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Analysis of factors associated with polyuria in spinal surgery: a retrospective study

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Abstract

Background Intraoperative urine output monitoring is an important indicator to judge patient volume, and perioperative polyuria can lead to a variety of complications, which seriously affect the quality of prognosis of patients. Previous studies have found that intraoperative polyuria in some patients may be associated with the use of anesthetic drugs, especially in spinal surgery patients, where cases of polyuria have been reported more commonly. Therefore, this retrospective study focused on the factors influencing polyuria during spinal surgery.

Methods Data from spine surgery patients in the Madison system of Tongji Hospital from September 2018 to December 2021 were collected. The age, sex, BMI, surgical information, preoperative and postoperative test results, LOS, and postoperative adverse reactions were extracted. The relevant data during the operation were recorded through the Madison system at the same time, including the time statistics of various types of surgery, the amount of liquid in and out of the operation, the use of anesthetic drugs, the use of vasoactive medications, and the results of blood gas analysis. The primary outcome was to analyze the factors influencing intraoperative polyuria. Secondary outcomes were analyzed, among adverse effects of intraoperative polyuria, etc.

Results Among the 903 included patient data, we concluded that the factors influencing intraoperative polyuria were female (OR, 1.933, 95% CI, 1.457–2.565), dexmedetomidine (OR, 1.876, 95% CI, 1.338–2.631), dopamine (OR, 1.413, 95% CI, 1.406–1.910). At the same time, different surgical sites also affected the symptoms of polyuria ($p < 0.001$). Intraoperative polyuria symptoms led to an increase in the incidence of infection ($p < 0.05$) and secondary surgery ($p < 0.05$). The length of hospital stay was also increased ($p < 0.05$) compared with the normal urine output group. There was no significant difference in the time of operation and preoperative and postoperative examination information($p > 0.05$).

Conclusions Females, dexmedetomidine, dopamine may be risk factors for intraoperative polyuria. Intraoperative polyuria will lead to various postoperative adverse reactions, increasing the proportion of postoperative infection and secondary surgery.

Keywords Intraoperative polyuria, Risk factors, Spine surgery

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Introduction

Intraoperative polyuria in adults is intraoperative urine output > 125 ml/h, accompanied by urine specific gravity < 1.005, urine osmolality of 50 ~ 200mOsm/(kg· H_2O). When the urine is as pale as water, intraoperative diabetes insipidus (DI) may be considered [1]. Studies have reported that polyuria symptoms have a particular incidence in anesthesia and sedation. Intraoperative polyuria may be secondary to severe intraoperative and postoperative complications such as hypovolemia and electrolyte abnormalities. This significant change in systemic water content can lead to hypernatremia and hyperosmolality in plasma, which, if not recognized and corrected, can lead to potentially severe neurological symptoms, including weakness, lethargy, myalgia, and coma. Because patients undergoing anesthesia or sedation cannot adjust their fluid intake to compensate, the anesthesiologists must monitor urine output, replenish the number of fluids, and manage any electrolyte abnormalities to prevent complications.

However, there were few studies analyzing factors associated with intraoperative polyuria. Only several case reports suggested that anesthetic drugs may be associated with perioperative DI, including drugs such as propofol [2, 3], dexmedetomidine [4–9], sevoflurane [10–15], ketamine [16–19], and other factors may be the use of dexamethasone and central diabetes insipidus [1]. The most notable of these are polyuria due to dexmedetomidine intraoperatively. Although this polyuria reaction has not been confirmed in human studies, an increasing number of case reports indicated a link between the use of dexmedetomidine and DI. In Lauren M.Van Decor's investigation, it was stated that anesthesiologists must consider whether anesthetics, especially dexmedetomidine, are potential risk factors for the development of DI [1].

