACS) that can present with organ dysfunction, might be observed.[3]

Based on this information, the hypothesis of our study was that lumbar disc surgery performed in the prone position will significantly increase IAP compared with colorectal surgery in the supine position, and this will have negative effects on renal function parameters (eg, urea, creatinine, and estimated glomerular filtration rate) (eGFR) in the perioperative period. The primary endpoint of the study was the IAP value; the secondary endpoints were the relationship between body-mass index (BMI) and IAP, renal function parameters, and the amount of intraoperative bleeding.

METHODS

This prospective, observational clinical study was conducted in accordance with the principles of the Declaration of Helsinki with approval from the Ankara Bilkent City Hospital Medical Researches Ethics Committee (Date: 20.03.2024, Decision No: TABED 2-24-21) and with informed consent from the participants.

Subject Selection, Inclusion and Exclusion Criteria

The study included patients aged 18-75 years with an American Society of Anesthesiologists (ASA) classification of I-III, who were undergoing spinal surgery or colorectal surgery with

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The exclusion criteria were obesity (BMI >35 kg/m²), a history of dementia, psychiatric disorders, severe heart disease, central nervous system diseases, renal or liver dysfunction, bleeding diathesis, active infection, pregnancy, chronic inflammatory disease, oral corticosteroid use, a history of allergy and conditions preventing cooperation in the postoperative period (eg, mental retardation, communication barriers, etc).

Intervention

Within the scope of the study, all patients fasted according to the standard protocol. In the preoperative period, patients' demographic characteristics and laboratory test values were recorded in the ward. The patient group for colorectal surgeries to be performed in the supine position was labelled as group S, and the patient group for spinal surgeries to be performed in the prone position was group P.

Intraoperatively, duration of surgery, heart rate, mean arterial pressure, intravesical pressure, bleeding and the amount of intravenous fluid administered were recorded. In the postoperative period, urea, creatinine, eGFR, 24-hour urine output, and length of stay in the ward and intensive care unit were recorded. IAP in patients was evaluated via intravesical pressure. The Modified Kron technique was used as the intravesical pressure measurement method.[4]

Anesthesia Management

Routine preoperative preparations were performed for patients taken to the operating room and standard monitoring was undertaken with peripheral oxygen saturation (SpO_2) level, electrocardiography (ECG), non-invasive blood pressure (NIBP) and bispectral index (BIS, A 2000 Bispectral Index, Aspect Medical Systems). After induction with 1 mg/kg lidocaine, 2 mg/kg propofol, 1 mcg/kg fentanyl, and 0.5 mg/kg rocuronium, the patients were intubated with an appropriate endotracheal tube. A urinary catheter was placed for urine monitoring and IAP also monitored. Anesthesia was maintained with continued sevoflurane and remifentanil in a 50% oxygen and 50% air mixture.

Patients undergoing lumbar stabilization were placed in the prone position. During positioning, lateral pillows were used to facilitate diaphragm movements, soft silicone pads used to prevent nerve compression and pillows placed under the tibia to prevent foot malposition. Additionally, the head was supported in a neutral position with silicone pillows and adjusted to avoid pressure to the eyes, nose and ears. Patients were administered 100 mg tramadol and 1 g paracetamol as analgesics. Body temperature was checked regularly and maintained at approximately 36°C. Post-operation, 2 mg/kg sugammadex was given to the patients. When respiratory function was restored after surgery (tidal volume >6 ml/kg and end tidal CO_2<50 mmHg), patients were extubated and transferred to the post-anesthesia care unit. Patients with an Aldrete score greater than 9 during follow-up were taken to the ward. Postoperative fluid management was standardized for both groups and administered according to the institutional postoperative fluid therapy protocol. For postoperative analgesia, all patients received both 100 mg tramadol and 1 g paracetamol three times a day intravenously.

Measurements and Outcome Parameters

Patient demographic characteristics and intraoperative data were recorded. Urea, creatinine and eGFR values were evaluated 24 hours preoperatively and at 1, 24, and 48 hours postoperatively. Intraoperative IAP measurements in both groups were performed using the Modified Kron method.[4] After administering a urinary catheter to each patient, 25 ml of sterile saline was injected into the catheter. The measurement was taken after the pressure transducer was aligned with the mid-axillary line and calibrated. Preoperative measurements were performed in the ward; intraoperative measurements were performed after anesthesia induction and intubation but during the stable period before the surgical incision. Postoperative measurements were recorded at 1, 24 and 48 hours in the ward.

