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Association between spinopelvic parameters and postoperative urinary retention in thoracolumbar spine surgery: a propensity-matched analysis

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Postoperative urinary retention (POUR) is a frequent complication following spine surgery, with reported incidence rates ranging from 5 to 70%. While numerous risk factors have been identified, the relationship between spinopelvic parameters and POUR has not been previously investigated. This retrospective study examined the potential association between spinopelvic alignment and POUR in patients undergoing thoracolumbar spine surgery. We analyzed data from 420 patients who underwent surgery for degenerative thoracolumbar conditions between March 2021 and February 2024. After applying exclusion criteria and performing propensity score matching, 190 patients (95 with POUR, 95 without POUR) were included in the final analysis. Radiological parameters, including lumbar lordosis (LL), lower lumbar lordosis (LLL), pelvic tilt, sacral slope, and pelvic incidence, were assessed using preoperative and postoperative standing radiographs. Multivariable logistic regression analysis identified decreased preoperative LLL (<27.77°) as an independent predictor of POUR (OR = 2.08, 95% CI = 1.10–3.91, *p* = 0.024). Additionally, higher intraoperative mean arterial pressure (>75.35 mmHg) was associated with increased POUR risk (OR = 2.73, 95% CI = 1.08–6.88, *p* = 0.033). Our findings suggest that spinopelvic alignment, particularly decreased LLL, may play a previously unrecognized role in the development of POUR following thoracolumbar spine surgery. This novel association expands our understanding of POUR pathophysiology and could inform preoperative risk assessment and perioperative management strategies. Future prospective studies are warranted to validate these findings and explore the underlying mechanisms.

Keywords Urinary retention, Thoracolumbar spine surgery, Risk factors, Lower lumbar lordosis, Spinopelvic alignment, Post-void residual volume

Postoperative urinary retention (POUR) is a common surgical complication, with incidence rates of 5–70% depending on factors such as patient demographics, surgery type, and perioperative management[1–3] It affects physical and psychological well-being and often requires catheterization, increasing the risk of urinary tract infections, urethral injury, and other complications. Additionally, POUR is associated with increased healthcare costs, prolonged hospital stays, and delayed recovery according to the Enhanced Recovery After Surgery (ERAS) protocols, which recommend early catheter removal[1,4,5] Multiple studies have identified risk factors for POUR, such as male sex, older age, diabetes mellitus, benign prostatic hyperplasia, longer operative time, administration of larger fluid volumes, and fusion surgeries[6] Micturition is regulated by the pontine micturition center and spinal nerve segments, highlighting the need to explore the relationship between spinal surgery, particularly those involving T11 to S4 and POUR[1] However, to our knowledge, no previous studies have investigated the association between spinopelvic parameters and POUR risk. In this study, we examined the potential risk factors for POUR, including radiological parameters, in addition to previously identified factors.

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Materials and methods

Study design and patient selection

We retrospectively reviewed the data of patients who underwent thoracolumbar spine surgery for degenerative diseases between March 2021 and February 2024 at our institution. All surgeries were performed by a single orthopedic spine surgeon with 8 years of post-fellowship experience. We included 420 patients with complete electronic medical records and imaging data. Exclusion criteria were: additional surgery due to acute complications, preoperative Foley catheter placement, discharge with an indwelling catheter, incomplete postoperative urinary assessments, known urological malignancies (e.g., prostate, bladder, or urethral cancer), or inadequate radiologic materials. This study was approved by the Institutional Review Board and Ethics Committee, which issued a waiver regarding the need for informed consent (Yonsei University IRB: 3-2024-0152). All studies were performed according to relevant guidelines and regulations.

Postoperative voiding care protocol

A standardized postoperative voiding care protocol was implemented for all patients. A Foley catheter was routinely inserted under general anesthesia before surgical draping to ensure proper placement before the procedure began. The catheter was removed within 3 days if the patient could ambulate with assistance. Patients were encouraged to void within 6 h after catheter removal and subsequently every 6 h. Post-void residual volume (PVR) was measured using a bladder scanner (BVI-3000 Bladder Scan, VerOlympic Inc., Bothell, WA, USA). If the PVR was < 300 mL for more than two consecutive measurements, voiding care was considered complete. Clean intermittent catheterization (CIC) was performed if PVR was ≥ 300 mL or if the patient was unable to void independently. Recatheterization was recommended for patients requiring more than three consecutive CICs or if the PVR exceeded 700 mL. Pharmacological treatment was administered based on consultation with the urology department[7].

Definition of POUR

For this study, POUR was defined as meeting any of the following criteria: a PVR volume exceeding 300 mL requiring CIC, reinsertion of a Foley catheter, or the necessity for consultation with the urology department. This definition was established to identify cases of urinary retention that necessitated clinical management through medical treatment, procedural intervention, or specialist consultation.

