Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Potassium Timing and Outcomes in Elective GI Tumor Surgery: A Propensity Score Analysis

Qunying Wang

203221@hospital.cqmu.edu.cn

The First Affiliated Hospital of Chongqing Medical University

Bangshu Zhao

The First Affiliated Hospital of Chongqing Medical University

Qian Wu

The First Affiliated Hospital of Chongqing Medical University

Fusen Huang

The First Affiliated Hospital of Chongqing Medical University

Qiuju Xiong

The First Affiliated Hospital of Chongqing Medical University

Dan Liu

The First Affiliated Hospital of Chongqing Medical University

Research Article

Keywords: anesthesia, gastrointestinal surgery, hypokalemia, perioperative outcomes, potassium supplementation

Posted Date: September 4th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10506987/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background and Objective

Hypokalemia is highly prevalent in patients undergoing elective gastrointestinal (GI) tumor surgery, yet the optimal timing of potassium supplementation—preoperative versus intraoperative—remains unresolved. This study aimed to (i) identify independent risk factors for preoperative hypokalemia and (ii) compare the effects of preoperative versus intraoperative potassium supplementation on perioperative outcomes in adults aged ≥ 45 years.

Methods

In this retrospective cohort study, 997 consecutive elective GI tumor surgery patients aged ≥ 45 years were screened at a single tertiary center (June 2022–June 2023). Multivariable logistic regression was first used to identify independent risk factors for preoperative hypokalemia. Subsequently, the timing of potassium supplementation (preoperative versus intraoperative) was treated as the exposure in a propensity score analysis estimating the average treatment effect on the treated (ATT). Five matching algorithms (nearest-neighbor, full, subclassification, Mahalanobis distance, and cardinality) were compared using the cobalt package, with balance defined as a standardized mean difference < 0.1. Full matching achieved optimal balance and was retained for the primary analysis. ATT weights were generated, and weighted linear or logistic regression was employed to estimate treatment effects. Sensitivity analyses were performed with the remaining four algorithms.

Results

Preoperative hypokalemia occurred in 419 (42.0%) patients; 417 (99.5%) were mild-to-moderate and 2 (0.5%) severe. Female sex was independently associated with increased risk (β = 0.11 mmol/L, 95% CI 0.06–0.15, P < 0.001). After full matching (n = 804 preoperative vs. 193 intraoperative), preoperative potassium optimization reduced anesthesia time by 12.2 minutes (β = −12.23 min, 95% CI − 21.60 to − 2.86, P = 0.011) without affecting PACU stay (β = −1.00 min, P = 0.64), postoperative length of stay (β = −0.20 days, P = 0.78), 30-day complications (OR = 0.86, 95% CI 0.44–1.66, P = 0.65), or composite major adverse events (OR = 0.85, 95% CI 0.46–1.58, P = 0.61). Sensitivity analyses with four alternative matching algorithms yielded consistent results (anesthesia time β ranging from − 7.23 to − 11.76 min, all P < 0.05).

Conclusions

Preoperative hypokalemia was highly prevalent in this cohort, with female sex as an independent risk factor. Preoperative potassium optimization shortened anesthesia time but did not improve short-term

recovery or morbidity in mild-to-moderate cases. These findings suggest that delaying surgery solely for mild-to-moderate hypokalemia may be unnecessary in hemodynamically stable patients, supporting a pragmatic shift toward intraoperative electrolyte monitoring and selective supplementation.

Introduction

Potassium is the most abundant intracellular cation and plays a key role in maintaining cellular electrophysiology, neuromuscular function, and acid–base balance.[1–3] Hypokalemia—commonly defined as a serum concentration below 3.5 mmol/L—may be asymptomatic or manifest with non-specific symptoms. When serum potassium falls below 2.5 mmol/L, life-threatening arrhythmias, including *torsades de pointes* and ventricular fibrillation, as well as respiratory-muscle paralysis, may ensue.[4–7]

The gastrointestinal (GI) tract plays the second-most pivotal role in potassium regulation after the kidneys.[2, 3] GI diseases and surgical interventions predispose patients to significant potassium depletion through vomiting, diarrhea, intestinal obstruction, or surgical fluid losses.[8] Studies have reported preoperative hypokalemia rates as high as 70.4% in GI surgery cohorts, significantly exceeding the 20% prevalence observed in general inpatient populations.[9–11] Age-related declines in muscle mass, comorbidities, and polypharmacy further exacerbate this risk.[12] Perioperative hypokalemia increases the risk of delayed recovery of gastrointestinal function, acute kidney injury, and adverse cardiovascular events, pneumonia and other complications, prolongs length of stay (LOS) and raises in-hospital mortality after gastrointestinal surgery.[13–15] Conversely, timely correction of hypokalemia has been shown to improve perioperative outcomes.