IAH grading was defined according to current recommendations as class I 12-15 mmHg, class II 16-20 mmHg, class III 21-25 mmHg, and class IV >25 mmHg. Additionally, patients' 24-hour urine outputs and lengths of stay in the ward and intensive care unit in the postoperative period were evaluated within the scope of the study.

Statistical Analysis

G*power 3.1.9.7 (Franz Faul, Universitat Kiel, Germany) software was used to calculate the sample size. For 90% power, an effect size of d=0.79 and α=0.05, a minimum of 70 (n1=35, n2=35) patients was sufficient. SPSS 22.0 software was used for statistical analysis. The normality of the data was examined using histogram curves and the Kolmogorov-Smirnov or Shapiro-Wilk tests. Frequency, Chi-squared, mean±standard deviation, and median (minimum-maximum) values were primarily used, while Mann-Whitney U, Wilcoxon's, independent samples T test, and ANOVA tests were performed with these values. The statistical significance level was accepted as $p<0.05$, and all p-values lower than 0.001 were indicated as $p<0.001$.

RESULTS

In this study, 80 patients were evaluated, including 40 patients in the prone position for spinal surgeries (group P) and 40 patients in the supine position for colorectal surgeries (group S). 75 patients met the specified criteria and 38 were assigned to group P and 37 to group S. No significant difference was observed between the groups in terms of age, ASA score, 24-hour urine output (ml), amount of intraoperative fluid received (ml) and lengths of stay in the ward and intensive care unit ($p>0.05$; **Table 1**). Significant differences were found between the groups in terms of sex, BMI, duration of surgery and amount of intraoperative bleeding ($p<0.05$; **Table 1**).

When the groups were split according to BMI (≤30 kg/m² and >30 kg/m²), no significant difference was found between the groups regarding the mean preoperative and postoperative urea, creatinine, and eGFR levels ($p>0.05$; **Table 2**). However, a moderate positive and significant correlation was observed between BMI and IAP values in patients undergoing lumbar and colorectal surgery ($p<0.001$, $r=0.53$ and $p<0.001$, $r=0.61$, respectively; **Table 3**).

The median IAP of patients undergoing lumbar surgery was 11 mmHg (range 7-12 mmHg) in the supine position and 14 mmHg (range 11-15 mmHg) in the prone position, and a significant difference was found between the positions ($p<0.05$;

Table 1. Demographic data and clinical characteristics

		Lumbar (n=38)	Colon (n=37)	p-value
Sex (n, %)	Female	29 (76.3%)	15 (40.5%)	0.002*
	Male	9 (23.7%)	22 (59.5%)	
Age (years)		59.50±9.59	57.27±17.00	0.48**
BMI (kg/m²)		28.37±4.00	25.37±5.34	0.008**
ASA score (n, %)				
I		8 (21.1%)	7 (18.9%)	0.942*
II		15 (39.5%)	14 (37.8%)	
III		15 (39.5%)	16 (43.2)	
24-hour urine output (ml, n=53)		2311.76±628.62	2128.61±623.11	0.32**
Intraoperative bleeding (ml, n=47)		600 (50-3800)	150 (50-700)	<0.001***
Intraoperative fluid intake (ml)		2300 (1200-5800)	2500 (500-5600)	0.70***
Ward stay (days, n=73)		6 (2-13)	6 (3-89)	0.55***
ICU stay (days, n=37)		1 (1-10)	1 (1-11)	0.58***
Surgery duration (min, n=75)		270 (150-600)	180 (120-420)	<0.001***

Data are presented as mean±SD, number (%), (n), or median (min-max). Statistically significant p-values are in bold font. *Chi-squared test, **Independent samples T test, ***Mann-Whitney U test. BMI: Body-mass index, ASA: American Society of Anesthesiologists, ICU: Intensive care unit, SD: Standard deviation, Min: Minimum, Max: Maximum

Figure 1). The increased intra-abdominal pressure observed in the prone position likely contributed to the observed differences between positions. Conversely, the median IAPs of patients undergoing lumbar and colorectal surgery in the supine position were 11 mmHg (range 7-12 mmHg) and 10 mmHg (range 7-13 mmHg), respectively, with no significant difference observed between the groups (p>0.05; Figure 1).