Radiologic assessment

Radiological parameters (lumbar lordosis LL [L1-S1 Cobb angle],[8] lower LL [LLL L4-S1 Cobb angle],[9] pelvic tilt, and pelvic incidence) were assessed using preoperative and postoperative standing whole-spine lateral radiographs. Postoperative radiographs were obtained during hospitalization once the patient was ambulatory to ensure accurate alignment measurements. Two experienced spine surgeons independently reviewed all radiographs using the Centricity software (Enterprise Web ver. 3.0; GE Healthcare, Chicago, IL, USA), and any discrepancies in measurements were resolved by consensus. The intraclass correlation coefficient for inter-observer agreement was 0.90–0.95 across all measured parameters, indicating excellent reliability.

Propensity score matching

To minimize confounding bias between POUR and non-POUR groups, we conducted propensity score matching (PSM). Propensity scores were calculated using logistic regression based on demographic and clinical covariates (age, sex, BMI, BPH, DM, CAOD, CVD, and CKD). Patients in the POUR group were matched 1:1 with non-POUR patients using nearest-neighbor matching without replacement, with a caliper width of 0.2 standard deviations of the logit of the propensity score. Baseline characteristics were reassessed post-matching to confirm balanced groups.

Statistical analysis

Continuous variables were presented as median with ranges or mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Normality of each variable was assessed using Kolmogorov-Smirnov test. Between matched groups, we used Mann–Whitney U test or Student's t-test for continuous variables and chi-squared or Fisher's exact tests for categorical variables. Continuous variables were assessed using receiver operating characteristic (ROC) curve analysis to identify optimal cutoff values. Youden's J index was utilized to determine the point that maximized the sum of sensitivity and specificity (sensitivity + specificity − 1). Univariable logistic regression analyses were performed on matched cohorts to identify factors associated with POUR. Variables with $p < 0.05$ in univariable analyses were entered into a multivariable logistic regression model using stepwise selection to determine independent predictors of POUR. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$. All analyses, including propensity matching, were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA).

Results

Patient demographics and POUR

Following propensity score matching, 190 patients (95 with POUR and 95 without POUR) were included in our analysis. (Fig. 1) Baseline characteristics, including age, BMI, sex, and comorbidities (BPH, DM, CAOD, CVD, and CKD), were evenly distributed between groups, indicating successful matching (all $p > 0.05$). The median age was similar in both groups (73.0 years, $p = 0.76$). BPH and CAOD, previously significant predictors in the unmatched analysis, showed no statistical significance after matching (BPH, $p = 0.556$; CAOD, $p = 0.52$). (Table 1)