Previous reports have reported a higher incidence of the disease in pituitary and spine surgery [1, 20, 21]. Studies have shown that about 75% of patients undergoing pituitary surgery will have perioperative DI [22, 23]. The association between DI and pituitary and sellar surgery has been clinically agreed upon, mainly related to intraoperative stimulation of the pituitary region and particular positions causing hypothalamic-pituitary hypoperfusion or stress response. Cases of sudden DI during scoliosis orthopedics have also been reported, which may be related to local hypoperfusion of the hypothalamic-pituitary gland due to cervical vertebral body traction [24, 25]. Still, the associated causes of polyuria during spinal surgery are not clear.

This retrospective study focuses on analyzing the influencing factors of polyuria during spinal fusion surgery, which is helpful for early prevention and timely treatment, maintaining the stability of intraoperative circulation, reducing postoperative complications, and improving prognosis.

Methods

Patients and data collection

Data were retrospectively collected from spine surgery patients in the Madison system of Tongji Hospital from September 2018 to December 2021. Through the electronic medical record system, we extracted the patient's age, gender, height, body mass index (BMI), preoperative diagnosis, surgical name, preoperative and postoperative test results including hemoglobin (Hb), hematocrit (Hct), urea nitrogen (BUN), creatinine (Cr), glomerular filtration rate (eGFR), serum sodium concentration (Na^+), serum potassium concentration (K^+), urine specific gravity, length of stay (LOS) hospitalized, and postoperative adverse reactions. At the same time, the relevant data during the operation were recorded through the Madison system, including anesthesia time, operation time, PACU time, intraoperative fluid intake, anesthetic drug use, vasoactive drug use, and blood gas analysis results.

Inclusion criteria: (1) Non-emergency patients undergoing spinal surgery; (2) Normal cardiopulmonary function, liver and kidney function; (3) The preoperative examination is normal.

Exclusion criteria: (1) Age < 18 years old; (2) Diuretics used intraoperatively; (3) Patients with missing basic data (such as height, weight, etc.); (4) Intraoperative urine output was not recorded; (5) Preoperative low urine output (< 0.5 ml/kg/h) [26].

Criteria for intraoperative polyuria

Intraoperative polyuria is urine output > 125 ml/h; this definition defaults to an adult weight of 60 kg. We included the weight in the polyuria definition index, and the data turned out to be > 2.1 ml/h/kg. According to this indicator, we searched 3875 spinal surgery data in the Madiston anesthesia system, divided into a normal urine output group and a polyuria group. Finally, 450 patients in the polyuria group met the screening criteria, and 453 cases in the normal urine output group met the screening criteria.

Outcomes

The primary results were to analyze the effect of drugs on urine output. The secondary results examined the association between intraoperative urine output and gender, age, operation time, PACU time, preoperative and postoperative test information, and postoperative adverse effects.

Data analysis

According to whether the intraoperative urine output is more remarkable than 2.1 ml/h/kg, it is divided into the polyuria group and the normal group. Then all continuous data are tested for normality, focusing on the significance p of the Kolmogorov-Smirnov test. If $p > 0.05$ in the result, it shows that the data conform to the normal distribution, and the data is entered into the table in the form of mean ± standard deviation; If the $p < 0.05$ in the result shows that the data do not conform to the normal distribution, the data is entered into the table in the form of the median (upper quartile - lower quartile). The difference between demographic characters (age, gender, BMI), time statistics (anesthesia time, operation time, PACU time, length of hospital stay), and postoperative adverse reactions (infection, secondary surgery, postoperative delirium) between the normal group and the polyuria group was analyzed. The chi-square test was used to analyze categorical variables, the independent sample t-test was used to analyze the continuous variables that satisfied the normal distribution, and the Levine variance equivalence test was checked to determine whether the variance between the two groups of samples was homogeneous and significant. And the nonparametric rank test was used to analyze the continuous numerical variables that did not meet the normal distribution.