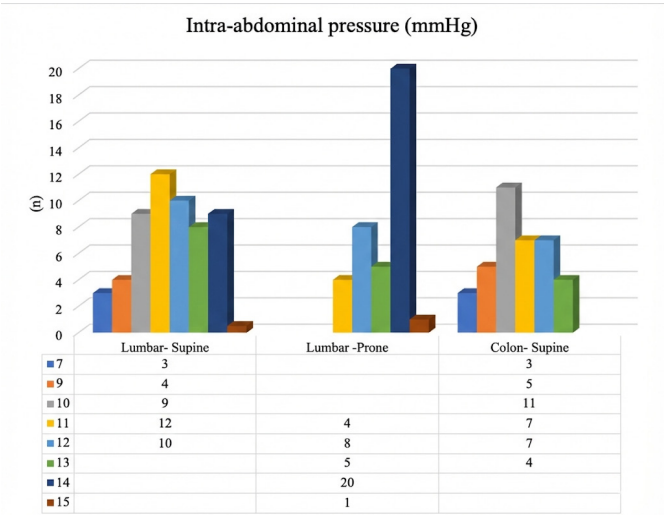

Figure 1. Intra-abdominal pressure values of the cases
Data are presented as number (n)

In patients undergoing lumbar surgery, although 28 cases were evaluated as normal according to IAH pressure grading in the supine position, class I IAH was detected in 24 patients in the prone position. The incidence of class I IAH in the prone position was significantly higher compared with the supine position (p<0.001; Figure 2). No cases were class II, class III, or class IV according to IAH grading.

Table 2. Comparison of urea, creatinine, and eGFR values according to BMI

		BMI ≤30 kg/m²	BMI >30 kg/m²	p-value*
Urea (mg/dl)	Preoperative	33.30±13.39	35.13±9.75	0.55
	Postoperative (1 hour)	30.23±13.45	30.80±8.05	0.83
	Postoperative (24 hours)	28.15±15.84	29.07±8.48	0.83
	Postoperative (48 hours)	26.05±15.53	31.13±10.73	0.14
Creatinine (mg/dl)	Preoperative	0.79±0.28	0.76±0.14	0.69
	Postoperative (1 hour)	0.72±0.27	0.69±0.11	0.65
	Postoperative (24 hours)	0.72±0.28	0.68±0.15	0.58
	Postoperative (48 hours)	0.69±0.25	0.70±0.12	0.95
eGFR (ml/dak/1.73m²)	Preoperative	91.46±24.71	89.06±16.33	0.65
	Postoperative (1 hour)	98.13±26.31	93.86±13.04	0.37
	Postoperative (24 hours)	97.03±24.62	96.00±15.12	0.83
	Postoperative (48 hours)	99.10±26.29	94.13±14.01	0.32

Data are presented as mean±SD. *Independent samples T test. eGFR: Estimated glomerular filtration rate, BMI: Body-mass index, SD: Standard deviation

Table 3. Evaluation of IAH grading according to BMI

BMI (kg/m²)	Lumbar (supine)			Lumbar (prone)			Colon (supine)		
	IAH		p*	IAH		p*	IAH		p*
	Normal	Class I		Normal	Class I		Normal	Class I	
	(n, %)	(n, %)		(n, %)	(n, %)		(n, %)	(n, %)	
Underweight	-	-		-	-		5 (19.2%)	-	
Normal weight	6 (21.4%)	1 (10%)	0.13	4 (100%)	3 (8.8%)	<0.001	9 (34.6%)	2 (18.2%)	0.17
Overweight	16 (57.1%)	3 (30%)		-	19 (55.9%)		11 (42.3%)	7 (63.6%)	
Obesity	6 (21.4%)	6 (60%)		-	12 (35.3%)		1 (3.84%)	2 (18.2%)	
Total	28 (100%)	10 (100%)		4 (100%)	34 (100%)		26 (100%)	11 (100%)	

