International Journal of General Medicine

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Preoperative Hypoalbuminemia, Functional Dependence, and Intraoperative Infusion Volume Associated with Postoperative Urinary Retention After Elective Spinal Surgery

Kai-Li Hu[1,2], Meng-Juan Yan[1,2], Wen Long[1,2], Xiao-Li Guan[1,2,*], Yi Gao[3,*]

[1]Department of Nursing, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China; [2]School of Nursing, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China; [3]Department of Thoracic Surgery, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China

*These authors contributed equally to this work

Correspondence: Yi Gao, Department of Thoracic Surgery, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China, Email gaoyi1990@aliyun.com; Xiao-Li Guan, Department of Nursing, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, Hubei, People's Republic of China, Email xiaoli_guan@126.com

Purpose: To investigate the prevalence and preoperative and intraoperative risk factors associated with postoperative urinary retention (POUR) in patients undergoing elective spinal surgery.

Methods: A cross-sectional, descriptive-analytical study was conducted at a tertiary hospital in China between October and November 2025. A total of 177 adult patients undergoing elective cervical, lumbar, or scoliosis surgery with planned postoperative catheter removal were included. Data collected included demographic and clinical characteristics. Univariate and multiple logistic regression analyses were performed to examine associations between preoperative factors and POUR.

Results: POUR occurred in 14.7% of patients. Multiple analysis identified three independent risk factors for POUR: intraoperative infusion volume exceeding 2000 mL (OR = 6.714, 95% CI: 1.980–22.764, P = 0.002), lower preoperative Barthel Index scores (OR = 0.379, 95% CI: 0.243–0.590, P < 0.001), and lower preoperative serum albumin levels (OR = 0.086, 95% CI: 0.008–0.881, P = 0.039).

Conclusion: Higher intraoperative fluid administration, lower functional status, and preoperative hypoalbuminemia are significant risk factors for POUR following spinal surgery. These findings provide a basis for future research aimed at developing predictive tools and targeted perioperative strategies to identify and manage patients at risk for POUR.

Keywords: postoperative urinary retention, spinal surgery, intraoperative fluid management, hypoalbuminemia, barthel index, risk factors

Introduction

Postoperative urinary retention (POUR) is a common complication following spinal surgery, defined according to previous literature as reinsertion of a Foley catheter based on retention urine volume > 400 mL, or requiring straight catheterization for urine volumes > 400 mL.[1,2] A meta-analysis involving over 30,000 patients reported a pooled POUR incidence of 15.1% following elective spine surgery.[3] This condition extends beyond transient discomfort, causing significant patient distress and frequently necessitating bladder catheterization.[4] Unplanned catheterization, particularly in the elderly, increases the risk of complications including delirium, urethral trauma, and infection,[5] along with other serious potential sequelae such as sepsis, bladder overdistension, acute kidney injury, surgical site infections, and venous thromboembolism.[6,7] POUR drives a cascade of adverse outcomes including prolonged hospital stays, increased patient morbidity, and substantial healthcare expenditures, imposing an estimated annual financial burden of $400–450 million in

https://doi.org/10.2147/IJGM.S592233
Received: 18 January 2026
Accepted: 26 February 2026
Published: 3 March 2026

the United States alone.[4,8,9] Consequently, POUR significantly diminishes the quality of postoperative recovery and impairs patient satisfaction.[10]

In recent years, research on POUR after spinal surgery has advanced considerably. With regard to study populations, although evidence spans all age groups and surgical types, research has predominantly focused on patients undergoing lumbar procedures, particularly older adults.[11–13] Older patients with multiple comorbidities, such as hypertension, osteoporosis, benign prostatic hyperplasia, and diabetes, have a POUR prevalence more than twice that of younger individuals.[11,12,14] Numerous risk factors for POUR have been reported, including demographic characteristics, comorbid conditions, and perioperative management variables. A large-scale meta-analysis has confirmed male sex, advanced age, benign prostatic hyperplasia (BPH), and diabetes as major risk factors for POUR, while also quantifying the impact of modifiable variables such as intraoperative fluid administration over 1700 mL and operative duration over 180 minutes.[11] Tian et al[15] developed a predictive nomogram incorporating variables including age and smoking history, enabling individualized risk stratification for POUR. Furthermore, Jasinski et al,[12] through a prospective quality improvement project, demonstrated that a bundled intervention, including standardized intraoperative catheterization, postoperative prophylactic medication, and early ambulation, significantly reduced the incidence of POUR. Methodologically, the field has relied on large-scale retrospective cohorts to identify variable associations, meta-analyses to synthesize multicenter evidence, and prospective studies to validate key findings.[3,11,12] Despite these advances, existing evidence has largely examined these factors in isolation, and a comprehensive evaluation of both baseline physiological status and intraoperative management variables within the same analytic framework remains limited.

