Original Article

Incidence rate of hypokalemic and its associated factors for patients undergoing noncardiac surgery: a retrospective analysis

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Background: Hypokalemia is common in hospitalized patients. In fact, untreated hypokalemia is associated with the incidence and mortality of adverse cardiac events. Timely recognition and treatment of these diseases are essential. Indeed, a little research has been conducted on the level of K^+ in perioperative patients. In this study, by comparing the changes of K^+ from when patients were admitted to hospital and to after they had entered the operating room, we analyzed the related factors of K^+ disorder after operating-room entry and identified factors related to the occurrence of perioperative K^+ disorder.

Methods: This single-center retrospective study included non-cardiac surgery patients who underwent admission blood gas analysis and blood gas analysis upon entering the operating room in the China-Japan Union Hospital of Jilin University between June 2019 and September 2020.

Results: Among the 258 patients who underwent non-cardiac surgery with anesthesia, 19 cases (7.4%) were hypokalemic on admission, and 102 cases (39.5%) were hypokalemic after admission to the operating room. The K^+ levels after operating-room entry were positively correlated with the K^+ concentration at admission ($r=0.363$; $P<0.05$). Female sex [odds ratio (OR) =0.451; 95% CI: 0.263–0.775; P=0.004], hypertension (OR =0.499; 95% CI: 0.281–0.885; P=0.017), and preoperative bowel preparation (OR =0.471; 95% CI: 0.258–0.860; P=0.014) were risk factors for hypokalemia for patients after operating-room entry.

Conclusions: Hypokalemia was found to be common in patients after operating-room entry. Even patients with normal K^+ at admission could have hypokalemia due to undergoing an operation, with female sex, hypertension, and bowel preparation being the risk factors for this condition.

Keywords: Electrolytes; homeostasis; hypokalemia; perioperative period

Submitted May 07, 2023. Accepted for publication Jun 13, 2023. Published online Jun 27, 2023.
doi: 10.21037/gs-23-183
View this article at: https://dx.doi.org/10.21037/gs-23-183

Introduction

Potassium (K^+) is the most abundant cation in human cells and plays a variety of essential roles, including maintaining cell metabolism, maintaining cell resting membrane potential, regulating intracellular and extracellular osmotic pressure, and regulating the acid-base balance (1,2). The human body contains about 45 mmol/kg of K^+, and while most K^+ is located intracellularly, some can be found in the extracellular fluid (ECF) (2-4). The dynamic balance of K^+ in the ECF is critical to the normal function of nerve and muscle cells (1,5).

Hypokalemia is a common electrolyte abnormality defined as serum potassium <3.5 mmol/L that may affect multiple organ systems; it can be life-threatening if serum potassium levels are <2.5 mmol/L (6,7). Hypokalemia may be caused by inadequate potassium intake, excess potassium loss, or transcellular shift of potassium (6-8). The incidence of hypokalemia in hospitalized patients is 2.6–23.2% (6-8), reaching 49.9% in emergency patients (9), 56% in patients receiving diuretics (10), and 70.4% in patients undergoing gastrointestinal surgery (11). Hyperkalemia is defined as serum potassium ≥5.5 mmol/L; is commonly found in patients with chronic kidney disease, diabetes, or cardiovascular disease; and can also lead to life-threatening arrhythmia and death (7,12,13). Hyperkalemia is observed in 1.1–10.0% of hospitalized patients (14).

The serum K^+ levels measured before anesthesia induction are generally lower than those measured 1–3 days before operation (15). Therefore, even if the routine examination at admission is normal, there is a risk of serious K^+ disorder occurring during operation, which must be given due attention (16,17). Perioperative K^+ disorders can increase mortality and prolong hospital stay (16,17). Arora *et al.* (17) showed that preoperative K^+ abnormality (<4.00 or >5.50 mmol/L) was associated with perioperative cardiovascular adverse events, including acute myocardial ischemia, arrhythmia, and sudden cardiac death. Jensen *et al.* (18) showed that plasma K^+ <2.90 mmol/l was associated with increased mortality from 0 to 7 and 8 to 30 days after admission. Perioperative K^+ disorders are common, with an incidence rate of 0.2–16.0% in the general population and reaching 2.9–71.0% in high-risk patients (19). Hypokalemia has been shown to be a predictor of adverse cardiovascular and renal outcomes (20). Untreated hypokalemia or hyperkalemia will prolong the hospital stay and increase mortality (21,22). It is thus crucial to recognize and manage K^+ disorders in time to improve the prognosis of patients undergoing surgery.