Data specific to middle-aged and elderly patients undergoing elective GI tumor surgery remain scarce, and the optimal timing of potassium supplementation—preoperative versus intraoperative—remains undefined. Current practice varies: some institutions mandate preoperative normalization, whereas others proceed with intraoperative correction under monitored conditions. [9, 16] The former risks surgical delays and operational inefficiency, while the latter may permit uncontrolled electrolyte depletion during anesthetic induction. We therefore conducted a retrospective cohort study (n = 997) with two objectives: (i) to identify independent risk factors for preoperative hypokalemia in patients aged ≥ 45 years undergoing elective GI tumor resection, and (ii) to estimate the average treatment effect on the treated (ATT) of preoperative versus intraoperative supplementation on perioperative outcomes using propensity-score methodology with multiple matching algorithms and sensitivity analyses. We hypothesized that preoperative optimization would reduce anesthesia time and improve short-term recovery compared with intraoperative supplementation.

This cohort study has been reported in line with the STROCSS guidelines.

Methods

Study Design and Setting

This retrospective cohort study was conducted at the Department of Anesthesiology, a single tertiary center in China. The study protocol was approved by the Institutional Review Board (approval number: K2023-258) and registered in the Chinese Clinical Trial Registry (registration number: ChiCTR2600116173, registration date: 2026-01-06). The study was conducted in accordance with the Declaration of Helsinki. Due to the retrospective nature of the study, the requirement for written informed consent was waived by the IRB.

Participants

Consecutive patients aged ≥ 45 years who underwent elective gastrointestinal tumor surgery between June 2022 and June 2023 were screened for eligibility. Inclusion criteria were: (1) American Society of Anesthesiologists (ASA) physical status I–III; (2) expected surgical duration > 30 minutes. Exclusion criteria included: (1) missing preoperative serum potassium values; (2) estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m²; (3) history of familial hypokalemic disorders; (4) emergency procedures; and (5) simultaneous multi-cavity operations.

Data Sources and Measurement

Demographic, clinical, and perioperative data were extracted from electronic medical records by trained research personnel using a standardized form. Variables included age, sex (male or female, based on chromosomal genotype and anatomy), body-mass index, ASA class, comorbidities (hypertension, diabetes mellitus, coronary artery disease, chronic obstructive pulmonary disease), Charlson Comorbidity Index, Nutritional Risk Screening 2002 score, type of surgery (gastric or intestinal), preoperative bowel preparation (oral laxatives and/or enema), and timing of potassium supplementation (preoperative versus intraoperative). Sex-based analysis was performed to identify differential risks of hypokalemia, consistent with the SAGER guidelines.[17] Gender as a social construct was not assessed.

Potassium Monitoring and Management

Arterial blood gas analysis was performed on admission to the operating theatre and before induction of anesthesia. Hypokalemia was defined as serum potassium < 3.5 mmol/L and categorized as mild (3.0–3.4 mmol/L), moderate (2.5–2.9 mmol/L) or severe (< 2.5 mmol/L). Potassium supplementation was administered immediately when hypokalemia was detected; with further doses guided by serial measurements. Patients who remained hypokalemic in the post-anesthesia care unit (PACU) continued supplementation until normokalaemia was achieved.

Outcomes

The co-primary endpoints were: (i) prevalence and independent risk factors of preoperative hypokalemia; (ii) ATT of preoperative versus intraoperative potassium supplementation on anesthesia time, PACU stay, postoperative length of stay, 30-day complications and composite major adverse events. Anesthesia time was defined as the interval from induction to anesthetic discontinuation; PACU stay, from PACU admission to ward discharge; and LOS, from the day of surgery to hospital discharge.

Statistical Analysis

Continuous variables were tested for normality using the Shapiro–Wilk test and expressed as mean ± standard deviation (SD) or median (interquartile range [9]); categorical variables were presented as counts (%). Between-group comparisons used Student's t-test, Mann–Whitney U test, χ^2 test, or Fisher's exact test as appropriate.

Statistical analysis was performed in two stages.

Stage 1: Multivariable logistic regression was used to identify independent risk factors for preoperative hypokalemia. Covariates included age, sex, body-mass index, comorbidities, Charlson Comorbidity Index, ASA class, bowel preparation (oral laxatives and/or enema), and Nutritional Risk Screening 2002 (NRS-2002) score.

