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Development and validation of a prediction model for postoperative urinary retention after prolapse surgery: A retrospective cohort study

Min Ju Kim[1†], Sungyoung Lee[2†], So Yeon Lee[3], Sumin Oh[4] and Myung Jae Jeon[5,6*]

Abstract

Background Postoperative urinary retention (POUR), a common condition after prolapse surgery with potential serious sequelae if left untreated, lacks a clearly established optimal timing for catheter removal. This study aimed to develop and validate a predictive model for postoperative urinary retention lasting > 2 and > 4 days after prolapse surgery.

Methods We conducted a retrospective review of 1,122 patients undergoing prolapse surgery. The dataset was divided into training and testing cohorts. POUR was defined as the need for continuous intermittent catheterization resulting from a failed spontaneous voiding trial, with passing defined as two consecutive voids ≥ 150 mL and a postvoid residual urine volume ≤ 150 mL. We performed logistic regression and the predicted model was validated using both training and testing cohorts.

Results Among patients, 31% and 12% experienced POUR lasting > 2 and > 4 days, respectively. Multivariable logistic model identified 6 predictors. For predicting POUR, internal validation using cross-validation approach showed good performance, with accuracy lasting > 2 (area under the curve [AUC] 0.73) and > 4 days (AUC 0.75). Split validation using pre-separated dataset also showed good performance, with accuracy lasting > 2 (AUC 0.73) and > 4 days (AUC 0.74). Calibration curves demonstrated that the model accurately predicted POUR lasting > 2 and > 4 days (from 0 to 80%).

Conclusions The proposed prediction model can assist clinicians in personalizing postoperative bladder care for patients undergoing prolapse surgery by providing accurate individual risk estimates.

Keywords Clinical decision-making, Pelvic organ prolapse, Urinary retention

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Background

Postoperative urinary retention (POUR) is a common complication in women undergoing prolapse surgery, with an incidence of 26-86% [1–5]. Although it is usually temporary, POUR may cause a delayed recovery with prolonged hospital stay and significant anxiety and distress to patients [2, 5, 6]. In addition, unrecognized POUR can lead to serious sequelae including urinary tract infection (UTI), detrusor dysfunction, and even damage to surgical repair [7]. Therefore, all women undergoing prolapse surgery need bladder drainage in the perioperative period, usually with the use of indwelling catheters [7]. However, the optimal timing of catheter removal has not been clearly established.

Currently, the majority of urogynecologists remove the indwelling catheter within 2 days postoperatively [8]. However, a systematic review found that early catheter removal (≤2 days) was associated with a reduced incidence of UTI and length of hospital stay but an increased risk of recatheterization compared with later catheter removal (>2 days) after prolapse surgery [9]. As recatheterization is often considered the worst part of the surgical experience and even a surgical complication for patients [10–12], the preferable timing of catheter removal needs to be viewed from the patient's perspective. One recent study showed that the mean time to return of bladder function after native tissue vaginal reconstruction was 4.1 days, with one-third of patients experiencing POUR beyond 4 days [13]. Given that postoperative bladder function may be influenced by various clinical and surgical factors [7], providing an individual risk estimate through a prediction model integrating these factors might be useful to guide the optimal timing of catheter removal.

The aim of this study was to develop and validate a prediction model for urinary retention lasting >2 and >4 days after prolapse surgery.

Methods

We reviewed the medical records of 1,122 Korean women who underwent prolapse surgery in a tertiary hospital in South Korea between October 2008 and February 2022. Among them, 82 patients who underwent intraoperative bladder injury repair (*n*=21), could not undergo a spontaneous voiding trial (e.g., oliguria from end-stage renal disease, history of urinary diversion surgery, *n*=3), had incomplete data regarding voided volume and postvoid residual (PVR, *n*=32), or received reinsertion of an indwelling transurethral catheter instead of intermittent catheterization after an unsuccessful initial voiding trial (*n*=26) were excluded from the analyses. The study was approved by the institutional review board (Seoul National University College of Medicine/Seoul National University Hospital 2207-078-1339).

All patients underwent a spontaneous voiding trial on postoperative day (POD) 1 or 2. An indwelling transurethral catheter was removed, and the bladder was allowed to fill spontaneously over no more than 4 h. Patients were then instructed to void as needed into a measuring container, after which straight catheterization was performed to assess PVR. Patients who had two consecutive voids ≥150 mL with a PVR ≤150 mL were considered to have passed the voiding trial [14]. Patients who failed the voiding trial were offered intermittent catheterization until they had two consecutive PVRs of ≤150 mL. POUR was defined as the need for continuous intermittent catheterization resulting from a failed voiding trial.