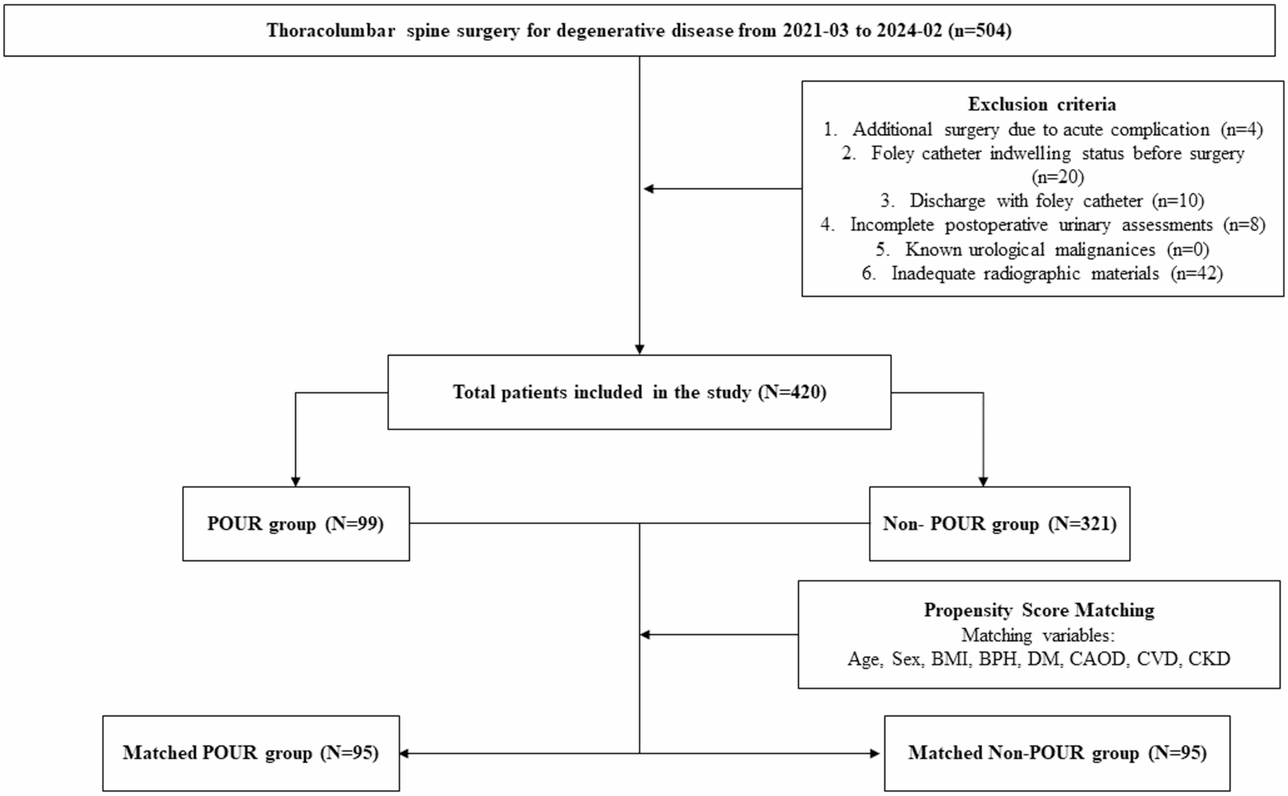

Fig. 1. Flow chart of the study selection process. POUR, postoperative urinary retention.

Variables	Total (N = 190)	No POUR (n = 95)	POUR (n = 95)	p-value
Age (years)	73.0(38.0–91.0)	73.0(43.0–91.0)	73.0(38.0–90.0)	0.76
BMI	24.1(14.4–39.5)	24.2(14.4–34.5)	24.0(16.8–39.5)	0.73
Sex (F/M)	118/72 (62.1%)	60/35 (63.2%)	58/37 (61.1%)	0.765
BPH (y/n)	31/159 (16.3%)	14/81 (14.7%)	17/78 (17.9%)	0.556
DM (y/n)	62/128 (32.6%)	32/63 (33.7%)	30/65 (31.6%)	0.757
CAOD (y/n)	25/165 (13.2%)	11/84 (11.6%)	14/81 (14.7%)	0.52
CVD (y/n)	22/168 (11.6%)	11/84 (11.6%)	11/84 (11.6%)	> 0.999
CKD (y/n)	7/183 (3.7%)	3/92 (3.2%)	4/91 (4.2%)	> 0.999

Table 1. Demographic data of the included patients after propensity score matching. POUR, postoperative urinary retention; BMI, body mass index; F, females; M, males; BPH, benign prostate hyperplasia; DM, diabetes mellitus; CAOD, coronary artery obstructive disease; CVD, cerebrovascular disease; CKD, chronic kidney disease; y, yes; n, no; N, number; The results are expressed as N (%) or median(min-max).

Receiver operating characteristic curve analysis for continuous variables

Continuous variables were evaluated using receiver operating characteristic (ROC) curve analysis to determine optimal cut-off values for predicting postoperative urinary retention (POUR). The optimal thresholds were identified based on Youden's J index, which maximizes the combined value of sensitivity and specificity. (Table 2) Among the assessed variables, Δ Lower LL (> -1.6°) demonstrated the highest diagnostic performance with an AUC of 0.63 (95% CI, 0.57–0.70) and a Youden's J index-optimized sensitivity of 87% and specificity of 40%. Intraoperative bleeding volume > 975 mL was also a significant predictor (AUC = 0.61, 95% CI, 0.54–0.67), with relatively high specificity (82%) but limited sensitivity (39%). Preoperative lower lumbar lordosis < 27.77° and average MAP > 75.35 mmHg showed moderate discriminative ability (AUC = 0.59 and 0.55, respectively), though their specificity and sensitivity profiles varied. Anesthesia time > 4.433 h did not reach statistical significance (p = 0.058). (Table 2)

Surgical and perioperative factors

Surgical characteristics, including the number of operated levels and procedure type, showed no significant differences between groups (p = 0.336 and p = 0.196, respectively). Median anesthesia time was similar (4.3

	AUC(95% CI)	*p*-value	Cutoff	Sensitivity (95% CI)	Specificity (95% CI)
Anesthesia time (h)	0.57(0.52–0.63)	0.058	> 4.433	0.58(0.48–0.68)	0.56(0.46–0.66)
Bleeding (L)	0.61(0.54–0.67)	< 0.001	> 975	0.39(0.29–0.49)	0.82(0.74–0.90)
Average MAP (mmHg)	0.55(0.50–0.60)	0.04	> 75.35	0.91(0.85–0.96)	0.20(0.12–0.28)
Lower LL	0.59(0.52–0.67)	0.013	< 27.77	0.62(0.52–0.72)	0.57(0.47–0.67)
Δ Lower LL	0.63(0.57–0.70)	< 0.001	>-1.6	0.87(0.79–0.94)	0.40(0.29–0.50)

Table 2. ROC derived cut-off value. ROC, Receiver operating characteristic; AUC, Area under curve; LL, lumbar lordosis;