Underweight: BMI <18.5; normal weight: BMI 18.5-24.9; overweight: BMI 25-29.9; and obesity: BMI 30-34.9. Data are presented as number (n, %). *Pearson's Chi-squared test. IAH: Intra-abdominal hypertension, BMI: Body-mass index

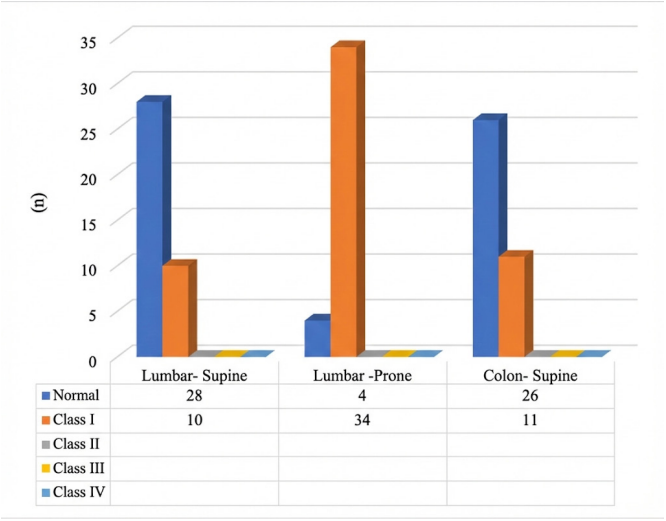

Figure 2. Distribution of cases according to IAH grading
Data are presented as number (n). IAH: Intra-abdominal hypertension

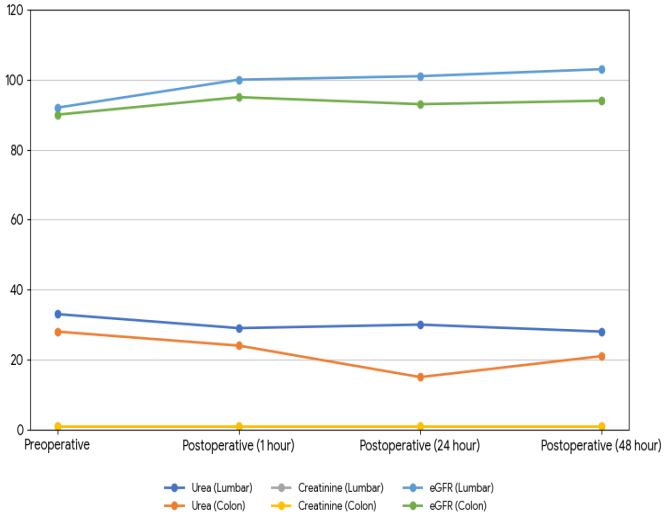

Figure 3. Urea, creatinine, and eGFR values
eGFR: Estimated glomerular filtration rate

In patients undergoing lumbar surgery, no significant difference was observed between the preoperative and postoperative 1, 24, and 48-hour eGFR values of patients with prone position IAP values of 11, 12 and 13 mmHg versus those with 14 mmHg and higher (p>0.05; Table 4). Comparison between the groups revealed no significant difference between them in terms of creatinine and eGFR values according to sampling time (p>0.05; Table 5, Figure 3). However, significant differences were observed between the groups in urea values at the postoperative 1-, 24-and 48-hour timepoints, and the values of patients undergoing lumbar surgery were higher in all of these instances (p<0.05; Table 5, Figure 3).

Table 4. Comparison of eGFR values in patients undergoing lumbar surgery according to prone position IAP

	IAP values in the prone position		
eGFR (ml/dak/1.73m2)	**<14 mmHg (n=17)**	**≥14 mmHg (n=21)**	**p***
Preoperative	85.94±19.74	92.52±16.19	0.27
Postoperative (1 hour)	95.17±20.02	94.61±16.53	0.92
Postoperative (24 hours)	90.00±20.51	95.47±17.03	0.38
Postoperative (48 hours)	90.41±19.38	96.00±14.95	0.33

eGFR (ml/min/1.73 m²) values are presented as mean±SD. *Independent samples T test. eGFR: Estimated glomerular filtration rate, IAP: Intra-abdominal pressure, SD: Standard deviation

In patients undergoing colorectal surgery, the amount of bleeding during the operation in 11 patients with class I IAH was higher compared with 26 patients with normal IAP (p<0.05; Table 6).