While prior research has identified numerous risk factors for POUR, further clarification of perioperative patient characteristics may be important for guiding individualized management and improving postoperative outcomes. Optimizing preoperative patient status is increasingly recognized as a key strategy in spinal surgery, and the concept of “prehabilitation” provides an evidence-informed framework to enhance physiological and functional reserves before surgery, potentially improving tolerance to surgical stress and supporting recovery.[16,17] In addition to patient-related characteristics, intraoperative management also represents a critical component of the perioperative risk profile for POUR. Surgical duration, anesthetic exposure, and intraoperative fluid administration may influence bladder function through mechanisms such as autonomic imbalance, detrusor overdistension, and postoperative inflammatory responses.[18] Within this context, systematic assessment and optimization of modifiable factors across the perioperative period, together with efforts to minimize surgical stress, may play a role in reducing perioperative complications and informing individualized care.[19] By considering patients’ overall perioperative condition, clinicians may better identify individuals at higher risk of POUR and implement targeted interventions to support surgical efficacy and recovery.

Building on the recognition that both baseline patient characteristics and perioperative management may influence postoperative outcomes, this study aims to investigate the prevalence of POUR and to examine preoperative and intraoperative factors associated with its occurrence following elective spinal surgery. By identifying potentially modifiable physiological, functional, and intraoperative variables, the findings may contribute to improved risk stratification and inform individualized perioperative management strategies for patients undergoing spinal procedures.

Materials and Methods

This study employed a cross-sectional, descriptive-analytical design conducted between October and November 2025. A convenience sampling approach was adopted, and data were collected through face-to-face interviews using a paper-based questionnaire administered by experienced nurses. The study was carried out in the spinal surgery department of a tertiary hospital in China, with the participation of 15 nurses and 6 physicians.

All patients who underwent spinal surgery during this period were screened for eligibility. Inclusion criteria were as follows: (1) age ≥ 18 years; (2) elective cervical, lumbar, or scoliosis surgery; (3) postoperative indwelling urinary catheter placement with planned removal during hospitalization; and (4) ability to comprehend the study objectives, provide informed consent, and independently complete the questionnaire. Exclusion criteria were as follows: (1) preexisting urinary tract or bladder diseases (eg, benign prostatic hyperplasia, bladder dysfunction, or other urological disorders); (2) severe paraplegia or quadriplegia requiring long-term catheterization; and (3) severe psychiatric or cognitive impairment that could interfere with study participation. The primary outcome was postoperative urinary retention (POUR), defined as the need for at least one intermittent catheterization due to inability to void adequately.[20]

The required sample size was calculated using G*Power version 3.1.9.6 (Heinrich Heine University, Düsseldorf, Germany). Previous studies have reported that the incidence of postoperative urinary retention (POUR) following elective posterior lumbar spine surgery is approximately 16.5%.[21] The analysis was based on the "Logistic regression: fixed model, single regression coefficient" option within the z tests family. An a priori power analysis for logistic regression was performed with the following assumptions: a two-sided significance level (α) of 0.05, statistical power (1 −β) of 0.85, an expected outcome proportion of 0.165, and an anticipated odds ratio of 2.0 for the primary predictor. Under these conditions, the minimum required sample size was calculated to be 143. To account for potential non-response or missing data, the sample size was increased by 10%, yielding a final target of 172 participants.

Instruments

Basic characteristics included patients' demographic and clinical data. Demographic data comprised age, gender, education level, body mass index (BMI), disease location, history of underlying diseases (diabetes, hypertension, coronary heart disease), smoking history, and drinking history. Clinical data included the preoperative activities of daily living (ADL) score, white blood cell (WBC) count, hemoglobin (Hb) level, albumin (ALB) level, urinary white blood cell count, intraoperative infusion volume, operative duration, intraoperative blood loss and use of a patient-controlled analgesia (PCA) pump.