Variables	Total (*N* = 190)	No POUR (*n* = 95)	POUR (*n* = 95)	*p*-value
Number of operated levels	2.0(1.0–9.0)	2.0(1.0–9.0)	2.0(1.0–9.0)	0.336
Type of surgery				0.196
Decompression only	9(4.74%)	6(6.32%)	3(3.16%)	
Decompression with PLF	33(17.37%)	13(13.68%)	20(21.05%)	
Decompression with PLIF	108(56.84%)	59(62.11%)	49(51.58%)	
OLIF with PPF	21(11.05%)	11(11.58%)	10(10.53%)	
Arthrodesis over 4 levels	19(10.00%)	6(6.32%)	13(13.68%)	
Anesthesia time (h)	4.5(1.9–12.0)	4.3(1.9–12.0)	4.7(2.3–11.9)	0.134
Fluid administration (L)	2.2(0.3–7.5)	2.0(0.7–7.5)	2.4(0.3–6.3)	0.022
Urine output (L)	0.99 ± 0.67	0.97 ± 0.67	1.02 ± 0.54	0.419
Estimated blood loss (L)	81.55 ± 9.40	81.50 ± 9.40	81.48 ± 7.30	0.024
Average MAP (mmHg)	82.364 ± 6.152	82.699 ± 6.328	81.267 ± 5.422	0.382
Intraoperative transfusion (y/n)	47/143(32.9%)	15/80 (18.8%)	32/63(50.8%)	0.004
Average MAP (mmHg)				0.041
≥ 75.35	28(14.7%)	19(20.0%)	9(9.5%)	
< 75.35	162(85.3%)	76(80.0%)	86(90.5%)	
Intraoperative dura tear (y/n)	14/175(8.0%)	5/90 (5.6%)	9/85 (10.6%)	0.258
Postoperative delirium (y/n)	29/160(18.1%)	11/84 (13.1%)	18/76 (23.7%)	0.149
Ambulation (POD)	4.0(1.0–20.0)	3.0(1.0–20.0)	4.0(1.0–17.0)	0.658
Gas passing (POD)	2.0(0.0–7.0)	2.0(0.0–7.0)	2.0(0.0–5.0)	0.644

Table 3. Surgical data of the included patients. POUR, postoperative urinary retention; PLF, posterolateral fusion; PLIF, posterior lumbar interbody fusion; OLIF, oblique lumbar interbody fusion; PPF, percutaneous pedicle fixation; MAP, mean arterial pressure; POD, postoperative day; y, yes; n, no; The results are expressed as N (%) or median(min-max).

vs. 4.7 h, $p = 0.134$). Intraoperative fluid administration was significantly higher in the POUR group (median 2.4 L vs. 2.0 L, $p = 0.022$), as was estimated blood loss (700 mL vs. 600 mL, $p = 0.024$). Urine output and mean intraoperative MAP showed no significant differences ($p = 0.419$ and $p = 0.382$, respectively). Intraoperative transfusion was more frequent in the POUR group (33.68% vs. 15.79%, $p = 0.004$). Additionally, lower MAP (≤75.35 mmHg) during surgery was significantly associated with POUR occurrence ($p = 0.041$). Dura tear incidence, postoperative delirium, time to ambulation, and first passage of abdominal gas did not differ significantly between groups. (Table 3)

Spinopelvic alignment parameters

Preoperatively, radiological spinopelvic parameters showed no significant differences between the POUR and non-POUR groups (lumbar lordosis [LL]: $p = 0.63$; lower lumbar lordosis [Lower LL]: $p = 0.095$; pelvic incidence [PI]: $p = 0.998$; pelvic tilt [PT]: $p = 0.167$). Postoperative measurements of these parameters also showed no significant intergroup differences.

However, the postoperative change in Lower LL was significantly greater in the POUR group compared to the non-POUR group (median change: 2.8° vs. 0.6°, $p = 0.005$). Changes in overall LL, PI, and PT did not differ significantly between groups ($p = 0.128$, $p = 0.057$, and $p = 0.056$, respectively). (Table 4)

Logistic regression anaylsis for determining risk factors of POUR

In univariate analysis, intraoperative transfusion (OR = 2.71, $p = 0.005$), significant blood loss (> 975 mL, OR = 2.93, $p = 0.002$), and substantial postoperative increase in lower lumbar lordosis (>-1.6°, OR = 4.26, $p < 0.001$) were significantly associated with POUR, although these were not included in the final multivariable model due to model optimization and to avoid collinearity. (Table 5)

Variables	Total (N = 420)	No POUR (n = 321)	POUR (n = 99)	p-value
Preoperative				
LL	32.4(-36.0-63.0)	34.4(-36.0-59.0)	30.2(-28.9-63.0)	0.63
Lower LL	27.3(-13.0-46.0)	29.4(-13.0-46.0)	25.2(-5.6-45.4)	0.095
PI	50.2(28.3–86.0)	51.3(35.0–86.0)	49.9(28.3–73.6)	0.998
PT	23.1(0.6–58.2)	21.9(1.1–57.0)	24.0(0.6–58.2)	0.167
Postoperative				
LL	38.2(-6.2-68.8)	38.4(-6.2-55.3)	38.0(-2.6-68.8)	0.711
Lower LL	29.7(-2.3-55.3)	30.0(-2.3-49.5)	29.2(9.7–55.3)	0.991
PI	50.5(26.0–86.0)	51.8(26.0–86.0)	50.0(28.3–73.8)	0.819
PT	21.3(1.3–51.7)	21.2(1.3–51.7)	21.3(3.0-43.9)	0.731
Difference				
ΔLL	4.2(-24.8-66.7)	3.2(-12.6-66.7)	5.1(-24.8-47.0)	0.128
ΔLower LL	1.5(-11.6-24.8)	0.6(-11.6-24.8)	2.8(-11.0-22.1)	0.005
Δ PT	-1.3(-24.8-29.9)	-0.9(-24.8-13.6)	-2.3(-19.4-29.9)	0.056