Regression analysis was analyzed for factors affecting intraoperative urine output. The dependent variable is intraoperative polyuria. The independent variables included demographic data, intraoperative fluid intake, and intraoperative drug statistics. The univariate screening was used first to exclude other confounders and variables with significant differences from the dependent variable ($p < 0.05$) in the above independent variables was included. The binary logistic regression analysis model included the above variables, and eight related variables (crystalloid, colloidal fluid, norepinephrine, dopamine, cis-atracurium, rocuronium bromide, antihypertensive drug, dexmedetomidine) were established to establish the regression model. Hosmer and Lemeshow's goodness-of-fit test ($p = 0.3 > 0.05$) showed that the model was meaningful and well-fitted.

Results

Demographic characteristics

After the screening, the data of 3875 patients collected in the Madison system were eventually divided into 450 polyuria groups and 453 normal urine output groups. The screening flowchart and the distribution of surgical sites are shown in Fig. 1. Table 1 shows the demographic characteristics of the two data sets, including sex, age, and BMI. There was no statistically significant difference in age and BMI between the two groups ($p > 0.05$). However, the proportion of female patients in the polyuria group was significantly higher than that of male patients ($p = 0.01$).

Surgical categories

The distribution of surgical analogs in the normal and polyuria groups is shown in Table 2. The results showed significant differences in the cervical spine, thoracolumbar vertebra, and lumbar spine groups ($p < 0.05$). Polyuria is more likely to occur with surgery for the cervical spine and thoracolumbar vertebra, while surgery for the lumbar spine is less prone to polyuria($p < 0.05$).

Risk factors for intraoperative polyuria

We first used univariate screening to exclude other confounding factors and then included variables with significant differences ($p < 0.05$) from the dependent variable in the above independent variables (Table 3). The results are shown in Table 6. There are nine variables that show differences between the two groups which are gender, crystalloid, colloid, dopamine, norepinephrine, antihypertensive drugs, cis-atracurium, rocuronium, and dexmedetomidine. The results may be biased due to the unknown type of antihypertensive drugs and the duration of intraoperative use, so they were not included in the binary logistic regression model. The binary logistic regression analysis model included gender, age, crystalloid, colloidal fluid, norepinephrine, dopamine, cis-atracurium, rocuronium bromide, and dexmedetomidine to establish the regression equation, and the results are shown in Table 4, which suggests that gender, total colloidal fluid, intraoperative dopamine, and dexmedetomidine may contribute to intraoperative polyuria ($p < 0.05$). Among them, female (OR = 1.937,95%CI, 1.508–2.645), the total amount of colloidal fluid (OR = 1.001,95%CI,1.000-1.001), intraoperative dopamine (OR = 1.371,95%CI,1.016–1.849), and dexmedetomidine (OR = 1.915,95%CI,1.367–2.682) may be risk factors for intraoperative polyuria.

Preoperative and postoperative test information

The results of preoperative laboratory tests, including hemoglobin (Hb), hematocrit (Hct), urea nitrogen (BUN), creatinine (Cr), glomerular filtration rate (eGFR), serum sodium concentration (Na^+), serum potassium concentration (K^+), urine specific gravity. Among them, hemoglobin (Hb), hematocrit (Hct), and creatinine (Cr) levels were divided into male and female subgroups for comparison is shown in Table 5. Table 6 shows the results of the patient's postoperative laboratory tests, the details are the same as above. The results showed no significant difference between the polyuria and normal groups in the preoperative and postoperative examination results.

Time statistics

The results of the duration of anesthesia, length of surgery, length of hospital stay, and time of PACU are shown in Table 7. The results showed no significant difference