Stage 2: To evaluate the effect of timing of potassium supplementation (preoperative verus intraoperative) on clinical outcomes, propensity scores analysis was performed. Propensity scores were estimated by logistic regression with the following covariates: crystalloid volume, colloid volume, blood loss, urine output, vecuronium dose and type of surgery (gastric versus intestinal). These covariates were selected based on their potential to influence both the decision to supplement preoperatively and perioperative outcomes, while avoiding collider bias by excluding post-treatment variables.

Five matching algorithms (nearest-neighbor, full, subclassification, Mahalanobis distance, and cardinality) were compared. Covariate balance was assessed using the cobalt package in R, with absolute standardized mean differences (ASMD) < 0.1 considered adequate balance.

Full matching achieved the best balance and was retained for the primary analysis. ATT weights were generated, and weighted linear or logistic regression was used to estimate treatment effects with robust standard errors. Sensitivity analyses were performed with the remaining four algorithms.

All statistical tests were two-sided; $P < 0.05$ was considered statistically significant. Analyses were conducted with R version 4.3.1.

Results

Participants

Of 1,055 patients screened, 58 were excluded (42 missing preoperative potassium values, 8 eGFR <60 mL/min/1.73 m², 8 familial hypokalemic disorders), leaving 997 in the final analytic cohort. Preoperative hypokalemia was present in 419 (42.02%), of whom 417 (99.5% of hypokalemic patients) had mild-moderate and 2 (0.5%) had severe hypokalemia. Baseline characteristics of the overall cohort are presented in eTable 1.

Risk Factors for Preoperative Hypokalemia

After multivariable adjustment, only female sex was independently associated with hypokalemia (β = –0.11 mmol/L, 95% CI −0.15 to −0.06, *P* < 0.001). No other covariates reached statistical significance (all *P* ≥ 0.05). (Table 1)

Table 1 Multivariable linear regression of preoperative serum potassium concentration (n = 997)

Variable	β-coefficient	95% CI	*P*-value
(Intercept)	3.101	2.88-3.323	0.001
age	-0.001	-0.004-0.002	0.508
Sex male	0.105	0.064-0.146	0.001
BMI(kg. m^{-2})	0.003	-0.003-0.01	0.359
Comorbidity	-0.005	-0.056-0.046	0.84
Charlson Index	0.004	-0.012-0.019	0.657
ASA III-IV	-0.006	-0.054-0.043	0.825
Oral laxative	-0.004	-0.028-0.02	0.749
Enema	0.012	-0.008-0.032	0.226
Nutrition risk	-0.003	-0.05-0.044	0.907

CI, confidence interval; ASA, American Society of Anesthesiologists. BMI, body-mass index; NRS-2002, Nutritional Risk Screening 2002. The β-coefficient for male sex indicates that male patients had higher serum potassium concentrations compared with female patients, after adjustment for covariates.

Effect of Timing of Potassium Supplementation

After full matching, 804 patients who received preoperative supplementation and 193 who received intraoperative supplementation were compared. All absolute standardized mean differences were < 0.1, indicating adequate balance (Figure 1 and eTable 2) .

Preoperative optimization was associated with a 12-minute reduction in anesthesia time (β = –12.23 min, 95% CI –21.60 to –2.86, *P* = 0.011). No significant differences were observed in PACU stay (β = –1.00 min, *P* = 0.64), postoperative length of stay (β = –0.20 days, *P* = 0.78), 30-day complications (OR = 0.86, 95% CI 0.44–1.66, *P* = 0.65) or composite major adverse events (OR = 0.85, 95% CI 0.46–1.58, *P* = 0.61). (Table 2 and Table 3).

Table 2 Weighted linear regression results of preoperative potassium supplementation on continuous outcomes (weights derived from full-matching propensity scores, ATT estimand)

Outcome	Covariate	Effect (β)	95% CI	*P*-value
Anesthesia-time	(Intercept)	-48.851	(-71.331, -21.6)	<0.001
	K-supplement1	-12.228	(-21.6, -2.857)	0.011
	Surgery-intestinal	-12.813	(-23.748, -1.878)	0.023
	Crystal (per mL)	0.078	(0.064-0.092)	<0.001
	Colloid (per mL)	0.077	(0.063-0.091)	<0.001
	Blood (per mL)	0.013	(-0.004, 0.030)	0.143
	Urine (per mL)	0.030	(0.014, 0.046)	<0.001
	Vecuronium(mg)	9.714	(7.650, 11.777)	<0.001
PACU-time	(Intercept)	72.989	(63.138, 82.84)	<0.001
	K-supplement1	-0.996	(-5.211, 3.219)	0.644
	Surgery-intestinal	-6.003	(-10.597, -1.408)	0.011
	Crystal (per mL)	-0.002	(-0.007, 0.003)	0.525
	Colloid (per mL)	0.001	(-0.005, 0.007)	0.710
	Blood (per mL)	-0.009	(-0.015, -0.003)	0.002
	Urine (per mL)	0.005	(-0.002, 0.012)	0.143
	Vecuronium(mg)	0.636	(-0.021, 1.293)	0.059
Post-operative LOS	(Intercept)	2.245	(-0.992, 5.482)	0.176
	K-supplement1	-0.198	(-1.568, 1.172)	0.777
	Surgery-intestinal	-0.302	(-1.701, 1.097)	0.673
	Crystal (per mL)	0.001	(0.000, 0.002)	0.137
	Colloid (per mL)	0.003	(0.001, 0.005)	0.002
	Blood (per mL)	0.000	(-0.002, 0.002)	0.890
	Urine (per mL)	0.002	(0.000, 0.004)	0.138
	Vecuronium(mg)	0.337	(0.140, 0.533)	<0.001