Table 4. Spinopelvic alignment parameters of the included patients. POUR, postoperative urinary retention; LL, lumbar lordosis; PI, pelvic incidence; PT, pelvic tilt; N, number; SD, Standard deviation; Δ, change (e.g., Δ Lower LL represents change in lower lumbar lordosis). The results are expressed as N (%) or median(min-max).

Multivariable logistic regression analysis after propensity score matching identified significant independent predictors of POUR. Higher intraoperative MAP (> 75.35 mmHg) was associated with increased POUR risk (OR = 2.73, 95% CI = 1.08–6.88, p = 0.033). Preoperative lower lumbar lordosis less than 27.77° was independently associated with greater POUR likelihood (OR = 2.08, 95% CI = 1.10–3.91, p = 0.024). (Table 6)

In summary, after controlling for confounding variables through propensity matching, high intraoperative MAP and decreased preoperative lower lumbar lordosis remained independent predictors for POUR in patients undergoing thoracolumbar spine surgery.

Discussion

This study explored spinopelvic alignment as a novel risk factor for POUR in thoracolumbar spine surgery. Although POUR is a recognized postoperative complication with known risk factors such as advanced age, male sex, BPH, and prolonged anesthesia, its relationship with spinopelvic parameters has been overlooked[3,7,10,11] Our findings suggest that decreased preoperative LLL is independently associated with an increased risk of POUR in patients undergoing thoracolumbar spine surgery. This novel association expands the framework for understanding POUR and offers insights into how biomechanical factors interact with bladder function.

The association between decreased LLL and POUR provides an innovative perspective on micturition mechanics. LLL, as part of spinopelvic alignment, affects the orientation of the pelvis and the engagement of the abdominal and lumbar musculature[9,12,13] These structures play crucial roles in generating and maintaining intra-abdominal pressure, which is a critical component of the Valsalva maneuver, a physiological mechanism essential for effective bladder emptying. The Valsalva maneuver involves an increase in intra-abdominal pressure achieved by forceful expiration against a closed airway, facilitating detrusor muscle contraction and subsequent urination[1,14–16] A decrease in the LLL may alter the biomechanical alignment of the pelvis and lumbar region, potentially diminishing the efficacy of this mechanism. Specifically, reduced lordosis may compromise the ability of the abdominal wall and pelvic floor muscles to coordinate effectively, thereby impairing the generation of sufficient intra-abdominal pressure for voiding. Although this hypothesis is biologically plausible, its exact mechanism remains unclear and warrants further investigation. The proposed relationship between LLL and POUR may also be contextualized within a broader understanding of pelvic biomechanics. Studies have shown that abnormal spinopelvic alignment can affect pelvic organ function, including bowel and bladder dynamics. For example, in patients with pelvic organ prolapse, changes in pelvic tilt and sacral slope have been linked to voiding and continence dysfunction. Similarly, reduced LLL may influence the orientation of the bladder and urethra, disrupting the pressure gradients necessary for effective voiding. Biomechanical studies have documented the role of the lumbar spine alignment in facilitating posture-dependent abdominal pressure generation. Altered alignment in the lower lumbar region could theoretically result in suboptimal engagement of the musculature involved in the Valsalva maneuver[8,17] The lumbosacral plexus (particularly nerve roots from L2 to S4), which innervates both the bladder and pelvic floor musculature, may be functionally influenced by alterations in spinal alignment. A reduction in LLL could theoretically lead to changes in dural tension, nerve root angulation, or foraminal narrowing, all of which may impair neural transmission involved in the coordination of micturition. Moreover, altered spinopelvic alignment may disrupt the spatial orientation of pelvic organs and their relationship to autonomic and somatic pathways that mediate bladder function. These factors could collectively compromise the detrusor reflex arc or the voluntary initiation of voiding. Future studies incorporating neurophysiological evaluations, such as electromyography or functional MRI, may further elucidate the role of these neuromuscular pathways in the development of POUR in patients with sagittal malalignment. In patients undergoing spine surgery, these dynamics may be further compounded by postoperative pain, muscular deconditioning, and the