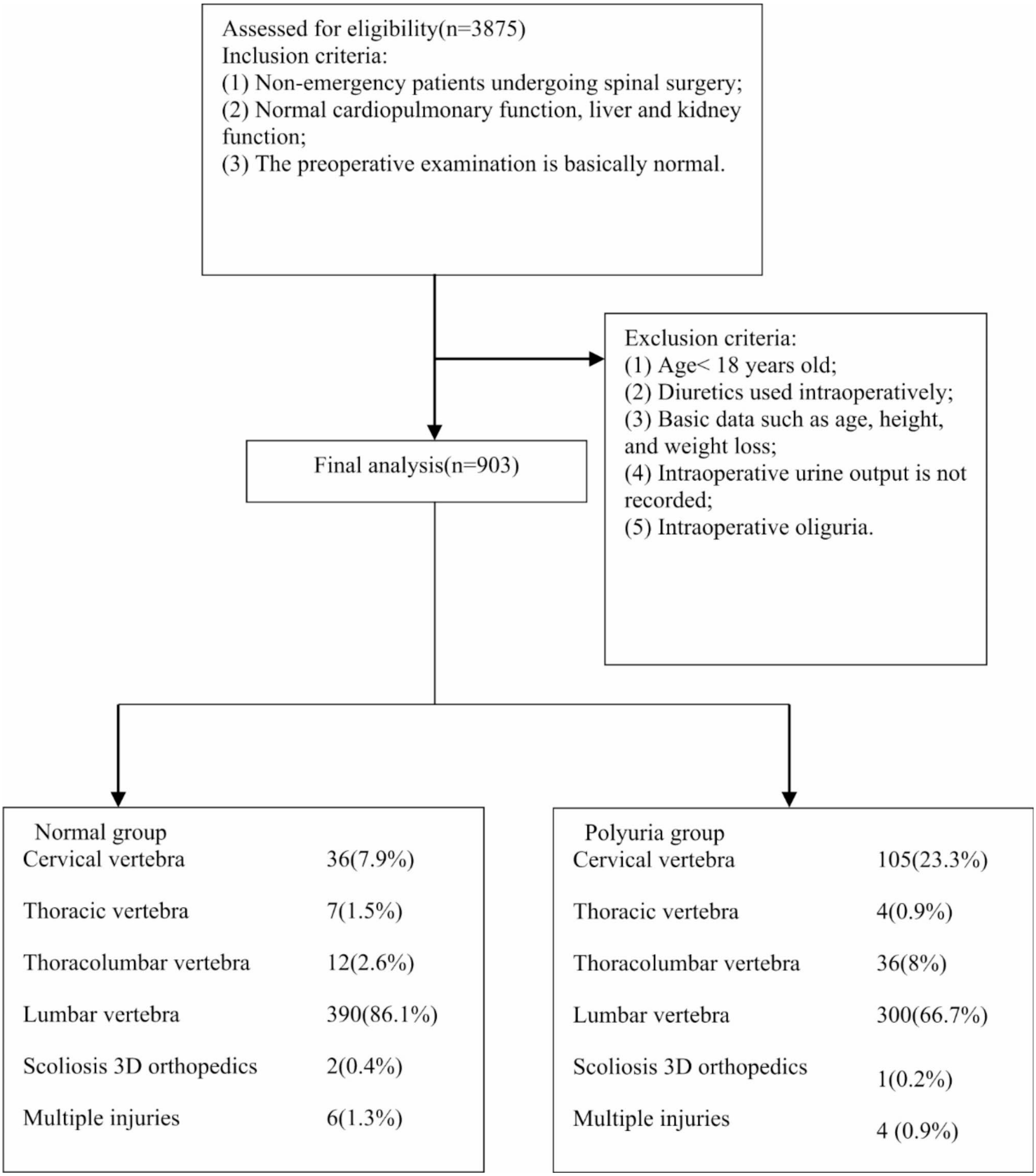

Fig. 1 Enrollment flow diagram

between the polyuria and normal urine output groups in the duration of anesthesia and surgery or the PACU subgroup ($p > 0.05$). However, the (length of stay) LOS hospitalized in the polyuria group was significantly greater than in the normal group ($p = 0.011$).

