Nomogram predicting early urinary incontinence after radical prostatectomy

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Abstract

Purpose One of the most frequent side effects of radical prostatectomy (RP) is urinary incontinence. The primary cause of urine incontinence is usually thought to be impaired urethral sphincter function; nevertheless, the pathophysiology and recovery process of urine incontinence remains unclear. This study aimed to identify potential risk variables, build a risk prediction tool that considers preoperative urodynamic findings, and direct doctors to take necessary action to reduce the likelihood of developing early urinary incontinence.

Methods We retrospectively screened patients who underwent radical prostatectomy between January 1, 2020 and December 31, 2023 at the First People's Hospital of Nantong, China. According to nomogram results, patients who developed incontinence within three months were classified as having early incontinence. The training group's general characteristics were first screened using univariate logistic analysis, and the LASSO method was applied for the best prediction. Multivariate logistic regression analysis was carried out to determine independent risk factors for early postoperative urine incontinence in the training group and to create nomograms that predict the likelihood of developing early urinary incontinence. The model was internally validated by computing the performance of the validation cohort. The nomogram discrimination, correction, and clinical usefulness were assessed using the c-index, receiver operating characteristic curve, correction plot, and clinical decision curve.

Results The study involved 142 patients in all. Multivariate logistic regression analysis following RP found seven independent risk variables for early urinary incontinence. A nomogram was constructed based on these independent risk factors. The training and validation groups' c-indices showed that the model had high accuracy and stability. The calibration curve demonstrates that the corrective effect of the training and verification groups is perfect, and the area under the receiver operating characteristic curve indicates great identification capacity. Using a nomogram, the clinical net benefit was maximised within a probability threshold of 0.01–1, according to decision curve analysis (DCA).

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Conclusion The nomogram model created in this study can offer a clear, personalised analysis of the risk of early urine incontinence following RP. It is highly discriminatory and accurate, and it can help create efficient preventative measures and identify high-risk populations.

Keywords Prostate cancer, Radical prostatectomy (RP), Urinary incontinence, Urethral pressure profile

Introduction

Among the cancers that affect men most frequently is prostate cancer. The most effective treatment for clinically localised prostate cancer is still radical prostatectomy (RP). The most significant side effect impacting quality of life after RP is urinary incontinence, which may influence the decision to proceed with RP as a therapeutic option. While controlling cancer is the main objective, patients should also prioritise secondary outcomes like recovering from incontinence. Therefore, optimising incontinence outcomes without sacrificing oncologic outcomes presents a challenge for prostate cancer surgeons. With most patients gradually regaining urine incontinence within a year of surgery [1] and even more patients regaining it within two years of surgery [2], many high-volume surgeons have demonstrated reasonable long-term control rates in their patient populations. But even in the hands of experts, early control is not always reliable [3]. There are now several characteristics that have been identified as potential risk factors for urine incontinence (PPI) following radical prostatectomy, including patient age, history of prostate surgery, preoperative voiding issues, body mass index, prostate volume, surgical method, pathological stage, and comorbidities [4, 5]. Ragusa A et al. also proposed to discuss whether the length of the operated urinary tract is the only critical factor for urinary tract recovery after radical prostatectomy [6]. Several variables have been linked to an early incontinence recovery after RP. Patients with type 2 diabetes require more time to recover from urine incontinence following laparoscopic radical prostatectomy than do non-diabetic patients [7]. Urinary incontinence after a radical prostatectomy can be predicted by the urethral pressure profile before the procedure [8]. Predictive models have yet to be wholly created for early PPIs, though. Thus, creating a model to help clinicians anticipate early PPIs is essential. This concept states that physicians determine the likelihood of an individual experiencing PPI at an early age and take appropriate action.

One of the statistical techniques that clinical prediction models employ the most frequently is the nomogram. It can visualise abstract and complex regression equations and facilitate the calculation of risk factor probability, in addition to its benefits of simplicity, intuitiveness, and ease of use. Using nomograms as an alternate or even a new standard is advised, as they have been demonstrated to be more dependable than other systems [9]. For clinical decision-making, this tool offers insightful information. It has been extensively utilised to assess patients' prognoses in recent years [10–14]. To create a risk assessment model, identify patients at risk of pressure ulcers (UPI) early, accurately manage patients, and allocate medical resources, the nomogram clinical prediction model was employed in this study to explore the independent risk factors of early urinary incontinence following RP.