	Variable	OR (95% CI)	p-value
Surgical factors	Number of levels	1.03(0.89–1.20)	0.655
	Type of surgery		
	Decompression only	ref	
	Decompression with PLF	3.08(0.65–14.52)	0.156
	Decompression with PLIF	1.66(0.39–6.99)	0.489
	OLIF with PPF	1.82(0.36–9.27)	0.472
	Arthrodesis over 4 levels	4.33(0.80-23.48)	0.089
	Anesthesia time (h)	1.12(0.95–1.33)	0.188
	Fluid administration (L)	1.23(0.97–1.57)	0.089
	Average MAP (mmHg)	1.02(0.97–1.07)	0.426
	Intraoperative transfusion	2.71(1.35–5.44)	0.005
	Anesthesia time (cutoff, h)		
	≤ 4.433	ref	
	> 4.433	1.74(0.98–3.08)	0.06
	Bleeding (cutoff, mL)		
	≤ 975	ref	
	> 975	2.93(1.50–5.70)	0.002
	Average MAP (cutoff, mmHg)		
	≤ 75.35	ref	
	> 75.35	2.39(1.02–5.59)	0.045
	Delirium	1.81(0.80–4.07)	0.153
Radiologic parameters	Preoperative		
	LL	1.00(0.98–1.01)	0.786
	Lower LL	0.98(0.95–1.01)	0.205
	PT	1.02(0.99–1.05)	0.292
	Lower LL (cutoff)		
	≥ 27.77	ref	
	< 27.77	2.15(1.17–3.97)	0.014
	Difference		
	Δ Lower LL (cutoff)		
	≤-1.6	ref	
	>-1.6	4.26(1.97–9.22)	< 0.001

Table 5. Univariable logistic regression analysis to determine POUR. POUR, postoperative urinary retention; OR, odds ratio; CI, confidence interval; BPH, benign prostate hyperplasia; CAOD, coronary artery obstructive disease; PLF, posterolateral fusion; PLIF, posterior lumbar interbody fusion; OLIF, oblique lumbar interbody fusion; PPF, percutaneous pedicle fixation; MAP, mean arterial pressure; LL, lumbar lordosis; PT, pelvic tilt; Δ, change (e.g., Δ Lower LL represents change in lower lumbar lordosis).

effects of anesthesia, all of which can impair micturition. The novelty of this study lies in the introduction of spinopelvic parameters into the POUR risk assessment model, which could be an important consideration for future research and surgical planning.

Intraoperative management often requires careful blood pressure (BP) control to minimize blood loss and improve surgical visibility. In spinal surgeries, where blood loss can be substantial, it is common for anesthesiologists to maintain a lower MAP intraoperatively. However, our study identified low intraoperative MAP as an independent predictor of POUR, suggesting that hypotension may inadvertently increase the risk of POUR. While a reduced MAP is intended to reduce perioperative bleeding and thus improve surgical outcomes, maintaining a low BP might compromise organ perfusion, particularly affecting bladder detrusor muscle function and urethral sphincter control, both of which are critical for normal voiding. The findings of this study highlight the need to balance intraoperative hypotension with adequate perfusion pressure to maintain organ function, particularly in patients at a high risk for POUR. According to ERAS protocols, which emphasize early mobilization and catheter removal, it is essential to consider the impact of intraoperative hypotension on postoperative urinary outcomes[1,4] Surgeons and anesthesiologists may need to establish individualized intraoperative BP targets that minimize bleeding without compromising bladder function, particularly in patients with preexisting risk factors for POUR. ERAS protocols emphasize early Foley catheter removal to reduce the risk of infection and encourage early mobilization[18–20] However, our findings suggest that for patients at high risk of POUR, such as those with low preoperative LLL or those who experienced extensive blood loss, early catheter removal may be counterproductive. In cases where POUR is likely, premature removal could lead to repeated catheterizations, increasing the risk of urethral trauma and urinary tract infections,[21] which are counterintuitive

Variables	OR (95% CI)	*p*-value
Average MAP (mmHg)		0.033
≤ 75.35	ref	
> 75.35	2.73(1.08–6.88)	
Postoperative delirium		0.238
No	ref	
Yes	1.72(0.70–4.22)	
Preoperative Lower LL (degree)		0.024
≥ 27.77	ref	
< 27.77	2.08(1.10–3.91)	

Table 6. Multivariate logistic regression analysis to determine POUR. POUR, postoperative urinary retention; OR, odds ratio; CI, confidence interval; BPH: benign prostatic hyperplasia; MAP, mean arterial pressure; LL, lumbar lordosis; ref, reference.

to the ERAS goals. This study underscores the need for a more nuanced approach to ERAS-based Foley catheter management. Identifying high-risk patients with POUR through preoperative and intraoperative assessments can help tailor catheter management strategies. For example, delaying Foley catheter removal until patients demonstrate sufficient spontaneous voiding capacity might reduce the need for re-catheterization and associated complications. An individualized catheter management plan based on the POUR risk factors identified in this study could optimize patient outcomes and align with the broader objectives of the ERAS protocols[22].