Based on a review of the literature [7], the following baseline demographic and clinical characteristics were selected as candidate predictors for POUR: age (years), body mass index (kg/m^2), diabetes mellitus, pelvic organ prolapse quantification stage, preoperative PVR (mL), type of surgery for apical prolapse, concomitant hysterectomy, anterior repair (AR), posterior repair (PR) and midurethral sling (MUS), intraoperative estimated blood loss (mL) and operation time (min). Type of anesthesia, volume of intraoperative fluid administration and postoperative UTI were not included because all patients underwent surgery under general anesthesia and had been catheterized during the operation to avoid bladder overdistension, and postoperative UTI is usually perceived as a consequence rather than a cause of POUR. The pelvic organ prolapse quantification examination was performed in a 45° upright sitting position with an empty bladder and preoperative PVR was measured by catheterization. The type of surgery for apical prolapse was classified as intraperitoneal native tissue apical suspension (high uterosacral ligament suspension, vaginal or laparoscopic), extraperitoneal native tissue apical suspension (sacrospinous ligament fixation or iliococcygeus suspension), sacrocolpopexy with mesh and colpocleisis. MUS included both retropubic and transobturator midurethral slings, with the latter being mostly used.

In statistical analyses, we utilized the R programming language and its packages. Ahead of the main analysis, the dataset was split into two parts (training and testing cohorts) with a 2:1 ratio, ensuring the balance of POUR status was maintained. Using the training cohort, we constructed the prediction model and conducted internal validation. A multivariable logistic regression using both exhaustive and stepwise variable selection was performed to construct a prediction model, as described in the previous study [15]. Missing risk factor values were assessed for missing at random, and multiple imputation by chained equations algorithm was applied to estimate missing values. Internal validation was performed using five- and ten-fold cross-validation and their performance was compared to check overfitting. For split validation,

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Table 1 Baseline characteristics of the training and testing cohorts

Characteristics	Total (n = 1040)	Training (n = 695)	Testing (n = 345)	P-value
Age, years	67.0 (61.0–73.0)	67.0 (61.0–73.0)	67.0 (61.0–72.0)	0.633
Body mass index, kg/m²	24.8 (22.9–26.8)	24.7 (22.9–26.8)	24.9 (22.9–26.8)	0.357
Diabetes	174 (16.7)	115 (16.5)	59 (17.1)	0.821
POPQ stage				0.669
2	201 (19.3)	135 (19.4)	66 (19.1)	
3	676 (65.0)	456 (65.6)	220 (63.8)	
4	163 (15.7)	104 (15.0)	59 (17.1)	
Preoperative PVR > 150 mL[a]	89/778 (11.4)	62/523 (11.9)	27/255 (10.6)	0.602
Surgery for apical prolapse				0.688
NTR (USLS)	482 (46.3)	316 (45.5)	166 (48.1)	
NTR (SSLF, ICG)	113 (10.9)	73 (10.5)	40 (11.6)	
SCP	377 (36.3)	258 (37.1)	119 (34.5)	
Colpocleisis	68 (6.5)	48 (6.9)	20 (5.8)	
Concomitant hysterectomy	748 (71.9)	498 (71.7)	250 (72.5)	0.785
Concomitant anterior repair	321 (30.9)	218 (31.4)	103 (29.9)	0.619
Concomitant posterior repair	607 (58.4)	408 (58.7)	199 (57.7)	0.752
Concomitant MUS	419 (40.3)	282 (40.6)	137 (39.7)	0.789
Estimated blood loss, mL	150 (100–220)	150 (100–210)	150 (100–235)	0.282
Operation time, min	160 (125–205)	160 (130–205)	155 (120–200)	0.378

ICG, iliococcygeus suspension; MUS, midurethral sling; NTR, native tissue repair; POPQ, pelvic organ prolapse quantification; PVR, postvoid residual; SCP, sacrocolpopexy; SSLF, sacrospinous ligament fixation; USLS, uterosacral ligament suspension

Data are presented as median (interquartile range) or number (%)

[a] Preoperative PVR results were not available for 262 cases, and they were not included as a denominator

the fitted model from the training cohort was applied to the testing cohort. Model calibration was visually performed using the calibration plot. Finally, the performance of model was measured using the area under the receiver operating characteristic curve (AUC).