Postoperative adverse reactions

The chi-square test counts the difference in postoperative adverse effects between the two groups, and the results are shown in Table 8. The table shows no apparent difference in the incidence of postoperative delirium among postoperative adverse effects. However, the incidence of

Table 1 Demographic characteristics of 903 patients

Demographic characteristics		Normal group	Polyuria group	*P*	OR	95%CI	
Gender	Male	277(61.1%)	207(46.00%)	0.010#	1.418	1.329	2.407
	Female	176(38.9%)	243(54.00%)		0.719	0.623	0.831
Age		55(48–64)	55(48–64)	0.062^	0.000	-1.000	2.000
BMI		24.65(22.49–26.64)	22.89(20.76–25.39)	0.727^	1.534	1.098	1.967

Data were expressed by median and interquartile range, or frequencies and percentages

OR odds ratio, CI confidence interval, BMI body mass index

#Chi-square test

^Mann-Whitney U test

Table 2 Surgical sites

	Normal group	Polyuria group	*P*	OR	95%CI	
Cervical vertebra	36(7.9%)	105(23.3%)	< 0.001#	0.292	0.196	0.436
Thoracic vertebra	7(1.5%)	4(0.9%)	0.551+	1.75	0.509	6.020
Thoracolumbar vertebra	12(2.6%)	36(8%)	< 0.001#	0.330	0.173	0.629
Lumbar vertebra	390(86.1%)	300(66.7%)	< 0.001#	3.095	2.224	4.308
Scoliosis 3D orthopedics	2(0.4%)	1(0.2%)	1.000+	1.991	0.18	22.037
Multiple injuries	6(1.3%)	4 (0.9%)	0.759+	1.497	0.419	5.340

Data were expressed by frequencies and percentages

OR odds ratio, CI confidence interval

#Chi-square test

+Corrected Chi-square test

Table 3 Univariate screening

Factors	*P**
Age (years)	0.582
Gender	< 0.001
Crystal liquid (ml)	< 0.001
Colloid solution (ml)	< 0.001
Red blood cell suspension (u)	0.345
Fresh frozen plasma (ml)	0.291
Platelet	0.316
Albumin (ml)	0.9
Sodium bicarbonate (ml)	0.945
Sufentanil (μg)	0.212
Remifentanil (mg)	0.99
Norepinephrine	0.448
Dopamine	0.008
Deoxyepinephrine	0.805
Methoxymine	< 0.001
Nitroglycerin	0.478
Perdipine	< 0.001
Cis-atracurium	0.041
Dexamethasone	0.805
Heptafluoroalkane	0.472
Rocuronium bromide	0.046
Dexmedetomidine	< 0.001
antihypertensive drugs	0.001

*Independent sample t-test

infection ($p = 0.049$) and second surgery ($p = 0.009$) in the polyuria group was higher than in the normal urine output group.

Discussion

In this study, we found a high proportion of 49.8% of cases with polyuria during spinal surgery. By analyzing basic data such as gender and age, we found that female has an impact on intraoperative urine output. In a study by ML Kadir on the incidence of postoperative diabetes insipidus in patients undergoing surgery for pituitary tumors, the incidence of postoperative DI was slightly dominant in women ($p = 0.073$), which is consistent with the results of this study [27]. However, the specific cause is still unclear, and we suspect that this may be related to the decline in dBC (bladder capacity) in middle-aged women because in the study of Yoon, J. H. et al., [28] it was stated that dBC is an influencing factor in the onset of nocturia in women. In men, polyuria due to these factors was not observed.

During the perioperative period, polyuria is thought to be primarily associated with pituitary surgery and rarely spinal surgery. Only two reports suggested that spinal surgery is associated with diabetes insipidus. In the study of Granger, S. and Ninan, D [9]., cervical traction should be considered a potential cause of intraoperative DI. This is consistent with the conclusions in this study that cervical spine fusion is associated with polyuria. This result may be due to local hypoperfusion of the hypothalamic-pituitary due to cervical vertebral body traction. There is no evidence suggesting that thoracolumbar and lumbar