The Barthel Index (BI) was used to evaluate patients' ADL and functional independence. It is one of the most widely used instruments in clinical practice.[22] The BI comprises 10 items: feeding, bathing, grooming, dressing, bowel control, bladder control, toilet use, transfers (bed to chair and back), mobility on level surfaces, and stairs.[23] Each item is rated on a four-level scale, yielding a total score ranging from 0 to 100 in increments of 5, where higher scores indicate greater independence in daily activities. According to the original scoring criteria, functional impairment is classified into five categories: total dependence (BI score 0–20), severe (BI score 21–60), moderate (BI score 61–90), mild (BI score 91–99), and total independence (BI score 100). Trained nurses assessed the BI scores upon patients' hospital admission.

Data Collection

Demographic data and data related to POUR were collected through face-to-face interviews using a structured questionnaire administered by trained nurses and entered into the electronic medical records (EMR) in accordance with institutional protocols. Operative data were extracted from the electronic medical record by trained study personnel following a standardized protocol developed by the research team to ensure accuracy and completeness. Two researchers independently performed data extraction, and any discrepancies were resolved through discussion and verification against the original records. The finalized dataset was reviewed by a senior investigator prior to analysis.

Statistical Analysis

Statistical analyses of the data were performed using SPSS version 29.0. The normal distribution of continuous variables was examined with the Kolmogorov–Smirnov test. Continuous quantitative variables that exhibited a normal distribution were expressed as the mean ± standard deviation, with intergroup differences evaluated through one-way analysis of variance (ANOVA). For categorical variables, intergroup comparisons were conducted using chi-square test. Multiple logistic regression models were employed to examine the influence of various indicators on POUR. Variables with $P < 0.05$ in univariate analysis were entered into the multiple logistic regression model. A significance threshold of $\alpha = 0.05$ was established for all statistical tests.

Results

A total of 177 patients met the inclusion criteria and completed the survey. The demographic characteristics of the study sample are presented in Table 1. The prevalence of POUR was 14.7% (95% CI: 10.2–19.8%). Univariate analysis showed that the Barthel Index, preoperative serum albumin level, and intraoperative infusion volume were significantly associated with POUR (P<0.05) in Table 1. These variables were subsequently entered into the multiple logistic

Table 1 Demographic Characteristics of Participants

Variables	Total (N=177)		No POUR (N=151)		POUR (N=26)		χ^2	*P*
	N	%	N	%	N	%		
Gender							1.251	0.263
Male	91	51.4	75	49.7	16	61.5		
Female	86	48.6	76	50.3	10	38.5		
Disease location							3.865	0.276
Cervical vertebrae	60	33.9	55	36.4	5	19.2		
Thoracic vertebrae	9	5.1	8	5.3	1	3.8		
Lumbar vertebrae	74	41.8	59	39.1	15	57.7		
Scoliosis	34	19.2	29	19.2	5	19.2		
Education							1.970	0.741
Illiteracy	6	3.4	5	3.3	1	3.8		
Primary	27	15.3	23	15.2	4	15.4		
Junior secondary	72	40.7	63	41.7	9	34.6		
Senior secondary	50	28.2	40	26.5	10	38.5		
Post-secondary and above	22	12.4	20	13.2	2	7.7		
Smoking							0.668	0.414
Yes	37	20.9	30	19.9	7	26.9		
No	140	79.1	121	80.1	19	73.1		
Drinking							0.022	0.881
Yes	22	12.4	19	12.6	3	11.5		
No	155	87.6	132	87.4	23	88.5		
Hypertension							0.019	0.890
Yes	39	22.0	33	21.9	6	23.1		
No	138	78.0	118	78.1	20	76.9		
Diabetes							0.001	0.975
Yes	7	4.0	6	4.0	1	3.8		
No	170	96.0	145	96.0	25	96.2		
Coronary heart disease							1.983	0.159
Yes	10	5.6	7	4.6	3	11.5		
No	167	94.4	144	95.4	23	88.5		
Barthel Index							42.701	<0.001
Total dependence	8	4.5	2	1.3	6	23.1		
Severe dependence	11	6.2	8	5.3	3	11.5		
Moderate dependence	13	7.3	8	5.3	5	19.2		
Mild dependence	22	12.4	16	10.6	6	23.1		
Total Independence	123	69.5	117	77.5	6	23.1		
WBC (*10^9/L)							1.104	0.576
<4	16	9.0	13	8.6	3	11.5		
4~10	148	83.6	128	84.8	20	76.9		
>10	13	7.3	10	6.6	3	11.5		
Hb (g/dL)							3.934	0.269
>110	164	92.7	140	92.7	24	92.3		
90~110	7	4.0	7	4.6	0	0		
60~90	5	2.8	3	2.0	2	7.7		
<60	1	0.6	1	0.7	0	0		
ALB (g/L)							29.339	<0.001
≤35	7	4.0	1	0.7	6	23.1		
>35	170	96.0	150	99.3	20	76.9		