Results

The proportion of patients who experienced POUR > 2 days and > 4 days were 31% and 12%, respectively. The baseline characteristics of the training (n = 695) cohort and testing (n = 345) cohort are summarized in Table 1. There were no significant differences between the two cohorts. The preoperative PVR results were missing in 262 (25%) patients because they did not undergo the test. There were no missing data on other variables.

Using the training cohort, our multivariable logistic model with exhaustive variable selection identified six predictors for the model: age, preoperative PVR, type

Table 2 Risk factors and their estimated contribution to the logistical model for predicting urinary retention after prolapse surgery

Variables	OR (95% CI)	
	Model for POUR > 2 days	Model for POUR > 4 days
Age (per year)	1.04 (1.02–1.05)	1.03 (1.00–1.05)
Preoperative PVR > 150 mL	2.61 (1.66–4.12)	3.66 (2.13–6.18)
NTR (USLS)	3.24 (2.31–4.60)	NA
NTR (SSLF, ICG)	7.86 (4.88–12.81)	3.93 (2.23–6.91)
Concomitant hysterectomy	2.16 (1.48–3.19)	2.90 (1.66–5.31)
Concomitant anterior repair	NA	2.43 (1.57–3.75)
Concomitant MUS	1.63 (1.22–2.19)	2.09 (1.39–3.16)

CI, confidence interval; ICG, iliococcygeus suspension; OR, odds ratio; MUS, midurethral sling; NA, not available; NTR, native tissue repair; POUR, postoperative urinary retention; PVR, postvoid residual; SSLF, sacrospinous ligament fixation; USLS, uterosacral ligament suspension

Logistic regression equation of model for POUR > 2 days: $-4.87 + 0.03 \times \text{Age} + 0.96 \times \text{Preoperative PVR} > 150 \text{ mL} + 1.18 \times \text{NTR (USLS)} + 2.06 \times \text{NTR (SSLG, ICG)} + 0.77 \times \text{Concomitant hysterectomy} + 0.49 \times \text{Concomitant midurethral sling}$

Logistic regression equation of model for POUR > 4 days: $-5.76 + 0.03 \times \text{Age} + 1.30 \times \text{Preoperative PVR} > 150 \text{ mL} + 1.37 \times \text{NTR (SSLG, ICG)} + 1.06 \times \text{Concomitant hysterectomy} + 0.89 \times \text{Concomitant anterior repair} + 0.74 \times \text{Concomitant midurethral sling}$

of surgery for apical prolapse, concomitant hysterectomy, AR and MUS. The stepwise selection also selected the same variables with the addition of body mass index (for the model lasting > 2 days) and operation time (for the model lasting > 4 days). The exhaustive model had a slightly higher AUC than the stepwise model and was selected as the final model. Increasing age, elevated preoperative PVR (> 150 mL), native tissue apical suspension, concomitant hysterectomy, and MUS had incremental effects on POUR lasting > 2 days. With the exception of uterosacral ligament suspension, all these variables had incremental effects on POUR lasting > 4 days, and concomitant AR also increased the risk of POUR lasting > 4 days (Table 2). Figure 1 presents the nomogram using the reference model with these predictors.