LOS, length of stay; PACU, post-anaesthesia care unit.

Table 3 Weighted logistic regression results of preoperative potassium supplementation on binary outcomes (weights derived from full-matching propensity scores, ATT estimand)

Outcome	Covariate	OR	95% CI	*P*-value
Post-complications	(Intercept)	0.107	0.028-0.405	0.001
	K_supplement1	0.859	0.443- 1.663	0.652
	Surgery intestinal	0.904	0.549-1.487	0.691
	Crystal (per mL)	1.000	1.000-1.001	0.100
	Colloid (per mL)	1.001	1.000-1.001	0.072
	Blood (per mL)	1.000	1.000-1.001	0.250
	Urine (per mL)	1.000	0.999-1.001	0.758
	Vecuronium(mg)	0.998	0.913-1.092	0.972
Post-adverse	(Intercept)	0.098	0.027-0.358	0.001
	K_supplement1	0.850	0.456-1.584	0.609
	Surgery intestinal	1.024	0.622-1.686	0.927
	Crystal (per mL)	1.000	1.000-1.001	0.061
	Colloid (per mL)	1.000	1.000-1.001	0.126
	Blood (per mL)	1.000	1.000-1.001	0.204
	Urine (per mL)	1.000	0.999-1.001	0.967
	Vecuronium(mg)	1.003	0.921-1.091	0.954

Composite adverse event = Post-complications, death, ICU admission, or 30-day readmission.

Sensitivity analyses using the four alternative matching algorithms produced consistent results. Preoperative supplementation was associated with significantly shorter anesthesia time across all methods (nearest-neighbor: β = −11.76 min, *P* = 0.103; subclassification: β = −7.88 min, *P* = NA; Mahalanobis distance: β = −7.23 min, *P* = 0.031; cardinality: β = −10.46 min, *P* = 0.061). No algorithm produced significant effects on PACU stay, postoperative length of stay, or complications (all *P* > 0.05) (eTable 3) .

Discussion

Principal Findings and Comparison with Previous Studies

In this large, single-center, retrospective cohort of middle-aged and elderly patients undergoing elective gastrointestinal tumor surgery, we observed a high prevalence of preoperative hypokalemia (42.02%). This figure is consistent with GI-specific reports (≈ 70%),[9] but substantially higher than that described in

general medical–surgical populations (2.6–23%).[10, 18] The discrepancy likely reflects the combination of age-related physiological changes and GI-specific potassium losses (vomiting, diarrhea, bowel preparation).

On multivariable analysis, female sex was the only independently associated with hypokalemia (β = 0.11 mmol/L, 95% CI 0.06–0.15, $P < 0.001$), a finding that aligns with previous reports.[18–20] Proposed, but unconfirmed, mechanisms include smaller total-body potassium stores secondary to reduced muscle mass and estrogen-mediated enhancement of ATP-sensitive potassium-channel activity, which may facilitate intracellular potassium shifts.[21, 22]

Contrary to historical data,[9, 16, 23–25] neither oral bowel lavage nor enema was significantly associated with preoperative hypokalemia after adjustment for confounders ($P = 0.749$ and $P = 0.226$, respectively). This absence of association might, at least in part, reflect our institutional practice of simultaneous electrolyte monitoring and selective supplementation during bowel preparation;[26, 27] residual or unmeasured confounding cannot be excluded.