Therefore, this study explored the changes in perioperative K^+ levels and analyzed the risk factors of hypokalemia after operating-room entry. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-183/rc).

Highlight box

Key findings
- Female sex, hypertension, and bowel preparation were identified as risk factors for hypokalemia in patients after operating-room entry.

What is known and what is new?
- Potassium plays various essential roles, including maintaining cell metabolism, maintaining cell resting membrane potential, regulating intracellular and extracellular osmotic pressure, and regulating the acid–base balance.
- Hypokalemia in patients after operating-room entry is common. Even patients with normal K^+ at admission may experience hypokalemia during an operation. Female sex, hypertension, and bowel preparation were identified as risk factors of hypokalemia after operating-room entry.

What is the implication, and what should change now?
- The occurrence rate of hypokalemia after during operation is very high, and further investigation into this issue is warranted. Particular attention should be paid to hospitalized patients with low potassium, female patients, patients with hypertension, and patients undergoing intestinal preparation. Active monitoring of the potassium ion level is the key to early detection and treatment.

Methods

Study design and patients

This single-center retrospective study included non-cardiac surgery patients who underwent admission blood gas analysis and blood gas analysis upon entering the operating room in the China-Japan Union Hospital of Jilin University between June 2019 and September 2020. This study was approved by the ethics committee of the China-Japan Union Hospital of Jilin University (No. 2021-NSFC-062). The requirement for informed consent was waived due to the retrospective nature of the study. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

The inclusion criteria were for patients were the following: (I) scheduled for noncardiac surgery and (II) available blood gas data at admission and immediately before operation. The non-inclusion criteria were patients undergoing heart surgery. The exclusion criteria were the following: (I) patients undergoing emergency operation; (II) age <13 years; (III) acute abdomen or dysfunction of major organs, such as the intestine, liver, heart, or kidney, or comorbidities related to K^+ disorder; (IV) pregnancy; (V) long-term diet or eating disorders; (VI) recent administration of diuretics, insulin or steroid hormones; (VII) excessive blood loss, blood transfusion, or K^+ supplementation before blood sample collection; and (VIII) incomplete clinical data.

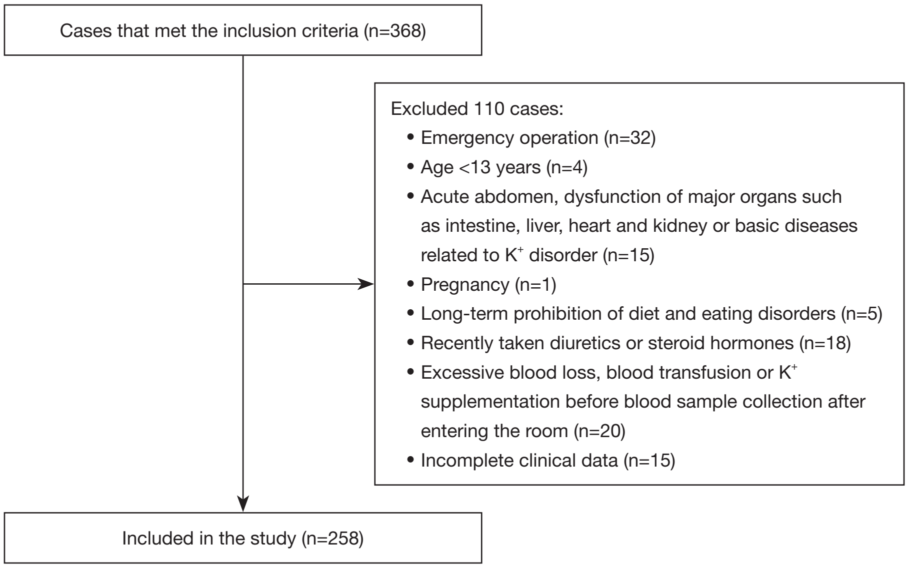

Figure 1 Case screening flowchart.