We next conducted validation of the model against both training and testing cohorts. On the training cohort, internal validation using five-fold cross-validation showed good performance for predicting POUR lasting > 2 (AUC 0.73, 95% confidence interval [CI] 0.72–0.74) and > 4 days (AUC 0.75, 95% CI 0.74–0.77). Subsequent analysis using ten-fold cross-validation showed that the model manifests stable prediction power (AUC 0.73 for POUR lasting > 2 days and 0.74 for POUR lasting > 4 days). On the testing cohort, split validation also showed good performance for predicting POUR lasting > 2 (AUC 0.73, 95% CI 0.72–0.74) and > 4 days (AUC 0.74, 95% CI 0.73–0.75) (Fig. 2A). Calibration curves demonstrated that the model accurately predicted the observed outcomes of POUR lasting > 2 and > 4 days (from 0 to 80%) (Fig. 2B).
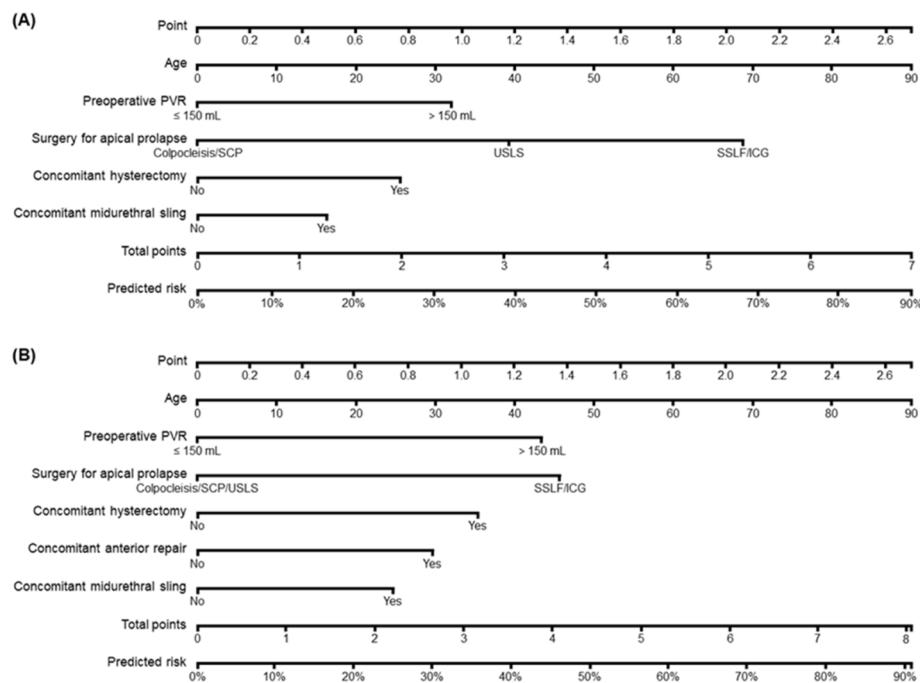
Fig. 1 Nomogram for predicting the risk of postoperative urinary retention > 2 days (**A**) and > 4 days (**B**). ICG, iliococcygeus suspension; PVR, postvoid residual; SCP, sacrocolpopexy; SSLF, sacrospinous ligament fixation; USLS, uterosacral ligament suspension

Discussion

In this study, we identified six predictors (age, preoperative PVR, type of surgery for apical prolapse, concomitant hysterectomy, AR and MUS) and developed a prediction model for POUR by the period after prolapse surgery. This model showed good predictive performance and accurately predicted the observed outcomes. The proposed model is provided as an online risk calculator (http://lsy.io/nomogramPOUR).

There exist three prediction models for POUR following pelvic floor surgery [16–18]. These models provide an individual risk estimate of failure to pass the initial voiding trial on POD 0–2. Although it may be helpful in view of preoperative counseling and managing patient expectations, it cannot guide the optimal timing of catheter removal. Our model provides an individual risk estimate of POUR lasting > 2 and > 4 days, which could be useful in personalizing postoperative bladder care for patients undergoing prolapse surgery.

Consistent with the existing models, several vaginal procedures performed for the correction of pelvic organ prolapse were included in our model as predictors for POUR. This is likely due to pelvic floor tension secondary to pain and neuropathy resulting from the disruption of peripheral pelvic nerve branches involved in bladder sensation and micturition [7]. Our study identified native tissue apical suspension as a risk factor for POUR and is in agreement with recent studies that showed native tissue apical suspension had a three- to fivefold greater risk

of acute POUR compared to sacrocolpopexy [19, 20]. Extraperitoneal native tissue apical suspension had a greater and prolonged risk of POUR than intraperitoneal apical suspension. The pathologic mechanism for this difference is not clear but may be related to higher rates of neurologic pain requiring opioid use and concomitant levator ani plication in women receiving extraperitoneal native tissue apical suspension [1, 21]. Unlike AR, PR was not identified as a significant predictor of POUR in our model. PR does not involve manipulation of the bladder or urethra but may impair voiding function by causing pain that prevents relaxation of the pelvic floor muscles, particularly when performed with levator ani plication [1]. We avoided levator ani plication as much as possible except for women receiving extraperitoneal native tissue apical suspension, which may explain why PR was not included as a predictor in the model.