(*Continued*)

Table 1 (Continued).

Variables	Total (N=177)		No POUR (N=151)		POUR (N=26)		χ^2	*P*
	N	%	N	%	N	%		
Urinary WBC							1.430	0.699
None	136	76.8	114	75.5	22	84.6		
+	26	14.7	24	15.9	2	7.7		
++	14	7.9	12	7.9	2	7.7		
+++	1	0.6	1	0.7	0	0		
Intraoperative infusion volume (mL)							5.426	0.020
≤2000	111	62.7	100	66.2	11	42.3		
>2000	66	37.3	51	33.8	15	57.7		
Operative duration (h)							0.138	0.933
≤3	24	13.6	21	13.9	3	11.5		
3~5	104	58.8	88	58.3	16	61.5		
>5	49	27.7	42	27.8	7	26.9		
Intraoperative blood loss (mL)							3.127	0.209
0	146	82.5	125	82.8	21	80.8		
≤500	21	11.9	16	10.6	5	19.2		
>500	10	5.6	10	6.6	0	0		
PCA							0.178	0.673
Yes	102	57.6	88	58.3	14	53.8		
No	75	42.4	63	41.7	12	46.2		
	Mean	**SD**	**Mean**	**SD**	**Mean**	SD	*T/Z*	*P*
Age (years)	45.64	19.14	44.74	19.11	50.88	18.80	−1.693[a]	0.090
BMI (kg/m^2)	22.61	3.76	22.59	3.80	22.76	3.63	−0.215	0.830

Notes: [a]mann–Whitney *U*-test; Bold values: P<0.05.
Abbreviation: SD, standard deviation.

regression model. In the multiple analysis, patients who received more than 2000 mL of intraoperative infusion had an independently increased risk of developing POUR compared with those who received 2000 mL or less (OR = 6.714, 95% CI: 1.980–22.764, P = 0.002). Furthermore, lower Barthel Index scores (OR = 0.379, 95% CI: 0.243–0.590, P < 0.001) and lower preoperative serum albumin levels (OR = 0.086, 95% CI: 0.008–0.881, P = 0.039) were also independently associated with a higher risk of POUR (Table 2).

Discussions

In this study of 177 patients, the prevalence of POUR was 14.7%, which aligns closely with the 15.1% rate reported in a prior meta-analysis of elective spine surgery patients.[3] More importantly, we identified preoperative hypoalbuminemia, a lower Barthel Index reflecting impaired activities of daily living and functional independence, and a higher

Table 2 Independent Correlates of POUR According to Multiple Logistic Regression Analysis

Variables	Multiple Logistic Regression Analysis		
	OR	95% CI	*P* value
Intraoperative infusion volume	6.714	1.980~22.764	0.002
Barthel Index	0.379	0.243~0.590	<0.001
ALB	0.086	0.008~0.881	0.039

Abbreviations: CI, confidence interval; OR, odds ratio.

https://doi.org/10.2147/IJGM.S592233

intraoperative infusion volume as independent risk factors for POUR in patients following spinal surgery. These findings effectively broaden the conventional risk assessment framework for POUR beyond demographic factors by incorporating indicators of systemic nutritional status, baseline physiological reserve, and intraoperative management, thereby offering a more holistic perspective for early identification of high-risk patients.