Data collection

The clinical data of the patients were collected, including age, sex, height, weight, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status (23), hypertension, diabetes, and preoperative gastrointestinal preparation. Blood gas results were collected and K^+ was recorded when the patient was admitted and upon entering the operating room. After collecting K^+ data from patients undergoing non-cardiac and non-emergency surgery surgery during perioperative period, these data were used to compare changes in potassium levels between admission and before surgery, seasonal changes in potassium levels, and possible causes of hypokalemia. K^+ disorders were divided into hyperkalemia and hypokalemia (24).

Statistical analysis

SPSS 22. 0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The continuous variables conforming to the normal distribution are expressed as mean ± SD and were analyzed with the Student *t*-test. The continuous data not conforming to the normal distribution are presented as the median and interquartile interval (Q25–Q75) and were analyzed with the nonparametric rank-sum test. The categorical data are expressed as number and percentage and were analyzed using the chi-squared test. The Pearson correlation coefficient was used for correlation testing. We separate patients into two different groups with potassium levels, those with normal potassium levels and those with hypokalemia. Comparing different characteristics between two groups with *t*-test, we selected the characteristics that affect changes in potassium for binary logistic regression. Two-tailed P values <0.05 were considered statistically significant.

Results

Characteristics of the patients

Among the 368 patients scheduled for surgery in the study period, 110 were excluded according to the exclusion criteria. Ultimately, 258 patients were included in the study (*Figure 1*). There were 110 males (42.6%) and 148 females (57.4%), with a median age of 54.5 (43.0–64.0) years. The median BMI was 23.9 (22.0–26.6) kg/m^2. Among them, 71 patients (27.5%) had hypertension, 38 (14.7%) had diabetes mellitus, and 61 (23.6%) underwent bowel preparation (*Table 1*).

Incidence of perioperative K^+ disorders

Among the 258 patients who underwent non-cardiac surgery with anesthesia, 19 (7.4%) cases were hypokalemic on admission including 1 (0.4%) with severe hypokalemia, 3 (1.2%) with moderate hypokalemia, 15 (5.8%) with mild hypokalemia, and 2 with hyperkalemia (0.78%). There were 102 cases (39.5%) of hypokalemia after entering the operating room, including 1 (0.4%) case of severe hypokalemia, 14 (5.4%) of moderate hypokalemia, and 87 (33.7%) of mild hypokalemia. There were no patients with hyperkalemia after entering the operating room (*Table 2*).

Correlation between K^+ levels in the operating room and at admission

Among the 19 patients with hypokalemia, 16 (84.2%) still had hypokalemia after entering the operating room. In addition, 86 patients with normal K^+ at admission had hypokalemia, accounting for 35.9% of those with normal K^+ at admission. Of the 2 patients with hyperkalemia admitted to the hospital, 1 developed hypokalemia after entering the operating room, and 1 patient was in the normal range (Figure S1).

The K^+ levels after operating-room entry were positively correlated with the K^+ concentration at admission (r=0.363; P<0.05; *Table 3* and Figure S2).

Seasonal variations of the K^+ levels

The seasonal variation trend of the K^+ levels at admission and after entry into the operating room is shown in Figure S3. The K^+ levels after operating-room entry were lower than those at admission across the 4 seasons of the year, but the seasonal changes were not significant (P>0.05; *Table 4*).

Factors associated with hypokalemia after entering the operating room

The patients were divided into the low-K^+ group (K^+ <3.50 mmol/L) and the normal-K^+ group (3.50 ≤ K^+ ≤ 5.00 mmol/L). The demographic characteristics are shown in *Table 5*. Binary logistic regression analysis found that female sex [odds ratio (OR) =0.451; 95% CI: 0.263–0.775; P=0.004], hypertension (OR =0.499; 95% CI: 0.281–0.885; P=0.017), and preoperative bowel preparation (OR =0.471; 95% CI: 0.258–0.860; P=0.014) were independently associated with hypokalemia after operating-room entry (*Table 6*).