Table 6. The effect of intraoperative hypertension on bleeding amount in colorectal surgery

	Colon (n=37)		
	Normal IAP (n=26)	**Class I IAH (n=11)**	**p***
Intraoperative bleeding, (ml, n=37)	225 (100-500)	100 (50-700)	0.02

Values are presented as median (min-max). Statistically significant p-values are in bold font. *Mann-Whitney U test. IAP: Intra-abdominal pressure. IAH: Intra-abdominal hypertension

DISCUSSION

Our study showed that IAP increases in the prone position in patients undergoing lumbar surgery and that the incidence of class I IAH was higher compared with the supine position. Additionally, there was a significant relationship between BMI and IAP. Postoperative urea levels at 1, 24 and 48 hours were higher in lumbar surgeries performed in the prone position. In patients undergoing colorectal surgery, the amount of intraoperative bleeding in those with class I IAH was higher compared with those without IAH.

Table 5. Comparison of urea, creatinine, and eGFR values in the preoperative and postoperative periods

		Lumbar (n=38)	**Colon (n=37)**	**p-value**
Urea (mg/dl)	Preoperative	33 (17-62)	28 (5-71)	0.10*
	Postoperative (1 hour)	29 (17-66)	24 (4-69)	0.03*
	Postoperative (24 hour)	30 (13-68)	15 (6-58)	<0.001*
	Postoperative (48 hour)	28 (13-77)	21 (4-68)	<0.001*
Creatinine (mg/dl)	Preoperative	0.71 (0.41-1.49)	0.83 (0.19-1.42)	0.36*
	Postoperative (1 hour)	0.66 (0.40-1.34)	0.72 (0.21-1.48)	0.41*
	Postoperative (24 hour)	0.65 (0.43-1.30)	0.71 (0.13-1.48)	0.75*
	Postoperative (48 hour)	0.66 (0.43-1.24)	0.68 (0.25-1.42)	0.64*
eGFR (ml/dak/1.73m²)	Preoperative	92.43±27.79	89.57±17.94	0.60**
	Postoperative (1 hour)	99.75±29.40	94.86±17.92	0.39**
	Postoperative (24 hour)	100.72±26.38	93.02±18.61	0.15**
	Postoperative (48 hour)	102.83±29.54	93.50±17.06	0.10**

eGFR (ml/min/1.73 m²) values are presented as mean±SD. Statistically significant p-values are in bold font. Urea (mg/dl) and creatinine (mg/dl) values are presented as median (min-max). *Mann-Whitney U test, **Independent samples T-test. eGFR: Estimated glomerular filtration rate, SD: Standard deviation, Min: Minimum, Max: Maximum

IAP is a crucial parameter affecting the perfusion of abdominal organs and general hemodynamic status.[6] It is reported that high IAP can impair the functions of abdominal organs and lead to renal damage.[6] In this context, the monitoring and management of IAP hold an important place in patients undergoing surgery. In a meta-analysis by Kwee et al.,[6] 53 studies evaluating complications associated with the prone position were examined of which two studies focused on increased IAP and its associated complications.[6-8] Akıncı et al.[7] compared the prone position and jackknife position in patients undergoing spinal surgery and observed a reduction in IAP and intraoperative bleeding amounts in patients in the jackknife position. The reason for more bleeding in the prone position was explained by the increased intra-abdominal and intrathoracic pressure that reduced venous return and raised venous pressure in the surgical area.[7]

In our study, IAP values measured in the prone position were higher than in the supine position, which aligns with the literature. Additionally, a significant difference between IAP and intraoperative bleeding amount in the colorectal surgery group was observed, also in accordance with the literature. The difference in intraoperative bleeding amounts in lumbar and colorectal surgeries can be explained by various reasons, such as the variability of surgeries, durations, and teams; however, the effect of increased IAP due to the prone position was also evaluated in this context.

Studies have stated that there is a strong correlation between BMI and IAP in individuals placed in the prone position.[9,10] Han et al.[9] examined three groups (normal, overweight, and obese) of surgery patients according to BMI, and reported that the increase in IAP was greater in the group with high BMI and in the prone position. Wilson et al.[10] emphasized that the IAPs of individuals with morbid obesity were higher than those with normal BMI, but this elevation was not sufficient for IAH. In our study, the IAP increase in the prone position in those with BMI higher than normal increased more significantly, consistent with the literature.