Findings from this study and previous reports indicate that intraoperative fluid management plays a key role in the development of POUR (OR=6.714). Patients who received more than 2000 mL of intraoperative fluids were at significantly higher risk of developing POUR following lumbar spine surgery. This finding is consistent with prior work.[24] Aiyer et al[21] identified intraoperative fluid administration as a significant risk factor for POUR ($p < 0.05$). In addition, perioperative fluid volumes exceeding 1000 mL have been reported to be associated with higher rates of urinary retention.[11] These mechanisms may include bladder overdistension, which can temporarily impair detrusor contractility, as well as tissue and pelvic edema that may hinder early postoperative mobility and reduce effective bladder emptying. These findings highlight the importance of careful, individualized fluid management during spinal surgery to minimize the risk of POUR. A goal-directed approach can help maintain hemodynamic stability while avoiding excessive fluid administration. Several studies suggest that goal-directed fluid therapy (GDFT) provides an effective framework for optimizing intravascular volume in patients undergoing major surgery.[25] GDFT involves adjusting perioperative fluid administration to prevent fluid overload, organ hypoperfusion, hypoxia, and hypovolemia.[26] Implementing GDFT during spinal procedures may therefore reduce complications such as POUR while supporting overall perioperative safety and recovery.

In addition, this study provides direct evidence that preoperative hypoalbuminemia is an independent risk factor for POUR, refining the established understanding of how nutritional status influences outcomes following spinal surgery.[27,28] These results are consistent with the large-scale registry analysis by Chaker et al,[29] who reported a broad association between hypoalbuminemia and various postoperative complications. However, this study analysis specifically establishes this relationship for POUR. Furthermore, while Zhao et al[13] established the predictive utility of the Geriatric Nutritional Risk Index (GNRI)-a composite score incorporating albumin-our findings extend beyond such integrative measures by demonstrating a clear, independent relationship between preoperative serum albumin levels and POUR risk. These findings suggest that preoperative serum albumin may serve as a practical and clinically accessible biomarker for assessing POUR risk, which may enhance its applicability across diverse clinical settings. The pathophysiological pathways linking hypoalbuminemia to POUR are likely multifactorial. As a marker of malnutrition and systemic inflammation, hypoalbuminemia may not only impair tissue repair and immune function but could also compromise the integrity of the autonomic nervous system, leading to diminished detrusor contractility and impaired bladder sensation.[13,30] In parallel, this study found that impaired baseline functional status, as indicated by a low Barthel Index, is a significant risk factor for POUR. The consistency of this association across diverse surgical populations suggests that preoperative functional dependence may serve as a universal determinant of postoperative voiding dysfunction.[31] The underlying mechanism likely involves the frailty and sarcopenia often associated with functional dependence, which directly impede early postoperative mobilization and the ability to assume physiologically optimal voiding positions, thereby mechanically compromising bladder emptying.[32,33] Collectively, hypoalbuminemia and low BI emerge as complementary biomarkers of physiological reserve, whose deficiency predisposes patients to POUR.

Therefore, an integrated and multimodal pre-habilitation strategy targeting these risk factors is warranted. For nutritional optimization, this research's findings strongly support adherence to established guidelines such as those from the European Society for Clinical Nutrition and Metabolism (ESPEN),[34] which should be implemented through structured nutritional assessment and individualized supplementation for hypoalbuminemia patients, with consideration given to delaying non-urgent surgery for 7–14 days when clinically indicated. Concurrently, the functional domain must be addressed with equal rigor. Sun et al[35] provides critical evidence for this, demonstrating that a higher Barthel Index (BI) at discharge was directly associated with superior self-care ability and functional independence after lumbar fusion. This underscores the BI as a modifiable therapeutic target, thereby supporting the implementation of targeted rehabilitation programs designed to actively improve functional capacity in patients with identified deficits. This comprehensive preoperative optimization reflects the systematic approach advocated by Smith et al[36] in their Enhanced Recovery After Surgery (ERAS) protocol for elective spine surgery. In addition, these efforts should be complemented by standardized postoperative care pathways incorporating early ambulation, prompted voiding, and prophylactic bladder ultrasound monitoring to directly mitigate POUR risk.[37,38] Through this integrated model, proactively optimizing patients' nutritional and functional reserves establishes a solid foundation for improving overall recovery outcomes. In addition, future research could focus on developing a simple risk-scoring tool based on the identified risk factors and testing its predictive performance in an independent patient cohort. Such prospective validation would help determine whether these factors can reliably identify patients at high risk for POUR and guide perioperative management strategies.