Patients and methods

Study population and experimental design

We conducted a retrospective study on patients who had surgery at the First People's Hospital of Nantong's Department of Urology between January 2020 and December 31, 2023. To each patient was offered all therapies suggested by the EAU recommendations by the risk of the condition. Qualifications for inclusion are as follows: (1) radical prostatectomy performed in our hospital; (2) preoperative imaging examination (SPECT/CT) showing no tumour metastasis; and (3) comprehensive clinical and follow-up data. (4) No further cancers. Exclusion standards: Patients with the following ailments were not accepted: (1) preoperative hormone treatment before surgery, pelvic radiation; (2) incomplete or absent medical records; and (3) cerebral infarction history. 171 RP patients met the inclusion criteria and were included in the study. Eight patients had a history of cerebral infarction, ten patients had insufficient clinical data, and eleven patients underwent either preoperative endocrine therapy or chemotherapy. These patients were, therefore, disqualified. In the end, 142 individuals with localized intermediate- and high-risk prostate cancer, with a clinical stage of T (2a to c) N0M0, ultimately made up the study population. Following catheter removal, it was recommended to all patients to undertake Kegel exercises. A flow chart of the case selection and study procedure is shown in Fig. 1.

Ethics and informed consent

The study complied with the Declaration of Helsinki's tenets. It was authorised by the Central Ethics Committee of the First People's Hospital of Nantong (ethical approval number 2022KT100), and informed consent was obtained from all subjects.

Data collection and variable definition

Demographic characteristics included gender, age, body mass index (BMI), hypertension, diabetes mellitus, prior
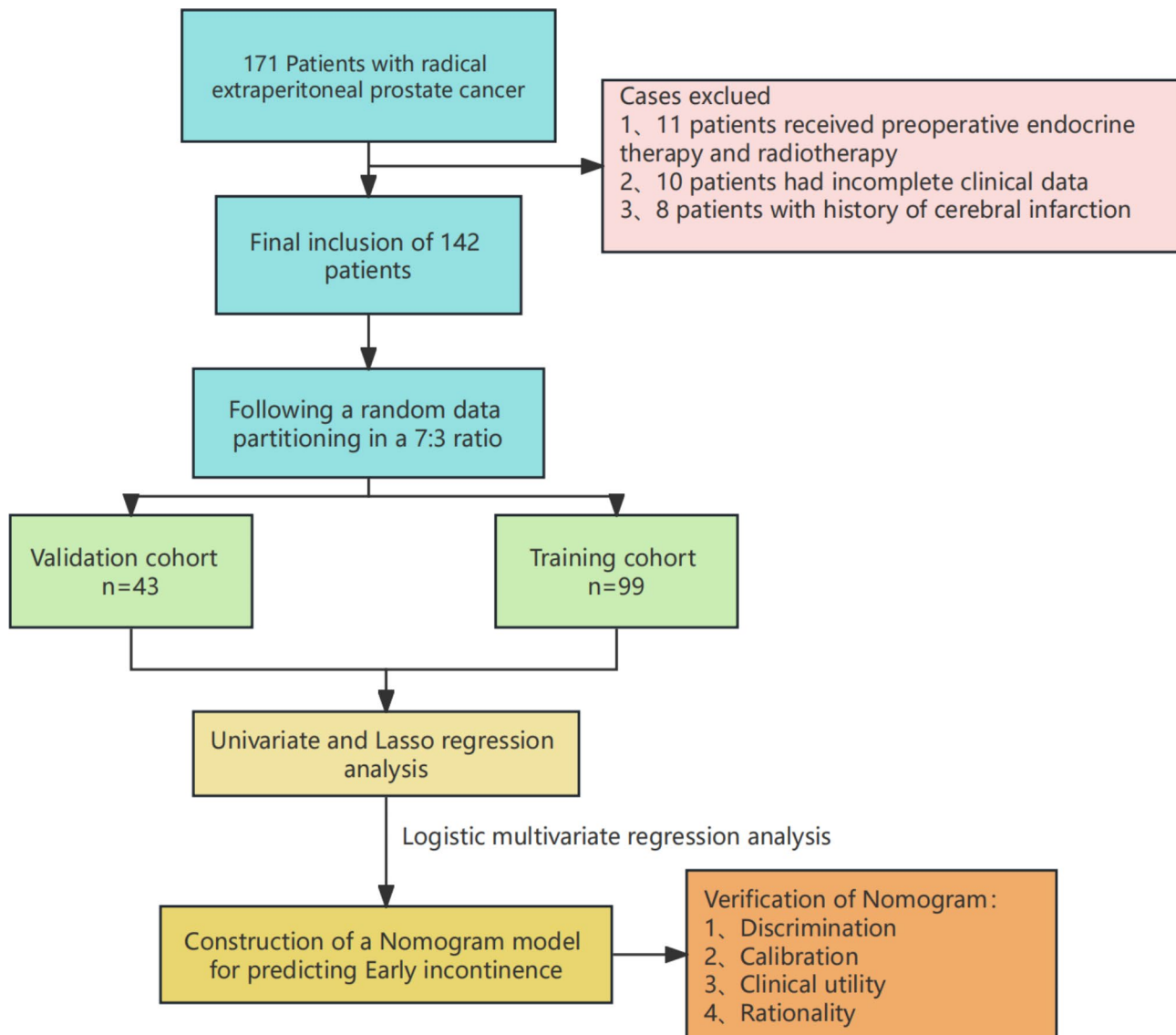
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Fig. 1 Research pathway diagram