Our study found that concomitant hysterectomy doubles the risk of POUR, which is consistent with recent studies [22–24]. Concomitant MUS was also found to be a risk factor, which was included as a significant predictor variable in one previous model [17] but not in the other two models [16, 18]. Although this discrepancy may be related to variations in sling tensioning, it may also be due to the difference in the study populations used for model development (training cohort). All of the patients in our study population underwent prolapse surgery, whereas many women who had undergone only anti-incontinence surgery were included in other existing models. A recent
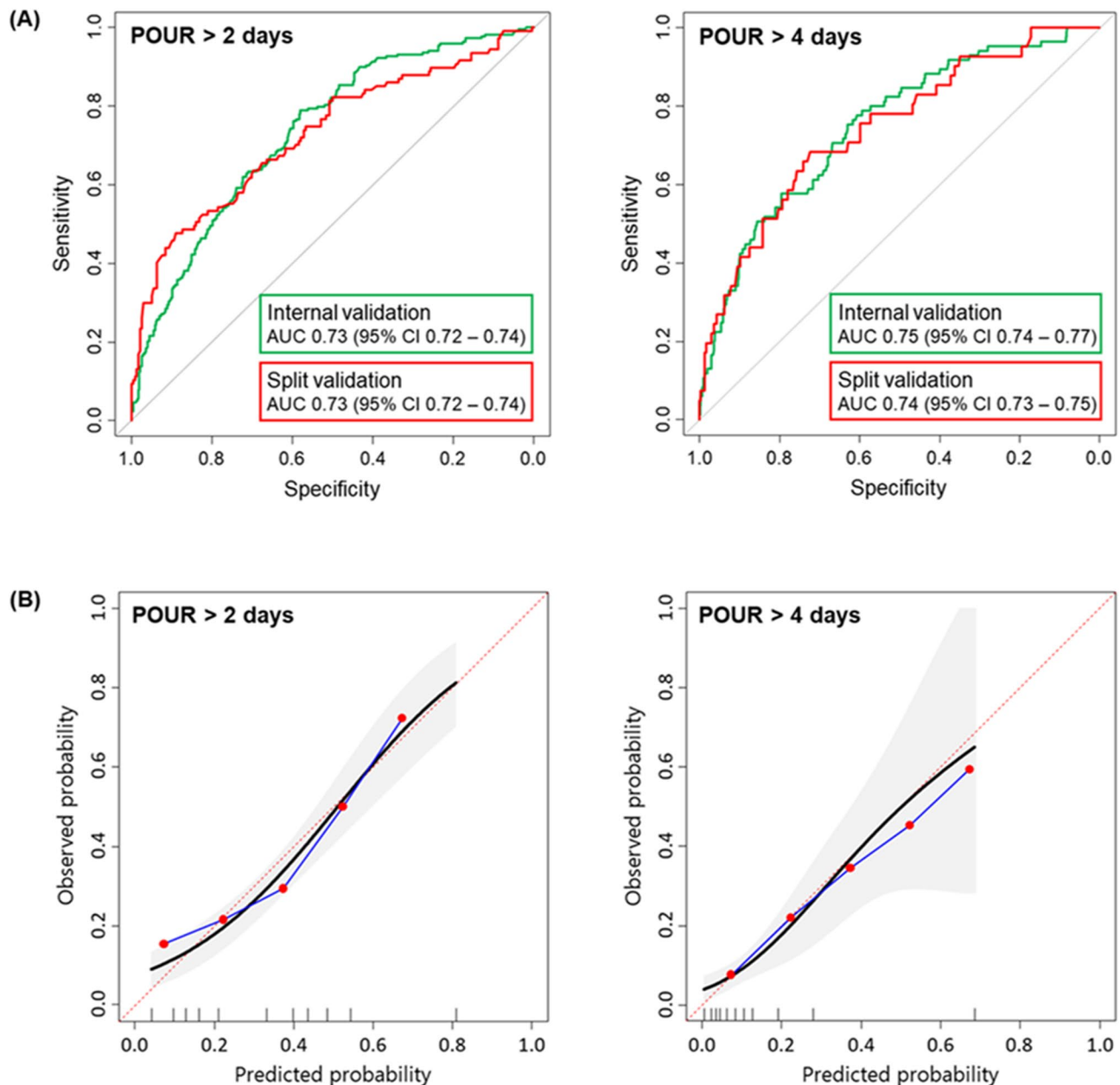
Fig. 2 (**A**) Prediction performance of the proposed model. Internal validation using five-fold cross-validation (green) and split validation using the testing cohort (red). AUC, area under the curve; CI, confidence interval; POUR, postoperative urinary retention. (**B**) Calibration curve of the prediction model. Dots indicate observed probabilities of each bin, and the blue line represents the calibration curve. The grey shading indicates 95% confidence intervals. POUR, postoperative urinary retention

systematic review also reported that concomitant MUS at the time of prolapse surgery increased the risk of POUR [25].