When cases were accepted with a threshold value of 30 kg/m^2 according to BMI, no significant difference was found in terms of urea, creatinine, and eGFR values. A reason for this finding could be the narrow range of the study group in terms of BMI (excluding patients with BMI >35 kg/m^2), surgical durations not being long enough to affect renal functions, and the role of effective fluid management.

In the review by Mobley et al.,[11] controversial results were reported regarding the relationship between prone position and renal functions. While Bradley et al.[12] stated that IAP values of 15 mmHg and higher negatively affected renal perfusion, Hering et al.[13] emphasized that IAP increase did not affect renal perfusion. In our study, IAP values of 14 mmHg and higher did not affect renal functions and these differences could be related to the variability of patient groups and surgery types.

Furthermore, in our study, both urea and creatinine concentrations decreased as the postoperative sampling time was extended; this decrease was significant in urea concentration, especially in the colorectal surgery group. These results were evaluated because of long preoperative fasting duration and effective hydration in the intraoperative period. Long-term preoperative fasting can lead to fluid loss and hypovolemia, reducing renal perfusion.[14] This circumstance increases the activation of the renin-angiotensin-aldosterone system and antidiuretic hormone.[15] If the process is not managed properly, renal dysfunction can become permanent.[14] With correct and controlled fluid replacement, intravascular volume is rebalanced, renal perfusion increases, and glomerular filtration is restored.[16] In this way, ischemia and tubular damage in the kidneys can regress, toxic metabolites can be excreted, and kidney capacity can be preserved.[15] Therefore, detailed planning of fluid management before, during, and after surgery is a crucial step for preventing hypovolemia and renal damage.[14,16] The study results indicate that fluid therapy administered to patients in the intraoperative and postoperative periods was adequate and effective.

Limitations

There are limitations to our study. The surgical team in our clinic restricts oral intake (solid and liquid) for 8 hours in the preoperative period, which might explain the decrease in urea and creatinine values after fluid therapy. Most of the participants in the lumbar surgery group were female and male in the colorectal surgery group, while BMI was higher in the lumbar surgery group and surgical duration and intraoperative bleeding amount was higher in the lumbar surgery group, which are some limitations of the study. Additionally, since the discharge times of the study population varied between 48-72 hours, only the blood results in the first 48 hours were evaluated to standardize. Regarding the effect of patient position on IAP, the possibility that the surgical intervention performed in the abdomen in the colorectal surgery group could affect the measurements in the postoperative period-although it was performed after the IAP measurement in the intraoperative period-is another limitation in the study. Furthermore, the non-evaluation of preoperative hemoglobin levels, amounts of blood and blood products given perioperatively, postoperative fluid and blood product replacements, and postoperative hemoglobin levels, which could affect renal functions other than IAP due to supine and prone positions, is another limitation of the study.

CONCLUSION

The prone position can lead to unwanted complications by causing increases in IAP. Increased IAP in the prone position may contribute to alterations in renal function parameters and increased intra-operative blood loss. If this surgical position is preferred, it is necessary to provide adequate and effective fluid therapy and carefully monitor renal function values, such as urea, creatinine, and eGFR.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study was approved by the Ankara Bilkent City Hospital Medical Researches Ethics Committee (Date: 20.03.2024, Decision No: TABED 2-24-21).

Informed Consent

Written informed consent was obtained from all individual participants prior to their inclusion in the study. Participants were fully informed about the study's aims, procedures, potential risks and benefits, and their rights-including the right to withdraw at any time without consequence. All participants voluntarily signed a written informed consent form.

Peer Review Process

This manuscript was subject to external peer review.

Conflict of Interest

The authors declare no conflicts of interest related to this study.

Financial Disclosure

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Author Contributions

Concept: ET, ŞMA; Design: ET, ŞMA, GE; Control: ŞMA, GE; Resources: ET, ŞMA, GE; Materials: ET, ŞMA; Data Collection and/or Processing: ET, ŞMA; Analysis and/or Interpretation: ŞMA, GE; Literature Review: ET, ŞMA, GE; Writing the Article: ET, ŞMA, GE; Critical Review: ŞMA, GE.

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