Table 1 Characteristics of the patients

Characteristic	Patients (n=258)
Age (years)	54.5 (43.0–64.0)
Sex	
Male	110 (42.6)
Female	148 (57.4)
Height (cm)	165.0 (160.0–170.0)
Weight (kg)	65.0 (60.0–75.0)
BMI (kg/m^2)	23.9 (22.0–26.6)
ASA	
I	33
II	146
III	69
IV	10
Hypertension	71 (27.5)
Diabetes	38 (14.7)
Gastrointestinal preparation	61 (23.6)

Data are presented as median (Q25–Q75) or n (%). BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 2 Distribution of the K^+ level in patients admitted to the hospital and operating room

Characteristic	Severe hypokalemia K^+ <2.50 mmol/L	Moderate hypokalemia 2.50 ≤ K^+ < 3.00 mmol/L	Mild hypokalemia 3.00 ≤ K^+ < 3.50 mmol/L	Normal 3.50 ≤ K^+ < 5.00 mmol/L	High potassium K^+ >5.00 mmol/L
Admission	1 (0.4)	3 (1.2)	15 (5.8)	237 (91.9)	2 (0.8%)
Operating room	1 (0.4)	14 (5.4)	87 (33.7)	156 (60.5)	0

Data are presented as n (%).

Table 3 Pearson correlation of K^+ concentration in the hospital and operating room

Characteristic	K^+ at admission	K^+ in the operating room	P	r
K^+ (mmol/L)	4.03 (3.78–4.26)	3.60 (3.30–3.80)	<0.05	0.363

Data are presented as median (Q25–Q75).

Table 4 Nonparametric comparison of K^+ concentration (mmol/L) of K^+-independent samples in the spring, summer, autumn, and winter

Characteristic	Spring	Summer	Autumn	Winter	P
K^+ at admission	4.00 (3.89–4.13)	4.04 (3.82–4.29)	4.00 (3.78–4.24)	4.04 (3.72–4.17)	0.895
K^+ in the operating room	3.75 (3.30–3.90)	3.60 (3.30–3.80)	3.50 (3.30–3.80)	3.60 (3.40–3.80)	0.695

Data are presented as median (Q25–Q75).

Table 5 Differences between the hypokalemia and normal potassium groups in the operating room

Characteristic	Hypokalemia group (n=102)	Normal potassium room (n=156)	P
Sex			0.010
Male	31 (30.4)	79 (50.6)	
Female	71 (69.6)	77 (49.4)	
Age (years)	57.0 (46.3–65.0)	54.0 (40.0–63.0)	0.407
BMI (kg/m^2)	23.6 (22.0–26.1)	24.0 (22.2–26.7)	0.916
ASA			0.372
I–II	74 (72.5)	105 (67.3)	
III–IV	28 (27.5)	51 (32.7)	
Hypertension	37 (36.3)	34 (21.8)	0.011
Diabetes	19 (18.6)	19 (12.2)	0.153
Bowel preparation	34 (33.3)	27 (17.3)	0.003

Data presented as median (Q25–Q75) or n (%). BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 6 Risk factors of hypokalemia in the operating room according to binary logistic regression analysis

Characteristic	Multivariable	
	OR (95% CI)	P
Sex		
Male	Reference	Reference
Female	0.451 (0.263–0.775)	0.004
Hypertension	0.499 (0.281–0.885)	0.017
Bowel preparation	0.471 (0.258–0.860)	0.014

OR, odds ratio; CI, confidence interval.

Discussion

This study showed that hypokalemia in noncardiac surgical patients entering the operating room was more frequent than at admission. The K^+ levels in the operating room were positively correlated with the K^+ levels at admission. In addition, female sex, hypertension, and gastrointestinal preparation were independently associated with hypokalemia after operating-room entry.

This study found that the rate of hypokalemia was 39.5%, which is higher than that of 2.6–23.2% observed in hospitalized patients (6-8), but within the range of patients undergoing gastrointestinal surgery (up to 70.4%) (11). Therefore, the results suggest that the monitoring of K^+ levels should be started as soon as possible to allow for the correction of hypokalemia before surgery. This would improve the patient outcomes since perioperative hypokalemia is associated with prolonged hospital stay and in-hospital mortality (16,17). Kuehn *et al.* (25) showed that the intaking of K^+ was beneficial to cardiac and that K^+ levels maintained between 4.00 and 4.50 mmol/L were beneficial to patients in general. In this study, only 41 patients (15.9%) entered the operating room with K^+ levels >4.00 mmol/L. The low frequency of the optimal K^+ levels suggests that the protective effect of K^+ on the patient's heart was weakened. Whether patients entering the operating room should have K^+ levels >4.00 mmol/L and whether potassium supplements should be actively given the need to be confirmed in further research.