Apart from surgical procedures, we also identified some clinical and demographic factors that were associated with POUR. Older age had an incremental effect on POUR as reported in many previous studies [18, 19, 26], which may be associated with age-related neuronal degeneration leading to bladder dysfunction [27]. Baseline bladder dysfunction was also identified as a

significant risk factor for POUR in our model. Consistently, elevated PVR was included as a risk factor in all existing models except one model that did not include it as a candidate variable [16–18].

With the concept of enhanced recovery after surgery (ERAS) gaining popularity, early catheter removal has become a clinical trend. The American Urogynecologic Society and International Urogynecologic Association Joint clinical consensus statement on ERAS after urogynecologic surgery also recommends that the catheter

be removed as soon as feasible once there is no clinical necessity [28]. Several randomized controlled trials and a systematic review of these trials showed that early catheter removal (on POD 1–2) is more advantageous than later removal (on POD 3–5), with a lower incidence of UTI and a shorter hospital stay, although it is associated with an increased risk of recatheterization [9, 29–31]. However, these trials either did not include or had a small number of patients who underwent native tissue apical suspension. Another randomized controlled trial found that women who had an unsuccessful same-day voiding trial after vaginal reconstructive surgery including native tissue apical suspension had a 7-fold higher risk of an unsuccessful repeat voiding trial when the repeat trial was performed within 4 days after surgery than when performed on POD 7. The rates of UTI were also higher in the earlier repeat voiding trial group [32].

Our prediction model provides an individual risk estimate of POUR lasting > 2 and > 4 days. This information may be useful in determining the optimal timing of catheter removal, especially when the patients are unable to learn self-catheterization or prefer to have an indwelling catheter. For example, in patients with > 50% risk of POUR > 2 days, the indwelling catheter removal needs to be delayed. According to the risk of POUR lasting > 4 days, the timing of catheter removal for these patients can be individualized: on POD 4 (if the risk < 50%) and 7 (if the risk > 50%). The risk estimate calculated from our prediction model will also aid in individualizing a repeat voiding trial in women who failed the initial voiding trial and are discharged with an indwelling catheter.

The current study has several strengths. Our model covers most types of prolapse surgery being performed in current practice, and therefore, it can be applied to most women undergoing prolapse surgery. Unlike other existing models, our model provides risk estimates of POUR by different time periods, which can be useful in personalizing postoperative bladder care. The large sample size enabled the split validation using the testing cohort completely separated from the training cohort, and we confirmed the model's discriminative ability and accuracy. Furthermore, the availability of an online risk calculator makes this model convenient to use. Nonetheless, this study has some limitations. The retrospective study design did not allow complete data collection, and preoperative PVR results were missing in 25% of patients. Instead of excluding eligible patients due to missing data, missing values were imputed using multiple imputation for model construction. In addition, information regarding postoperative opioid use, which may impact voiding function, could not be collected. In our institution, opioids are not routinely used for pain control but are used for breakthrough pain when acetaminophen and non-steroidal anti-inflammatory drugs are not sufficient. Second,

all procedures were performed by a single surgeon, and patients only had an MUS if they had stress incontinence, which may limit the generalizability of the results. Lastly, it may be arguable whether the proposed model is applicable to populations with different baseline characteristics from ours. The predictive accuracy of our model needs to be validated further in cohorts with different backgrounds.

Conclusions

We successfully developed and validated a clinical prediction model to calculate the risk of POUR after prolapse surgery. For patients planning to undergo prolapse surgery, our prediction model might be a useful tool for clinicians to personalize postoperative bladder care. Further external validation will be required to verify this model's utility in clinical practice with different patient characteristics.

Abbreviations

POUR   Postoperative urinary retention
UTI   Urinary tract infection
PVR   Postvoid residual
POD   Postoperative day
AR   Anterior repair
PR   Posterior repair
MUS   Midurethral sling
AUC   Area under the curve
CI   Confidence interval
ERAS   Enhanced recovery after surgery

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study complied with the Declaration of Helsinki and was approved by the Institutional Review Board of Seoul National University College of Medicine/ Seoul National University Hospital (2207-078-1339). Informed consent was waived by the Institutional Review Board because of the retrospective nature of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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