Table 4 Binary logistic regression analysis of intraoperative polyuria

	Normal group	Polyuria group	*P*	OR	95%CI	
Age(year)	55(48–64)	55(48–64)	0.494	0.996	0.984	1.008
Gender (Female)	277(61.1%)	207(46.00%)	< 0.001	1.937	1.508	2.645
Crystalloid(ml)	1600(1250–2000)	1750(1250–2500)	0.063	1.000	1.000	1.000
Colloidal fluid(ml)	500(500–1000)	1000(500–1000)	< 0.001	1.001	1.000	1.001
Dexmedetomidine	310(68.4%)	370(82.2%)	< 0.001	1.915	1.367	2.682
Dopamine	128(28.3%)	164(36.4%)	0.039	1.371	1.016	1.849
Norepinephrine	264(58.3%)	251(55.8%)	0.111	0.792	0.594	1.055
Cis-atracurium	374(82.6%)	347(77.1%)	0.088	0.617	0.354	1.075
Rocuronium bromide	112(24.7%)	138(30.7%)	0.647	1.123	0.684	1.843

Data were expressed by median and interquartile range, or frequencies and percentages

OR odds ratio, CI confidence interval

Table 5 Preoperative examination information

		Normal group	Polyuria group	*P*	OR	95%CI	
Hb(g/L)	Male	141.87 ± 15.52	138.85 ± 15.92	0.506*	0.038	0.170	5.850
	Female	123.33 ± 13.28	122.94 ± 13.36	0.663*	0.773	-2.230	3.000
Hct(%)	Male	41.40 ± 4.89	40.55 ± 4.68	0.158*	0.600	-0.200	1.300
	Female	37.00(35.10-39.15)	38.39 ± 21.73	0.525^	0.200	-0.500	0.900
BUN(mmol/L)		5.48(4.47–6.70)	5.30(4.30–6.50)	0.149^	0.160	-0.700	0.400
Cr(μmol/L)	Male	76(68–85)	74(66-83.75)	0.081^	2.000	0.000	5.000
	Female	59(52.25–65.75)	58(51–65)	0.436^	1.000	-1.000	3.000
eGFR(ml/min)		97.10(87.30-105.40)	97.30(89.70-106.40)	0.215^	-1.200	-3.100	0.700
Na^+(mmol/L)		141.20(141.10-142.30)	141.20(139.70-142.50)	0.896^	0.000	-0.300	0.300
K^+(mmol/L)		4.01(3.82–4.22)	4.03(3.82–4.25)	0.336^	-0.020	-0.070	0.030
Urine specific gravity		1.02(1.015–1.024)	1.018(1.015–1.023)	0.196^	0.001	0.000	0.001

Data were expressed by median and interquartile range or mean value ± standard deviation

OR odds ratio, CI confidence interval

*Independent sample t-test

^Mann-Whitney U test

Table 6 Postoperative examination information

		Normal group	Polyuria	*P*	OR	95%CI	
Hb(g/L)	Male	111.50(98.00-123.00)	109.50(99.00-123.00)	0.506^	0.000	-4.000	4.000
	Female	97.00(86.00-105.00)	98.00(88.00-108.00)	0.272^	-2.000	-5.000	1.000
Hct(%)	Male	32.90(29.00-36.05)	32.31 ± 5.94	0.939^	0.000	-1.100	1.200
	Female	28.51 ± 5.07	29.00(26.60–35.60)	0.327^	-0.500	-1.400	0.500
BUN(mmol/L)		6.52(5.25–10.170	5.42(4.02–8.38)	0.434^	0.100	-0.180	0.400
Cr(μmol/L)	Male	74(65–85)	72(63–82)	0.328^	2.000	-2.000	5.000
	Female	54(47–65)	57(50–66)	0.096^	-2.000	-5.000	0.000
eGFR(ml/min)		95.10(84.05-107.98)	97.30(91.15-109.05)	0.942^	0.100	-2.600	2.700
Na^+(mmol/L)		140.60(138.80-141.80)	142.20(138.70-143.05)	0.070^	-0.400	-0.800	0.000
K^+(mmol/L)		4.02(3.65–4.56)	3.93(3.67–4.10)	0.364^	0.030	-0.040	0.100
Urine specific gravity		1.01(1.01–1.02)	1.02(1.01–1.02)	0.646^	-0.001	-0.006	0.003