Using propensity-score-matched average treatment effect on the treated (PSM-ATT) analysis, preoperative potassium supplementation showed no significant effect on duration of post-anesthesia care unit (PACU) stay, postoperative length of stay, 30-day morbidity, or composite major adverse events. However, supplementation was associated with a 12-minute reduction in anesthesia time (β = − 12.2 min, 95% CI − 21.6 to − 2.9). While statistically modest, this reduction represents a clinically meaningful efficiency gain in high-volume surgical centers; assuming 4–6 elective GI procedures per operating room per day, a 12-minute reduction per case could translate to 48–72 minutes of additional operative capacity daily, potentially accommodating one additional procedure or reducing overtime costs.[28] These results diverge from some reports that abnormal preoperative serum potassium levels are associated with adverse postoperative outcomes in patients undergoing surgery;[13–15, 26, 29–32] however, several recent cohorts[25–27, 33] have reported similarly null effects on hard endpoints. Nevertheless, these findings warrant cautious interpretation.

First, the vast majority of hypokalemia was mild–moderate (severe hypokalemia < 2.5 mmol/L, 0.5%), limiting statistical power to detect clinically relevant recovery differences. Second, enhanced recovery after surgery (ERAS) protocols at our institution standardize extubation and discharge criteria, potentially attenuating any marginal benefits of isolated potassium optimization. Third, delayed discharge is multifactorial, influenced by factors such as pain control, return of bowel function, and social support, with hypokalemia representing only one component. Finally, the observed anesthesia time reduction may translate into improved operating-room throughput without compromising patient safety, though this warrants prospective validation.

Clinical implications

Preoperative potassium screening may be considered with greater priority in female and older patients. For hemodynamically stable patients with mild-to-moderate hypokalemia alone may not have warranted

delaying surgery; electrolyte-monitored intraoperative supplementation offers an alternative that preserves scheduled workflow while maintaining physiological surveillance. Severe hypokalemia remains rare and requires individual risk–benefit assessment; our findings should not be interpreted as endorsing intraoperative supplementation for severe hypokalemia, where the risks of arrhythmia and hemodynamic instability remain substantial.

Limitations

This single-center, retrospective study can demonstrate associations but cannot establish causality. Despite propensity-score weighting, residual confounding may persist from unmeasured factors such as surgeon experience, intraoperative electrolyte monitoring frequency, dynamic preoperative potassium fluctuations, and discharge practices. The cohort was restricted to elective gastrointestinal tumor resections in patients ≥ 45 years with preserved renal function; results may not generalize to emergency surgery or those with significant renal impairment. Most hypokalemia was mild–moderate (severe < 2.5 mmol/L: n = 2, 0.5%), so the sample contained few severe cases, limiting power to detect outcome differences at lower potassium thresholds. Fourth, we acknowledge that the lack of predefined age-subgroup analysis (e.g., < 75 versus ≥ 75 years) is a limitation of our study design; pooling patients aged 45–54 years with those ≥ 75 years may mask age-specific effects. We agree that further work with larger cohorts and predefined age subgroups (e.g., 45–54, 55–64, 65–74, ≥ 75 years) would be valuable. Finally, center-specific ERAS protocols and anesthetic routines could attenuate external validity

Conclusion

In this retrospective cohort of middle-aged and older patients undergoing elective GI tumor resection, preoperative hypokalemia occurred in 42% and female sex was independently associated with preoperative hypokalemia. Preoperative supplementation of mild-to-moderate hypokalemia was associated with a median 12-minute reduction in anesthesia time, but showed no difference in short-term recovery or morbidity. On the basis of these observational data, surgical delay solely for mild-to-moderate hypokalemia may not be required in otherwise hemodynamically stable patients, favoring intraoperative electrolyte monitoring and selective supplementation. Severe hypokalemia remains rare and requires individualized risk–benefit assessment.

Declarations

Competing interests: The authors declare that they have no competing interests.

Funding: The authors received no funding for this work.

Ethics approval and consent to participate : This study was approved by the Institutional Review Board of The First Affiliated Hospital of Chongqing Medical University (approval No. K2023-258) and registered at the Chinese Clinical Trial Registry (registration No. ChiCTR2600116173, registration date: 2026-01-06). The study was conducted in accordance with the Declaration of Helsinki. Due to the retrospective nature

of the study and the use of de-identified electronic medical record data, the requirement for written informed consent was waived by the Institutional Review Board.

Clinical trial number: not applicable.

Consent for publication: Not applicable. This manuscript does not contain any individual person's identifiable data, images, or videos.

Availability of data and materials: Due to patient privacy protection regulations, raw clinical data cannot be publicly shared. Anonymized aggregated data can be obtained from the corresponding author upon reasonable request.

Competing interests The authors declare that they have no competing interests.

Funding The authors received no funding for this work.