Limitations

This study has several limitations. First, although the overall sample size met the predefined requirement, the number of patients who developed POUR was relatively small. The limited number of outcome events may have constrained the stability of the multiple regression model and increased the potential risk of overfitting. While the number of variables included in the multiple model was carefully restricted, the findings should be interpreted with caution and require validation in larger, independent cohorts. Second, the single-center design may limit the generalizability of the results and potentially introduce selection bias. Third, some clinical variables were collected through face-to-face interviews using a standardized questionnaire administered by trained nurses, while operative data were extracted from the electronic medical record. Although standardized procedures were applied to enhance data accuracy, the possibility of minor residual information bias cannot be entirely excluded. Future prospective, multicenter studies are warranted to systematically assess these potential sources of bias and to strengthen the validity and generalizability of the findings.

Conclusion

In this study of 177 patients undergoing spinal surgery, postoperative urinary retention (POUR) occurred in 14.7% of cases. Higher intraoperative fluid administration, preoperative hypoalbuminemia, and lower functional status, as measured by the Barthel Index, were identified as independent risk factors for POUR. These findings expand the conventional risk assessment framework by incorporating indicators of intraoperative management, nutritional status, and baseline physiological reserve, providing a more comprehensive approach to identifying patients at high risk. Careful perioperative management targeting these factors, including individualized goal-directed fluid therapy, nutritional optimization, and functional prehabilitation, may help reduce the incidence of POUR and improve postoperative recovery. Future studies should validate these risk factors in larger, multicenter cohorts and develop simple, evidence-based risk-scoring tools to guide clinical decision-making and optimize perioperative care.

Data Sharing Statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Ethics Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, in accordance with the Declaration of Helsinki (Approval Code: TJ-IRB202511058). All potential participants were verbally informed by nurses about the study's purpose, procedures, and expected outcome. Written informed consent was obtained from all participants prior to data collection.

Acknowledgments

Xiao-Li Guan and Yi Gao are co-correspondence authors for this work. The authors would like to thank the patients who participated in this study and appreciate their efforts.

Funding

This work was supported by the Tongji Hospital Nursing Special Research Foundation (2023D07) and Teaching and Research Fund of the Second Clinical College of Tongji Hospital (TJJXYJ2024031) and Tongji Hospital Funding for Horizontal Project (2020092).

Disclosure

The authors declare no competing interests in this work.