Data were expressed by median and interquartile range, or mean value ± standard deviation

OR odds ratio, CI confidence interval

^Mann-Whitney U test

fusion surgeries have an impact on intraoperative urine output. Further prospective studies are needed to explore the relationship between surgeries involving different spinal segments and intraoperative urine volume. However, our study did not show that polyuria is associated with scoliosis 3D orthopedics, which may be because the sample size is too small. It can be seen that the phenomenon of polyuria caused by spinal surgery does exist, especially in the operation of cervical vertebral body traction during the process, which should attract the attention of anesthesiologists to prevent diabetes insipidus and various adverse reactions in the perioperative period.

Table 7 Time statistics

	Normal group	Polyuria group	*P*	OR	95%CI	
Anesthesia time(min)	311(237-401.5)	305.5(235-388.5)	0.674^	7.000	-8.000	21.000
Surgery time(min)	255(189.5–345)	250.5(193–328)	0.422^	5.000	-8.000	20.000
LOS(d)	14(11–19)	15(12–20)	0.011^	-1.000	-2.000	0.000
PACU time(min)	36(23-54.25)	38(26–60)	0.072^	-3.000	-6.000	0.000

Data were expressed by median and interquartile range

OR odds ratio, CI confidence interval

^Mann-Whitney U test

Table 8 Postoperative adverse reactions

	Normal group	Polyuria group	*P*	OR	95%CI	
Infection	4(0.90%)	13(2.90%)	0.049+	0.299	0.097	0.926
Second surgery	1(0.20%)	11(2.40%)	0.009+	0.088	0.011	0.687
Postoperative delirium	0(0.00%)	2(0.40%)	0.476+	1.004	0.998	1.011

Data were expressed by frequencies and percentages

OR odds ratio, CI confidence interval

+Corrected Chi-square test

Dexmedetomidine was considered a risk factor for intraoperative polyuria in this retrospective study ($p < 0.001$, OR = 1.915, 95% CI, 1.367–2.682), consistent with previously reported case reports. There are the following possible causes of dexmedetomidine as to how intraoperative polyuria occurs. Dexmedetomidine is a highly selective, short-acting α-2 agonist. Several studies have evaluated the association between dexmedetomidine and the development of DI. Studies in dogs and rats have shown that α-2 agonists reduce the release of antidiuretic hormone (AVP) and peripheral nephrogenic response to AVP, resulting in a diuretic response [29, 30].

No other literature was found on the effect of colloidal fluids on intraoperative urine output. Based on the anesthesia records, the colloids used intraoperatively included hydroxyethyl starch (Voluven) and succinylated gelatin (Gelofusine). The ratio of cases used was approximately 1:1. Studies have shown no difference in renal dysfunction [31], renal failure, or renal replacement therapy in patients undergoing surgery treated with hydroxyethyl starch(HES). And the use of colloids compared with crystalloids alone improved hemodynamic stability, reduced the need for vascular inhibitors ($P < 0.001$) and reduced the length of hospital stay ($P < 0.001$). In this study, although colloidal fluid was significantly different between the normal group and the polyuria group, it only showed a slight increase in urine output ($p < 0.001$, OR = 1.001, 95% CI, 1.000-1.001), the reasons need to be further explored, and it is not thought that colloidal fluid has a stimulating effect on urine output.

At the same time, vasoactive drugs also affect intraoperative urine output. Among them, the cause of dopamine-causing polyuria (OR = 1.371,95%CI,1.016–1.849) may be that dopamine can selectively relax renal blood vessels [32], increase renal blood volume, and improve glomerular filtration rate; early application blocks the deterioration of renal failure and has the effect of excreting sodium and diuresis.