Authors' contributions: Bangshu Zhao: Data curation, Formal analysis, Investigation, Methodology, Writing-original draft (co-first author). **Qian Wu**: Data curation, Investgation, Methodology, Validation, Writing-original draft (co-first author). **Fusen Huang**: Investigation, Resources, Validation. **Qiuju Xiong**: Investigation, Resources, Data curation. **Dan Liu**: Investigation, Resources, Validation. **Qunying Wang**: Conceptualization, Project administration, Resources, Supervision, Writing – review and editing (**Corresponding author).**

† **Bangshu Zhao** and **Qian Wu** contributed equally to this work and are co-first authors.

Acknowledgements: The authors have no acknowledgments to declare.

Submission declaration: We confirm that this manuscript is original, has not been published previously, and is not under consideration elsewhere. All authors have approved the manuscript and agree with its submission to BMC Gastroenterology. If accepted, the article will not be published elsewhere in the same form, in English or in any other language, without the written consent of the copyright-holder.

Declaration of generative AI and AI-assisted technologies: During the preparation of this work, the authors used AI-assisted language editing tools to improve readability, assist with translation, and provide formatting suggestions. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

References

1. Kardalas E, Paschou SA, Anagnostis P, Muscogiuri G, Siasos G, Vryonidou A. Hypokalemia: a clinical update. Endocr Connect Apr. 2018;7(4):R135–46. 10.1530/ec-18-0109.
2. Sumida K, Biruete A, Kistler BM. e. New Insights Into Dietary Approaches to Potassium Management in Chronic Kidney Disease. J Ren Nutr. 2023;33(6s):S6–12. 10.1053/j.jrn.2022.12.003.

3. McDonough AA, Youn JH. Potassium Homeostasis: The Knowns, the Unknowns, and the Health Benefits. Physiology (Bethesda) Mar. 2017;32(2):100–11. 10.1152/physiol.00022.2016.
4. Krogager ML, Kragholm K, Thomassen JQ, et al. Update on management of hypokalaemia and goals for the lower potassium level in patients with cardiovascular disease: a review in collaboration with the European Society of Cardiology Working Group on Cardiovascular Pharmacotherapy. Eur Heart J Cardiovasc Pharmacother Nov. 2021;3(6):557–67. 10.1093/ehjcvp/pvab038.
5. Kovesdy CP, Matsushita K, Sang Y, et al. Serum potassium and adverse outcomes across the range of kidney function: a CKD Prognosis Consortium meta-analysis. Eur Heart J May. 2018;1(17):1535–42. 10.1093/eurheartj/ehy100.
6. Alfonzo AV, Isles C, Geddes C, Deighan C. Potassium disorders–clinical spectrum and emergency management. Resuscitation Jul. 2006;70(1):10–25. 10.1016/j.resuscitation.2005.11.002.
7. Palmer BF, Clegg DJ. Physiology and Pathophysiology of Potassium Homeostasis: Core Curriculum 2019. Am J Kidney Dis Nov. 2019;74(5):682–95. 10.1053/j.ajkd.2019.03.427.
8. Bowling CB, Pitt B, Ahmed MI, et al. Hypokalemia and outcomes in patients with chronic heart failure and chronic kidney disease: findings from propensity-matched studies. Circ Heart Fail Mar. 2010;3(2):253–60. 10.1161/circheartfailure.109.899526.
9. Zhu Q, Li X, Tan F, et al. Prevalence and risk factors for hypokalemia in patients scheduled for laparoscopic colorectal resection and its association with post-operative recovery. BMC Gastroenterol. 2018;18(1):152. 10.1186/s12876-018-0876-x.
10. Greco A, Rabito G, Pironi M, et al. Hypokalaemia in hospitalised patients. Swiss Med Wkly. 2016;146:w14320. 10.4414/smw.2016.14320.
11. Nilsson E, Gasparini A, Ärnlöv J, et al. Incidence and determinants of hyperkalemia and hypokalemia in a large healthcare system. Int J Cardiol Oct. 2017;15:245:277–84. 10.1016/j.ijcard.2017.07.035.
12. Flynn MA, Nolph GB, Baker AS, Martin WM, Krause G. Total body potassium in aging humans: a longitudinal study. Am J Clin Nutr Oct. 1989;50(4):713–7. 10.1093/ajcn/50.4.713.
13. Arora P, Pourafkari L, Visnjevac O, Anand EJ, Porhomayon J, Nader ND. Preoperative serum potassium predicts the clinical outcome after non-cardiac surgery. Clin Chem Lab Med. Jan 2017;1(1):145–53. 10.1515/cclm-2016-0038.
14. Lu G, Xu L, Zhong Y, Shi P, Shen X. Significance of serum potassium level monitoring during the course of post-operative rehabilitation in patients with hypokalemia. World J Surg Apr. 2014;38(4):790–4. 10.1007/s00268-013-2319-8.
15. Yang M, Li Q, Zhou Y, et al. Risk factors for hypokalemia and its association with postoperative recovery in patients scheduled for radical gastrectomy: a retrospective study. BMC Anesthesiol Aug. 2023;22(1):285. 10.1186/s12871-023-02246-2.
16. Reumkens A, Masclee AA, Winkens B, van Deursen CT, Sanduleanu S, Bakker CM. Prevalence of hypokalemia before and after bowel preparation for colonoscopy in high-risk patients. Gastrointest Endosc Oct. 2017;86(4):673–9. 10.1016/j.gie.2017.01.040.