Our study corroborates several previously identified risk factors for POUR, including advanced age, BPH, and longer duration of anesthesia. Advanced age remains one of the strongest predictors of POUR because elderly patients often experience diminished bladder contractility and detrusor muscle dysfunction, which are exacerbated by spinal surgery. The prevalence of BPH among male patients also significantly contributes to the risk of POUR due to mechanical obstruction and reduced bladder outlet flow. Interestingly, our findings showed that these established risk factors may interact with spinopelvic alignment parameters, thereby compounding the risk of POUR. For instance, elderly patients with reduced LLL may face an even greater challenge in achieving an effective postoperative Valsalva maneuver. Similarly, patients with BPH who also have suboptimal spinopelvic alignment may experience compounded voiding difficulties.

The clinical implications of this study are multifaceted and relevant for preoperative planning and postoperative management. Recognizing LLL as a risk factor provides surgeons with an additional parameter for the preoperative assessment of POUR risk. For high-risk patients identified based on spinopelvic parameters, preemptive strategies such as modified anesthesia protocols, individualized BP management, and customized catheter care plans could be beneficial. Furthermore, patients could be counseled about the increased risk of POUR associated with their specific spinal alignment characteristics, allowing them to set realistic expectations for postoperative recovery. From an intraoperative perspective, our findings suggest a balanced approach to BP management. While minimizing blood loss remains a priority, it is important to avoid prolonged periods of low MAP, particularly in patients predisposed to POUR. Close monitoring of the MAP and adjustments based on individual risk factors for POUR, such as age and spinal alignment, could reduce the incidence of postoperative complications without compromising surgical outcomes.

This study has certain limitations. The retrospective design may have introduced a selection bias, and the study was conducted at a single institution, potentially limiting its generalizability. Additionally, POUR is a multifactorial condition that may not result solely from reduced muscle tone or detrusor function. Dysfunction of the sphincter mechanism could also contribute to urinary retention, as previously identified in related studies[23–25] However, our study design did not allow us to distinguish between these mechanisms. Therefore, our analysis focused on the observed outcome, namely the presence of urinary retention. Given the outcome-based nature of our findings, we were compelled to approach POUR from a results-oriented perspective, acknowledging the limitations of being unable to fully separate the underlying mechanisms. Future prospective studies with larger and more diverse patient populations are warranted to validate these findings. Additionally, we relied on radiographic measurements to assess spinopelvic alignment, which may not fully capture the dynamic changes in LL during activities such as the Valsalva maneuver. Future investigations utilizing dynamic imaging modalities, such as flexion-extension radiographs, real-time MRI, or EOS-based functional assessments, may provide more precise insights into how changes in spinal alignment during physiological activity affect bladder function and POUR risk.

Conclusion

In this retrospective study, we identified decreased lower lumbar lordosis (LLL) as a novel predictor of postoperative urinary retention (POUR) in patients undergoing thoracolumbar spine surgery. Additionally, intraoperative hypotension was independently associated with increased POUR risk. These findings suggest that spinopelvic alignment may play a previously underrecognized role in urinary outcomes following spine surgery. However, given the limitations of this study—including its retrospective design, single-center setting, and sample size—our conclusions should be interpreted with caution. Further prospective, multicenter studies are warranted to validate these results and to better understand the mechanisms underlying the observed associations before any changes to clinical practice are considered.

Data availability

The data that support the findings of this study are available from the corresponding author, [Ji-Won Kwon], upon reasonable request.