This study showed that the K^+ levels between admission and the operating room were significantly but weakly correlated, suggesting that the K^+ levels in the operating room might be predicted according to the admission K^+ levels, at least in part. Nonetheless, the low R^2 value indicated that only a small part of the variance was explained by the correlation. Future studies are warranted to establish multivariable predictive models for K^+ levels in patients after operating-room entry for elective surgery. The patients with normal K^+ at admission but low K^+ in the operating room accounted for 84.3% of the patients with low K^+ in the operating room, highlighting the importance of multiple K^+ measurements after admission since the hypokalemia in these patients could be easily overlooked. Because most of the clinical symptoms of hypokalemia are masked by general anesthesia and since the occurrence of K^+ disorders cannot be completely predicted by electrocardiography, the diagnosis of hypokalemia in the operating room depends upon the monitoring of blood K^+.

Cheung *et al.* (26) reported that K^+ levels varied by season in hemodialysis patients. In this study, no statistically significant seasonal variations were observed in the K^+ levels of patients undergoing elective surgery. Of course, hemodialysis affects the electrolyte levels, and the combined influence of hemodialysis and seasons could more severely affect the K^+ levels.

This study showed that female sex, hypertension, and preoperative bowel preparation were independently associated with hypokalemia in the operating room. These patients should be the focus of postadmission screening. Women are more prone to hypokalemia than men are (27), which might be due to the sexual hormones. Estrogen can act on the adenosine triphosphate-sensitive K^+ channel (KATP), which belongs to the inward rectifier potassium channel protein and affects the intracellular K^+ levels (28).

Aldosterone regulates sodium retention and potassium excretion, which makes patients with hypertension and long-term activation of the renin-angiotensin aldosterone system have a weaker ability to regulate K^+ levels (29). Both hypokalemia and hyperkalemia are associated with an increased risk of death in patients with hypertension, suggesting that maintaining normal K^+ levels might improve the prognosis of patients with hypertension (30). Most antihypertensive drugs affect potassium homeostasis in some way (31). K^+ supplementation can alleviate hypertension without obvious side effects (32) and thus may be recommended as an auxiliary antihypertensive drug for patients with essential hypertension.

Patients with gastrointestinal preparation had a higher frequency of hypokalemia. Reumkens *et al.* (33) found that the frequency of hypokalemia in most patients after receiving low-volume polyethylene glycol bowel preparation was 23.6%, among whom 2 had severe hypokalemia, leading to ventricular arrhythmia and failed resuscitation. Therefore, patients who have to undergo bowel preparation should be closely monitored for K^+ levels.

Hypokalemia is associated with poor COVID-19 outcomes (34). In addition, patients with hypokalemia tend to have lower fasting blood glucose, lower Glasgow Coma Scale (GCS) score, and longer time from onset to treatment, which are predictors of adverse outcomes of stroke, cardiovascular disease, and kidney conditions (35). Early intravenous K^+ supplementation after abdominal surgery was reported to be conducive to the recovery of gastrointestinal function (16). Monitoring during supplementation is also essential because K^+ supplementation is a common cause of hyperkalemia in hospitalized patients (22). In this study, among the 15 patients who received preoperative potassium supplementation, there was 1 case of hyperkalemia, 9 of normal K^+ levels, and 5 of hypokalemia after operating-room entry. Monitoring helps understand the treatment results and provides a reference for formulating the treatment plan.

This study had limitations. First, it used a single-center design with a relatively small sample size. Second, it was possible that there were differences in K^+ levels between the venous and arterial blood. Third, the occurrence of hyperkalemia was too low to perform related analyses. Finally, due to the fact that most patients did not complete postoperative blood gas re-examination, this study was unable to observe the postoperative potassium levels and their relationship with prognosis in patients undergoing non-cardiac surgery of different types.