17. Heidari S, Babor TF, De Castro P, Tort S, Curno M. Sex and Gender Equity in Research: rationale for the SAGER guidelines and recommended use. Res Integr Peer Rev. 2016;1:2. 10.1186/s41073-016-0007-6.
18. Sun H, Weaver CM. Rising Trend of Hypokalemia Prevalence in the US Population and Possible Food Causes. J Am Coll Nutr Mar-Apr. 2021;40(3):273–9. 10.1080/07315724.2020.1765893.
19. Sagild U. Total exchangeable potassium in normal subjects with special reference to changes with age. Scand J Clin Lab Invest. 1956;8(1):44–50. 10.3109/00365515609049242.
20. Bardak S, Turgutalp K, Koyuncu MB, et al. Community-acquired hypokalemia in elderly patients: related factors and clinical outcomes. Int Urol Nephrol Mar. 2017;49(3):483–9. 10.1007/s11255-016-1489-3.
21. Rodenburg EM, Stricker BH, Visser LE. Sex-related differences in hospital admissions attributed to adverse drug reactions in the Netherlands. Br J Clin Pharmacol Jan. 2011;71(1):95–104. 10.1111/j.1365-2125.2010.03811.x.
22. Webb C, Collins P. Estrogen and adenosine triphosphate-sensitive potassium channels. *Circulation*. Jun 24. 2003;107(24):e221; author reply e221. 10.1161/01.Cir.0000077524.24975.02
23. Bilotta F, Giovannini F, Aghilone F, et al. Potassium sparing diuretics as adjunct to mannitol therapy in neurocritical care patients with cerebral edema: effects on potassium homeostasis and cardiac arrhythmias. Neurocrit Care Apr. 2012;16(2):280–5. 10.1007/s12028-011-9652-2.
24. Ho JM, Juurlink DN, Cavalcanti RB. Hypokalemia following polyethylene glycol-based bowel preparation for colonoscopy in older hospitalized patients with significant comorbidities. Ann Pharmacother Mar. 2010;44(3):466–70. 10.1345/aph.1M341.
25. Wang BB, Hu L, Hu XY, Han D, Wu J. Risk Factors Asscociated with Hypokalemia during Postanesthesia Recovery and Its Impact on Outcomes in Gynecological Patients: A Propensity Score Matching Study. Curr Med Sci Apr. 2024;44(2):441–9. 10.1007/s11596-024-2848-4.
26. Chu T, Wu Z, Xu A. Association between preoperative hypokalemia and postoperative complications in elderly patients: a retrospective study. BMC Geriatr Sep. 2022;12(1):743. 10.1186/s12877-022-03445-1.
27. Sédaba B, Azanza JR, Campanero MA, Garcia-Quetglas E, Muñoz MJ, Marco S. Effects of a 250-mL enema containing sodium phosphate on electrolyte concentrations in healthy volunteers: An open-label, randomized, controlled, two-period, crossover clinical trial. Curr Ther Res Clin Exp Sep. 2006;67(5):334–49. 10.1016/j.curtheres.2006.10.004.
28. Macario A. What does one minute of operating room time cost? J Clin Anesth Jun. 2010;22(4):233–6. 10.1016/j.jclinane.2010.02.003.
29. Ebrahim M, Larsen PB, Hannani D, Liest S, Jorgensen LN, Jorgensen HL. Preoperative risk factors including serum levels of potassium, sodium, and creatinine for early mortality after open abdominal surgery: a retrospective cohort study. BMC Surg Jan. 2021;26(1):62. 10.1186/s12893-021-01070-0.
30. Ranti D, Mikhail CM, Ranson W, et al. Risk Factors for 90-day Readmissions With Fluid and Electrolyte Disorders Following Posterior Lumbar Fusion. Spine (Phila Pa 1976) Jun.

2020;15(12):E704–12. 10.1097/BRS.0000000000003412.