References

1. Baldini G, Bagry H, Aprikian A, Carli F, Warner D, Warner M. Postoperative urinary retention: anesthetic and perioperative considerations. *Anesthesiology*. 2009;110(5):1139–1157. doi:10.1097/ALN.0b013e31819f7aea
2. Porche K, Maciel CB, Lucke-Wold B, et al. Preoperative prediction of postoperative urinary retention in lumbar surgery: a comparison of regression to multilayer neural network. *J Neurosurg Spine*. 2021;36(1):32–41. doi:10.3171/2021.3.SPINE21189
3. Chang Y, Chi KY, Tai TW, et al. Risk factors for postoperative urinary retention following elective spine surgery: a meta-analysis. *Spine J*. 2021;21 (11):1802–1811. doi:10.1016/j.spinee.2021.05.009
4. Burger DH, Kappetein AP, Boutkan H, Breslau PJ. Prevention of urinary retention after general surgery: a controlled trial of carbachol/diazepam versus alfusozine. *J Am Coll Surg*. 1997;185(3):234–236. doi:10.1016/S1072-7515(01)00921-8
5. Darrah DM, Griebling TL, Silverstein JH. Postoperative urinary retention. *Anesthesiol Clin*. 2009;27(3):465–484. doi:10.1016/j.anclin.2009.07.010
6. Strickland AR, Usmani MF, Camacho JE, et al. Evaluation of risk factors for postoperative urinary retention in elective thoracolumbar spinal fusion patients. *Global Spine J*. 2021;11(3):338–344. doi:10.1177/2192568220904681
7. Jung HJ, Park JB, Kong CG, Kim YY, Park J, Kim JB. Postoperative urinary retention following anterior cervical spine surgery for degenerative cervical disc diseases. *Clin Orthop Surg*. 2013;5(2):134–137. doi:10.4055/cios.2013.5.2.134
8. Blackwell RH, Vedachalam S, Shah AS, et al. Postoperative urinary retention is an independent predictor of short-term and long-term future bladder outlet procedure in men. *J Urol*. 2017;198(5):1124–1129. doi:10.1016/j.juro.2017.06.023
9. Gandhi SD, Patel SA, Maltenfort M, et al. Patient and surgical factors associated with postoperative urinary retention after lumbar spine surgery. *Spine*. 2014;39(22):1905–1909. doi:10.1097/BRS.0000000000000572
10. Zakaria HM, Lipphardt M, Bazydlo M, et al; MSSIC Investigators. The preoperative risks and two-year sequelae of postoperative urinary retention: analysis of the michigan spine surgery improvement collaborative (MSSIC). *World Neurosurg*. 2020;133:e619–e626. doi:10.1016/j.wneu.2019.09.107
11. Reed LA, Mihas AK, Fortin TA, et al. Risk factors for postoperative urinary retention following lumbar spine surgery: a review of current literature and meta-analysis. *Global Spine J*. 2023;13(6):1658–1670. doi:10.1177/21925682221146493
12. Jasinski J, Tong D, Yoon E, et al. Preventing postoperative urinary retention (POUR) in patients undergoing elective lumbar surgery: a quality improvement project. *Qual Manag Health Care*. 2023;32(4):270–277. doi:10.1097/QMH.0000000000000394
13. Zhao Y, Huang Y, Wang Z, Song Y, Chen Q, Feng G. Geriatric nutrition risk index is useful to assess the risk of postoperative urinary retention in elderly patient undergoing lumber interbody fusion. *Eur Spine J*. 2025;34(9):4057–4063. doi:10.1007/s00586-025-08957-z
14. Mormol JD, Basques BA, Harada GK, et al. Risk factors associated with development of urinary retention following posterior lumbar spinal fusion: special attention to the use of glycopyrrolate in anesthesia reversal. *Spine*. 2021;46(2):E133–e138. doi:10.1097/BRS.0000000000003678
15. Tian D, Liang J, Song JL, et al. Construction and validation of a predictive model for postoperative urinary retention after lumbar interbody fusion surgery. *BMC Musculoskelet Disord*. 2023;24(1):813. doi:10.1186/s12891-023-06816-w
16. Durrand J, Singh SJ, Danjoux G. Prehabilitation. *Clin Med Lond*. 2019;19(6):458–464. doi:10.7861/clinmed.2019-0257
17. Gillis C, Ljungqvist O, Carli F. Prehabilitation, enhanced recovery after surgery, or both? A narrative review. *Br J Anaesth*. 2022;128(3):434–448. doi:10.1016/j.bja.2021.12.007
18. Karani R, Mahdy A, Asghar F. Postoperative urinary retention in patients who undergo joint arthroplasty or spine surgery. *JBJS Rev*. 2020;8(7): e1800040. doi:10.2106/JBJS.RVW.18.00040
19. Katiyar P, Reyes J, Coury J, Lombardi J, Sardar Z. Preoperative optimization for adult spinal deformity surgery: a systematic review. *Spine*. 2024;49(5):304–312. doi:10.1097/BRS.0000000000004823
20. Papageorge CM, Howington B, Leverson G, Kennedy GD, Carchman EH. Preoperative tamsulosin to prevent postoperative urinary retention: a randomized controlled trial. *J Surg Res*. 2021;262:130–139. doi:10.1016/j.jss.2020.12.055
21. Aiyer SN, Kumar A, Shetty AP, Kanna RM, Rajasekaran S. Factors influencing postoperative urinary retention following elective posterior lumbar spine surgery: a prospective study. *Asian Spine J*. 2018;12(6):1100–1105. doi:10.31616/asj.2018.12.6.1100
22. Ocagli H, Cella N, Stivanello L, Degan M, Canova C. The Barthel index as an indicator of hospital outcomes: a retrospective cross-sectional study with healthcare data from older people. *J Adv Nurs*. 2021;77(4):1751–1761. doi:10.1111/jan.14708
23. Mahoney FI, Barthel DW. Barthel, functional evaluation: the barthel index. *Md State Med J*. 1965;14:61–65.
24. Cetik RM, Gum JL, Lafage R, et al; International Spine Study Group. Intraoperative fluid management in adult spinal deformity surgery: variation analysis and association with outcomes. *Spine Deform*. 2025;13(1):241–250. doi:10.1007/s43390-024-00966-0
25. Ongaigui C, Fiorda-Diaz J, Dada O, Mavarez-Martinez A, Echeverria-Villalobos M, Bergese SD. Intraoperative fluid management in patients undergoing spine surgery: a narrative review. *Front Surg*. 2020;7:45. doi:10.3389/fsurg.2020.00045
26. Manning MW, Dunkman WJ, Miller TE. Perioperative fluid and hemodynamic management within an enhanced recovery pathway. *J Surg Oncol*. 2017;116(5):592–600. doi:10.1002/jso.24828
27. Lee NJ, Kothari P, Kim JS, et al. Nutritional status as an adjunct risk factor for early postoperative complications following posterior cervical fusion. *Spine*. 2017;42(18):1367–1374. doi:10.1097/BRS.0000000000002119
28. Han D, Wang SK, Cui P, Kong C, Wang P, Lu SB. Preoperative nutritional status screened by MNA-SF predicts major complications in elderly patients undergoing lumbar fusion surgery. *Clin Interv Aging*. 2024;19:2031–2042. doi:10.2147/CIA.S481610
29. Chaker AN, Rademacher AF, Easton M, et al. The impact of serum albumin levels on postoperative complications in lumbar and cervical spine surgery: an analysis of the Michigan spine surgery improvement collaborative registry. *J Neurosurg Spine*. 2024;41(6):792–802. doi:10.3171/2024.5.SPINE24113
30. Hirase T, Taghlabi KM, Cruz-Garza JG, Faraji AH, Marco RAW, Saifi C. Preoperative serum albumin level predicts length of stay and perioperative adverse events following vertebral corpectomy and posterior stabilization for metastatic spine disease. *Global Spine J*. 2024;14 (7):2004–2011. doi:10.1177/21925682231163814