transurethral resection of the prostate, PSA, fPSA, f/t, PSAD, prostate volume V (ml), prostate health index PHI, PI-RADS Score, Lesion size (cm), Gleason Score, history of diabetes, Maximal urethral closure pressure (cmH2O), Functional urethral length (mm), and Lower urinary tract symptoms, all of which were derived from electronic medical records.

Definition of early incontinence

Every patient completed the International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form (ICIQ-UI SF) [15]. As previously mentioned, the Valsalva physical examination or cough test assessed the patient's continence status three months following surgery [16]. Doctors who were not involved in the treatment in our outpatient clinic conducted these

examinations. Individuals were deemed to have perfect urinary continence (complete dryness) if they coughed or did not lose urine during the Valsalva test. Patients were considered adequate urine continence if they remained dry but required 0–1 pads while going about their regular lives. Urinary incontinence was defined as needing more than one liner daily, leakage during coughing or Valsalva testing, and leakage at sleep. Three groups based on how long the incontinence lasted were identified: early (within three months), middle (4~12 months), and late (between thirteen to twenty-four months). Patients who used more than 1 pad per day for 3 months after radical prostatectomy and/or had urinary leakage during cough or Valsalva test and/or at night were considered as having early incontinence.

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Surgical technique

All operations were performed by an experienced surgeon using laparoscopic radical prostatectomy via an extraperitoneal approach. No nerve was preserved during the operation, and no posterior (Rocco stitch) or anterior reconstruction of the rhabdopshincter was performed. The specific steps were as follows: the patient is tilted between 15 and 20 degrees while lying supine in the Trendelenburg position. After the catheter was inserted, a 3-cm incision was created beneath the umbilicus. The posterior rectus sheath was then revealed by sequential dissection. By inserting the middle finger behind the rectus muscle and using balloon dilatation and blunt finger dissection, the surgeon produced the extraperitoneal space. The camera was inserted into the infraumbilical incision using a 12 mm trocar. The transperitoneal technique then established pneumoperitoneum. Two 5-mm ports were then made and positioned so they could be seen. Another laparoscopic port was inserted in the suprapubic area following the identification and dissection of the left iliac fossa. As a result, four trocars were made: two surgical ports, one for the helper and one for the camera. Insert the camera through this port once the pneumoperitoneum has reached a pressure of 12 to 15 mmHg. One accessory port and the other three ports were visible. Initially, an inverted "U"-shaped incision was made on both sides of the median umbilical ligaments. Subsequently, the intrapelvic fascia was made visible and cut. The dorsal venous complex was sealed via vascular sealing following bladder neck dissection. The vas deferens were severed, and the seminal vesicles were dissected after the catheter was removed. The prostate can be dissected once the connection between the prostate and the proximal urethra is sliced. The apex of the prostate is separated from the superficial Denonvilliers' fascia. The bladder neck was preserved by urethrovesical anastomosis. Lastly, a drain is inserted into the pelvis and often withdrawn once the surgical wound has closed.

Gleason score criteria

Two experienced physicians sectioned and stained the surgical specimens. They were pathologically scored using the Gleason grading system [17] (primary histologic score+secondary histologic score=total score), with grade 1 cell differentiation scored at ≤6, grade 2 cell differentiation scored at 3+4=7, grade 3 cell differentiation scored at 4+3=8, grade 4 cell differentiation scored at 4+4, 3+5, 5+3=8, and grade 5 cell differentiation scored at 9–10. The less distinct the cells are, the higher the score.