31. Borgmann H, Kamal MM, Metzger A, et al. High-Normal Preoperative Potassium Level Is Associated with Reduced 30-Day Morbidity and Shorter Hospital Stay after Radical Cystectomy. J Clin Med Feb. 2022;22(5). 10.3390/jcm11051174.
32. Han W, Gao C, Zhao R. The silent potassium avalanche: unchecking preoperative hypokalemia leading to perioperative cardiac arrest in an insulin-treated diabetic patient undergoing a Whipple procedure: a case report. BMC Anesthesiol Nov. 2025;28(1):596. 10.1186/s12871-025-03481-5.
33. Cihoric M, Kehlet H, Lauritsen ML, Hojlund J, Foss NB. Electrolyte and Acid-Base Disturbances in Emergency High-Risk Abdominal Surgery, a Retrospective Study. World J Surg Jun. 2022;46(6):1325–35. 10.1007/s00268-022-06499-9.

Figures

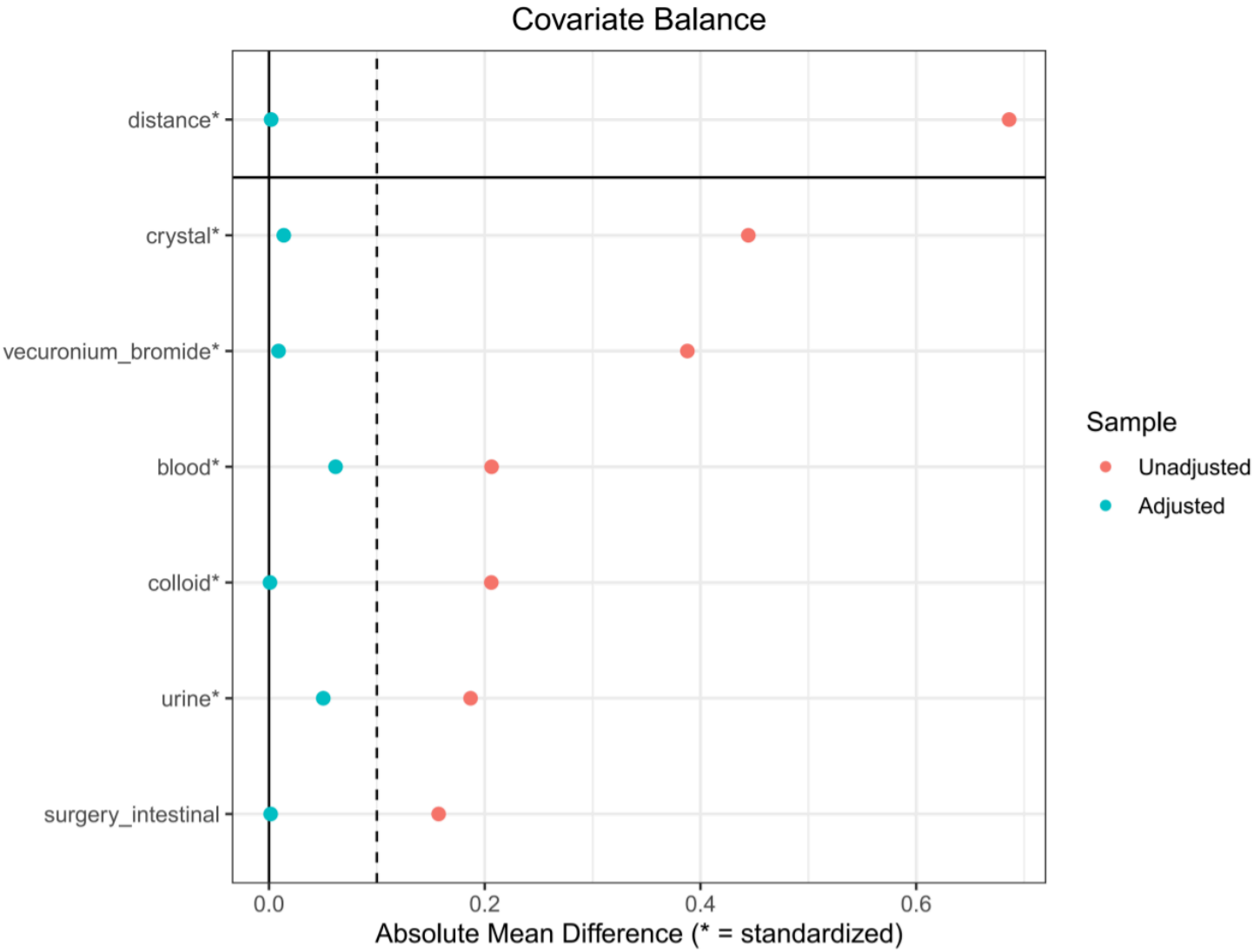


Figure 1

Covariate balance before and after full-matching.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- eTable13.docx