Prognostic factors in the polyuria group were LOS, postoperative infection, and secondary surgery. This supports the evidence that polyuria can cause various adverse effects, affecting recovery time and prognosis. However, our study did not show a correlation between polyuria and postoperative delirium, possibly due to the unclear definition of postoperative delirium in the electronic medical record system. From this point of view, polyuria can lead to a poor prognosis, and increased urine output during surgery can lead to severe postoperative complications if not treated in time. Furthermore, based on the postoperative adverse event records and found no reports of severe adverse reactions. Only one patient exhibited increased postoperative urine output (24-hour urine volume of 2700 mL), but the urinalysis results were normal. No patients were diagnosed with diabetes insipidus postoperatively.

The limitations of this article are: (1) The inherent defects of retrospective analysis: The measurement of exposure factors may have problems such as memory bias and information bias; Lack of details due to unclear factors recorded in the electronic medical record system and the Madiston system, such as postoperative adverse effects. (2) The types of surgery in this study were unevenly distributed and could not be analyzed in subgroups. (3) The time and dose of intraoperative drugs are inaccurate, so it is impossible to analyze the relationship between the specific dose of drugs and polyuria, and the cut-off value for the safe use of drugs cannot be found. Future prospective studies on dexmedetomidine may be conducted, and better alternatives to dexmedetomidine may be sought.

Conclusions

Our study found that female gender, dexmedetomidine, dopamine, use of antihypertensive drugs, and surgical site may be associated with intraoperative polyuria. And intraoperative polyuria would lead to various postoperative adverse reactions, increasing the proportion of postoperative infection and secondary surgery and a corresponding increase in LOS. Prevention of intraoperative polyuria in future work may be an area where anesthesiologists need to raise their attention. And it is time to think about whether there are any other drugs which could replace dexmedetomidine to reduce the occurrence of adverse reactions such as polyuria and improve the prognosis of spine surgery patients.

Abbreviations

DI	Diabetes insipidus
BMI	Body mass index
LOS	Length of stay
CI	Confidence interval
Hb	Hemoglobin, Hct: hematocrit, BUN: Urea nitrogen, Cr: Creatinine, eGFR: Estimated glomerular filtration rate
OR	Odds ratio
PACU	Postanesthesia care unit
SPSS	Statistical Package for Social Sciences
dBC	Bladder capacity
AVP	Antidiuretic hormone
HES	Hydroxyethyl starch
CKD	Chronic kidney disease
SGLT2	Sodium-glucose co-transporter type 2
AKI	Acute kidney injury

Supplementary Information

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Supplementary Material 1

Author contributions

Xu initially designed the framework and contributed significantly to the drafting and editing of the manuscript; Zhou involved in data collection, manuscript writing, and editing supplementary files; Tian, Chu, Yu and Xin contributed to the development of this manuscript. All authors read and approved the final version of the manuscript.

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Data availability

All data generated during this study are included in this published article and its Supplementary information files. All methods were performed in accordance with the relevant guidelines and regulations by the Declaration of Helsinki and must have been approved by an appropriate ethics committee. Available upon request from corresponding author at ajxu@tjh.tjmu.edu.cn.

Declarations

Ethics approval and consent to participate

Ethics approval and Consent to Participate were performed in accordance with the relevant guidelines and regulations by the Declaration of Helsinki.

Ethics approval

The Ethics Committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No: IORG0003571) gave a final APPROVAL on 03/09/2022 for the study Analysis of factors associated with polyuria in spinal surgery: a retrospective study which is conducted by Xu Aijun at Department of Anesthesiology, Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology.

Consent for publication

Not applicable.

Consent to participate

The Ethics Committee of Tongji Hospital Affiliated to Tongji Medical College of Huazhong University of Science and Technology approved a waiver of written informed consent for individuals because of the retrospective nature of the study.

Conflict of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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