Histopathological evaluation

The same genitourinary pathologist (>15 years of experience) evaluated all biopsy samples. The location, percentage of malignant tissue per core, and Gleason score (GS) based on the International Society of Urological Pathology 2005 consensus [18] were recorded for each prostate cancer-positive biopsy core.

Statistical analysis

The continuous data were evaluated using the Student's t-test or the Mann-Whitney U test, and the results were reported as mean±standard deviation (SD) or median and interquartile range. Alternatively, categorical data reported as numbers (%) was evaluated using Fisher's exact or Chi-square tests. We used LASSO regression to reduce the dimension of high-dimensional data to identify the best predictive characteristics and variables of PPI [19]. Next, we used univariate logistic regression analysis on the training group to determine the PPI risk factors, and variables with *P* values less than 0.05 were included in the multiple logistic regression model to screen for independent risk factors. Lastly, the concordance index (C-index), receiver operating characteristic (ROC) curve, Hosmer – Lemesgoodhow nest test, and calibration curve [20] were used to assess the accuracy, stability, recognition ability, and structure of the training and validation group models. The results of the logistic regression analysis were visualized using the "rms" and "regplot" software packages in R software version 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria). We assessed our predictive model's clinical usefulness using Decision Curve Analysis (DCA). DCA balances true and false positives while quantifying the model's net gain at various threshold probabilities [21]. Quantifying the net benefit at various threshold probabilities in surgical cohorts for prostate cancer will help assess the clinical value of the early PPI nomogram [22]. Except for individual markers, every definition was statistically significant ($P<0.05$).

Results

Clinical features

We collected data from 142 patients who underwent radical prostatectomy at the First People's Hospital of Nantong from January 1, 2020, to December 31, 2023. 68 cases (47.89%) developed early postoperative urinary incontinence, and 74 cases (52.11%) did not. Table 1 describes the demographic characteristics of the patients.

Risk factors associated with PPIs

Univariate analysis showed that 21 variables were statistically significant ($P<0.05$). Table 2 summarizes the results of the univariate analysis. The 21 significant variables from the univariate analysis were internally validated using a 10-fold cross-validation approach with pi incidence as the dependent variable and Lambda. Min was selected as λ filter variable. Figure 2 describes how the

Table 1 Baseline characteristics of patients

Characteristics	Total(*N* = 142)	Early incontinence(*N* = 68)	Non-early incontinence(*N* = 74)	*P*
Age(year), n(%)				
≤65	50 (35.21%)	15 (22.06%)	35 (47.30%)	0.003
>65	92 (64.79%)	53 (77.94%)	39 (52.70%)	
BMI(kg/m^2)	22.79[19.38;25.14]	21.23[19.16;24.30]	24.22 [20.76;26.12]	0.002
PSA(ng/ml)	12.75 [7.80;23.98]	11.95 [7.66;22.25]	12.90 [8.12;29.20]	0.446
fPSA(ng/ml)	1.34 [0.92;2.58]	1.19 [0.81;2.06]	1.46 [1.03;3.26]	0.087
fPSA/tPSA	0.10 [0.07;0.14]	0.10 [0.07;0.14]	0.10 [0.08;0.15]	0.356
V(ml)	48.09[33.19;72.09]	39.97 [29.95;69.10]	56.58 [37.12;78.53]	0.003
PSAD	0.42 [0.22;0.82]	0.45 [0.23;0.74]	0.39 [0.22;0.83]	0.709
PHI	53.71[38.96;78.54]	48.86 [36.44;78.28]	56.81 [44.34;86.08]	0.084
Lesion size(cm)	1.30 [0.90;1.90]	1.30 [0.90;1.63]	1.33 [0.90;2.20]	0.147
PI-RADS Score, n(%)				
3	35 (24.65%)	14 (20.59%)	21 (28.38%)	0.029
4	61 (42.96%)	37 (54.41%)	24 (32.43%)	
5	46 (32.39%)	17 (25.00%)	29 (39.19%)	
Gleason Score, n(%)				
3 + 3	9 (6.34%)	4 (5.88%)	5 (6.76%)	0.112
3 + 4	52 (36.62%)	33 (48.53%)	19 (25.68%)	
4 + 3	38 (26.76%)	15 (22.06%)	23 (31.08%)	
4 + 4	27 (19.01%)	10 (14.71%)	17 (22.97%)	
4 + 5	14 (9.86%)	5 (7.35%)	9 (12.16%)	
5 + 4	2 (1.41%)	1 (1.47%)	1 (1.35%)	
Diabetes History, n(%)				
NO	67 (47.18%)	41 (60.29%)	26 (35.14%)	0.005
Yes	75 (52.82%)	27 (39.71%)	48 (64.86%)	
LUTS, n(%)				
NO	80 (56.34%)	46 (67.65%)	34 (45.95%)	0.015
Yes	62 (43.66%)	22 (32.35%)	40 (54.05%)	
History of electrocision, n(%)				
NO	72 (50.70%)	44 (64.71%)	28 (37.84%)	0.002
Yes	70 (49.30%)	24 (35.29%)	46 (62.16%)	
MUCP (cmH2O)	48.50[42.00;68.00]	65.50 [42.00;68.25]	46.00 [42.00;68.00]	0.404
FUL (mm)	36.00[32.00;43.00]	42.00 [33.00;45.00]	33.50 [31.00;42.00]	0.001