Conclusions

Patients are more likely to be hypokalemic when they enters the operating room than when they are admitted. Even patients with normal K^+ at admission could experience hypokalemia in the operating room, which deserves further attention. Female sex, hypertension, and bowel preparation are risk factors of hypokalemia after operating-room entry. Active monitoring of potassium ion level is key to the early detection and treatment of this condition.

Acknowledgments

Funding: This study was supported by funding from the Key R&D Projects of Jilin Science and Technology Development Plan (No. 20200404165yy).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-183/rc

Data Sharing Statement: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-183/dss

Peer Review File: Available at https://gs.amegroups.com/article/view/10.21037/gs-23-183/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-183/coif). All authors report that this study was supported by funding from the Key R&D Projects of Jilin Science and Technology Development Plan (No. 20200404165yy). The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of China-Japan Union Hospital of Jilin University (No. 2021-NSFC-062). The requirement for written informed consent to participate was waived due to the retrospective nature of the study.

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(English Language Editor: J. Gray)

Cite this article as: Wang N, Gao D, Shi Y, Song J, Liu X, Su Z. Incidence rate of hypokalemic and its associated factors for patients undergoing noncardiac surgery: a retrospective analysis. Gland Surg 2023;12(6):816-823. doi: 10.21037/gs-23-183

Supplementary

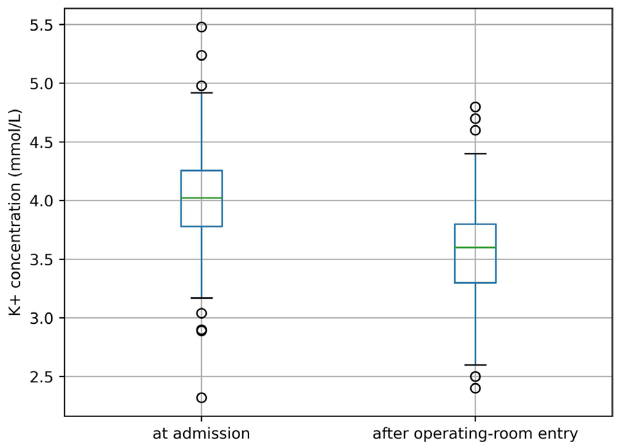

Figure S1 Changes in K^+ levels in patients at admission and after operating-room entry.

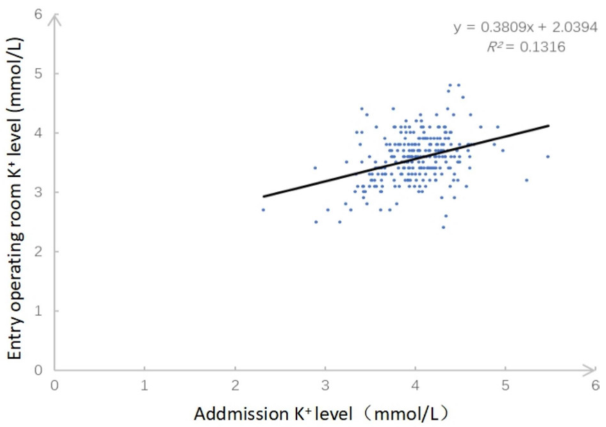

Figure S2 Scatter diagram of K^+ concentration at admission and after operating-room entry.

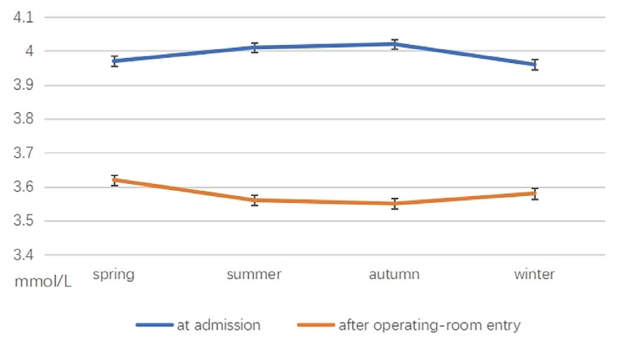

Figure S3 Seasonal variation of K^+ levels in different seasons.

https://dx.doi.org/10.21037/gs-23-183