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References

1. Baldini, G., Bagry, H., Aprikian, A. & Carli, F. Postoperative urinary retention: anesthetic and perioperative considerations. *Anesthesiology* **110**, 1139–1157. https://doi.org/10.1097/ALN.0b013e31819f7aea (2009).
2. Darrah, D. M., Griebling, T. L. & Silverstein, J. H. Postoperative urinary retention. *Anesthesiol Clin.* **27**, 465–484. https://doi.org/10.1016/j.anclin.2009.07.010 (2009). table of contents.
3. Cambise, C. et al. Postoperative urinary retention (POUR): A narrative review. *Saudi J. Anaesth.* **18**, 265–271. https://doi.org/10.4103/sja.sja_88_24 (2024).
4. McDermott, C. D. et al. Postoperative urinary retention. *Urogynecol. (Phila)*. **29**, 381–396. https://doi.org/10.1097/spv.0000000000001344 (2023).
5. Bjarnesen, J. & Lose, G. [Postoperative urinary retention]. *Ugeskr Laeger*. **153**, 1920–1924 (1991).
6. Reed, L. A. et al. Risk factors for postoperative urinary retention following lumbar spine surgery: A review of current literature and Meta-Analysis. *Global Spine J.* **13**, 1658–1670. https://doi.org/10.1177/21925682221146493 (2023).
7. Lee, K. S., Koo, K. C. & Chung, B. H. Risk and management of postoperative urinary retention following spinal surgery. *Int. Neurourol. J.* **21**, 320–328. https://doi.org/10.5213/inj.1734994.497 (2017).
8. Roussouly, P. & Pinheiro-Franco, J. L. Sagittal parameters of the spine: Biomechanical approach. *Eur. Spine J.* **20** (Suppl 5), 578–585. https://doi.org/10.1007/s00586-011-1924-1 (2011).
9. Kim, H. J. et al. Upper versus lower lumbar lordosis corrections in relation to pelvic Tilt - An essential element in surgical planning for sagittal plane deformity. *Spine (Phila Pa. 1976)*. **47**, 1145–1150. https://doi.org/10.1097/brs.0000000000004370 (2022).
10. Chiu, H. H. et al. Risk factors of acute urinary retention after spine surgery. *Med. (Baltim)*. **103**, e40708. https://doi.org/10.1097/md.0000000000040708 (2024).
11. Reed, L. A. et al. Risk factors for postoperative urinary retention following lumbar spine surgery: A review of current literature and Meta-Analysis. *Global Spine J.* **13**, 1658–1670. https://doi.org/10.1177/21925682221146493 (2022).
12. Schwab, F., Lafage, V., Patel, A. & Farcy, J. Sagittal plane considerations and the pelvis in the adult patient. *Spine (Phila Pa. 1976)*. **34**, 1828–1833. https://doi.org/10.1097/BRS.0b013e3181a13c08 (2009).
13. Barrey, C., Roussouly, P., Perrin, G. & Le Huec, J. C. Sagittal balance disorders in severe degenerative spine. Can we identify the compensatory mechanisms? *Eur. Spine J.* **20** (Suppl 5), 626–633. https://doi.org/10.1007/s00586-011-1930-3 (2011).
14. Miller, J. M., Ashton-Miller, J. A. & DeLancey, J. O. A pelvic muscle Precontraction can reduce cough-related urine loss in selected women with mild SUI. *J. Am. Geriatr. Soc.* **46**, 870–874. https://doi.org/10.1111/j.1532-5415.1998.tb02721.x (1998).
15. Pham, K. N. et al. Preoperative Valsalva voiding increases the risk of urinary retention after midurethral sling placement. *Int. Urogynecol. J.* **21**, 1243–1246. https://doi.org/10.1007/s00192-010-1177-2 (2010).
16. Koch, K. et al. Complication pattern of sacral primary tumor resection: A study on the risk factors of surgical site infection and bowel or bladder dysfunction and their associations with length of hospital stay. *Asian Spine J.* **17**, 851–861. https://doi.org/10.31616/asj.2022.0404 (2023).
17. Hodges, P. W., Eriksson, A. E., Shirley, D. & Gandevia, S. C. Intra-abdominal pressure increases stiffness of the lumbar spine. *J. Biomech.* **38**, 1873–1880. https://doi.org/10.1016/j.jbiomech.2004.08.016 (2005).
18. McIntosh, S. et al. Timing of urinary catheter removal after colorectal surgery with pelvic dissection: A systematic review and meta-analysis. *Ann. Med. Surg. (Lond)*. **73**, 103148. https://doi.org/10.1016/j.amsu.2021.103148 (2022).
19. Ljungqvist, O. et al. Opportunities and challenges for the next phase of enhanced recovery after surgery: A review. *JAMA Surg.* **156**, 775–784. https://doi.org/10.1001/jamasurg.2021.0586 (2021).
20. Ljungqvist, O., Scott, M. & Fearon, K. C. Enhanced recovery after surgery: A review. *JAMA Surg.* **152**, 292–298. https://doi.org/10.1001/jamasurg.2016.4952 (2017).
21. Nagaoki, T. et al. Association between preoperative urine culture and urinary tract infection after spinal surgery. *Asian Spine J.* **17**, 176–184. https://doi.org/10.31616/asj.2021.0533 (2023).
22. Kehlet, H. & Wilmore, D. W. Evidence-based surgical care and the evolution of fast-track surgery. *Ann. Surg.* **248**, 189–198. https://doi.org/10.1097/SLA.0b013e31817f2c1a (2008).
23. Keita, H. et al. Predictive factors of early postoperative urinary retention in the postanesthesia care unit. *Anesth. Analg.* **101**, 592–596. https://doi.org/10.1213/01.Ane.0000159165.90094.40 (2005).
24. Fraser, M. O. New insights into the pathophysiology of Detrusor-Sphincter dyssynergia. *Curr. Bladder Dysfunct. Rep.* **6**, 93–99. https://doi.org/10.1007/s11884-011-0083-x (2011).
25. Darrah, D. M., Griebling, T. L. & Silverstein, J. H. Postoperative urinary retention. *Anesthesiol. Clin.* **27**, 465–484. https://doi.org/10.1016/j.anclin.2009.07.010 (2009).

Author contributions

JWK, JL, KSS, SYP, and BHL conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. JL, HSK, SHM, SP, and NK designed the data collection instruments, collected data, performed the initial analyses, and reviewed and revised the manuscript. JWK, JL, JWS, SYP, BHL, and KSS conceptualized and designed the study, coordinated and supervised data collection, and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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Declarations

Competing interests
The authors declare no competing interests.

Ethical review committee statement
This study was approved by our Institutional Review Board and Ethics Committee, which issued a waiver regarding the need for informed consent. And all studies were performed in accordance with relevant guidelines and regulations.

Additional information
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