Abbreviations PHI, Prostate Health Index; LUTS,lower urinary tract symptoms; MUCP, Maximal urethral closure pressure; FUL,Functional urethral length

Lasso method numerically screens variables using seven variable coefficients varying with penalty coefficients. When the coefficient is 0, the coefficient of the initial integration factor is compressed and removed from the model. Each row corresponds to a variable. As shown in Fig. 2, the target covariates were determined using the area under the ROC curve (ACU) with 10-fold cross-validation. Each red dot indicates the confidence interval at the corresponding λ value for the covariate of interest, and two lines indicate Lambda: min and Lambda. Lse Seven variables were finally selected, including age, body mass index, prostate volume, history of diabetes, lower urinary tract symptoms, history of transurethral resection of the prostate, and functional urethral length.

We assigned the seven resulting variables and analyzed them using logistic multivariate regression. To investigate collinearity between variables, we performed a large number of collinearity diagnoses on the logistic regression analysis results. The results showed that the variance inflation factor (VIF) of each index was less than 5, and there was no collinearity. Regression analysis was performed using the full inclusion method, and finally, 7 factors were included in the regression model (Table 3).

Modal mapping model for estimating early PPI risk after RP
The enrolled patients were split into training and test groups in a 3:1 ratio using a randomized stratified grouping technique (supplementary file). To assess the risk likelihood of early PPI in patients following RP, we generated individualized nomogram estimation based on the risk factors determined by Lasso regression and binary logistic regression (Fig. 3).

Validation of nomogram models
The AUC was 0.790 (95% CI: 0.7011–0.8798) for the training cohort model (Figs. 4) and 0.716 (0.5615–0.8714) for the testing cohort model (Fig. 4). The model is well-calibrated in both training and testing cohorts.

Table 2 Univariate Cox regression analysis of risk factors associated with early urinary incontinence in patients undergoing RP

Characteristics	B	SE	OR	CI	Z	*P*
Age(year)	−1.168	0.4511	0.311	0.311(0.124–0.736)	-2.588	0.01
BMI(kg/m^2)	0.208	0.06459	1.231	1.231(1.09–1.406)	3.215	0.001
PSA(ng.ml)	0.007	0.00762	1.007	1.007(0.994–1.025)	0.945	0.345
fPSA	0.042	0.07532	1.043	1.043(0.904–1.234)	0.559	0.576
fPSA/tPSA	1.167	3.48713	3.211	3.211(0.003–4691.)	0.335	0.738
V(ml)	0.027	0.00934	1.027	1.027(1.009–1.047)	2.847	0.004
PSAD	0.303	0.29755	1.354	1.354(0.791–2.615)	1.019	0.308
PHI	0.003	0.00488	1.003	1.003(0.993–1.013)	0.531	0.595
Lesion size(cm)	0.411	0.27039	1.509	1.509(0.929–2.681)	1.521	0.128
PI-RADS Score 4	-0.97	0.55628	0.379	0.379(0.122–1.102)	-1.745	0.081
PI-RADS Score 5	-0.059	0.59223	0.942	0.942(0.286–2.987)	-0.1	0.92
Gleason Score 3 + 4	-0.734	0.80364	0.48	0.48(0.087–2.257)	-0.913	0.361
Gleason Score 4 + 3	-0.27	0.83407	0.764	0.764(0.133–3.833)	-0.323	0.746
Gleason Score 4 + 4	-0.154	0.88102	0.857	0.857(0.138–4.762)	-0.175	0.861
Gleason Score4 + 5	0.049	0.96239	1.05	1.05(0.149–7.079)	0.051	0.96
Gleason Score5 + 4	-0.511	1.59164	0.6	0.6(0.018–19.21)	-0.321	0.748
Diabetes History	1.102	0.41985	3.009	3.009(1.337–6.977)	2.624	0.009
LUTS	0.894	0.41551	2.446	2.446(1.094–5.613)	2.152	0.031
History of electrocision1	1.024	0.41631	2.784	2.784(1.244–6.401)	2.459	0.014
MUCP(cmH2O)	-0.018	0.0153	0.982	0.982(0.953–1.012)	-1.158	0.247
FUL(mm)	-0.077	0.03423	0.926	0.926(0.865–0.989)	-2.24	0.025