31. Higashikawa T, Shigemoto K, Goshima K, et al. Postoperative urinary retention in Japanese elderly males with a femoral neck or trochanteric fracture. *Acta Med Okayama*. 2022;76(4):409–414. doi:10.18926/AMO/63895
32. Nakajima H, Honjoh K, Watanabe S, Takeura N, Kubota A, Matsumine A. Risk factors for de Novo postoperative urinary retention in posterior lumbar spine surgery. *Global Spine J*. 2025;15(5):2669–2678. doi:10.1177/21925682241308508
33. Camino-Willhuber G, Tani S, Schonnagel L, et al. Association of frailty and preoperative hypoalbuminemia with the risk of complications, readmission, and mortality after spine surgery. *World Neurosurg*. 2023;174:e152–e158. doi:10.1016/j.wneu.2023.03.095
34. Weimann A, Braga M, Carli F, et al. ESPEN practical guideline: clinical nutrition in surgery. *Clin Nutr*. 2021;40(7):4745–4761. doi:10.1016/j.clnu.2021.03.031
35. Sun Z, Qi Y. Application of enhanced recovery after surgery care protocol in the perioperative care of patients undergoing lumbar fusion and internal fixation. *J Orthop Surg Res*. 2022;17(1):240. doi:10.1186/s13018-022-03099-0
36. Smith L, Barkyoumb D, Kaiser WC, et al. Standardizing preoperative care for elective spine surgery: the university of Oklahoma elective spine surgery protocol. *Geroscience*. 2025. doi:10.1007/s11357-025-01908-y
37. Brouwer TA, van den Boogaard C, van Roon EN, Kalkman CJ, Veeger N. Non-invasive bladder volume measurement for the prevention of postoperative urinary retention: validation of two ultrasound devices in a clinical setting. *J Clin Monit Comput*. 2018;32(6):1117–1126. doi:10.1007/s10877-018-0123-6
38. Hansen AB, Olsen KS. The number of in-out catheterisations is reduced by mobilising the postoperative patient with bladder needs to the toilet in the recovery room: a randomised clinical trial. *Eur J Anaesthesiol*. 2015;32(7):486–492. doi:10.1097/EJA.0000000000000214