Abbreviations PHI, Prostate Health Index; LUTS, lower urinary tract symptoms; MUCP, Maximal urethral closure pressure; FUL, Functional urethral length
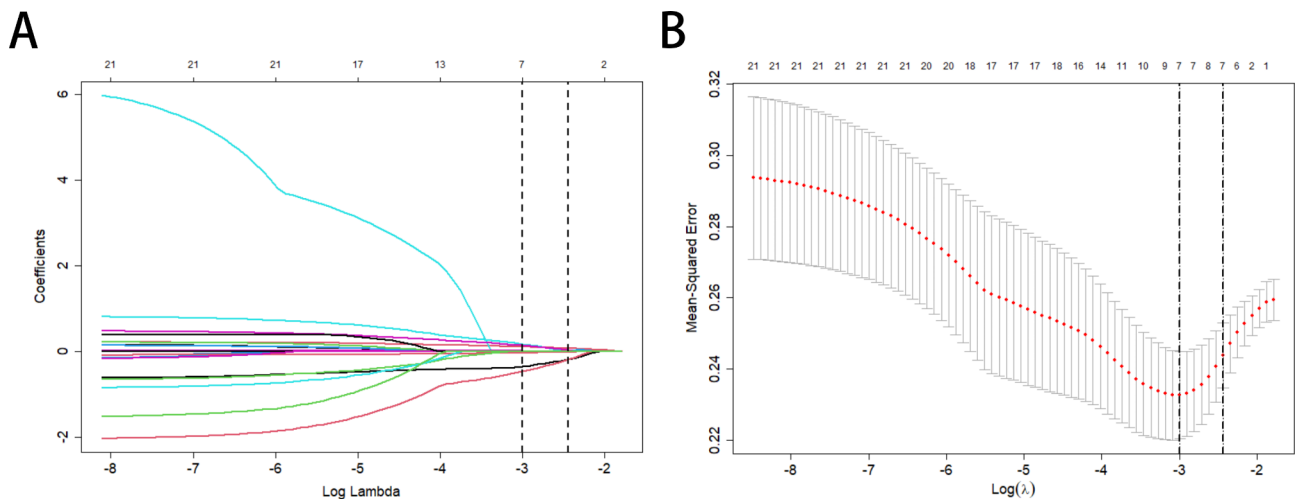

Fig. 2 LASSO-based significant variable selection. (**A**) Coefficient profile plotted versus log (lambda) for all variables. (**B**) ten-fold cross-validation used to validate the optimal lambda in the LASSO model. LASSO, the least absolute shrinkage and selection operator (LASSO)

Table 3 Multivariate Logistic regression analysis of risk factors for PPI

Variables	B	SE	OR	CI	Z	*P*
Age(year)	-0.549	0.61346	0.577	0.577 (0.168–1.919)	-0.895	0.371
BMI	0.171	0.07171	1.186	1.186 (1.034–1.374)	2.385	0.017
V(ml)	0.019	0.01065	1.019	1.019 (0.999–1.042)	1.791	0.073
Diabetes History	0.027	0.62445	1.028	1.027 (0.285–3.414)	0.044	0.965
LUTS	0.52	0.49047	1.681	1.681 (0.638–4.436)	1.059	0.29
History of electrocision	0.441	0.51188	1.554	1.554 (0.559–4.241)	0.862	0.389
FUL(mm)	-0.067	0.04049	0.936	0.935 (0.862–1.012)	-1.644	0.1

Abbreviations LUTS, lower urinary tract symptoms; MUCP, Maximal urethral closure pressure; FUL, Functional urethral length
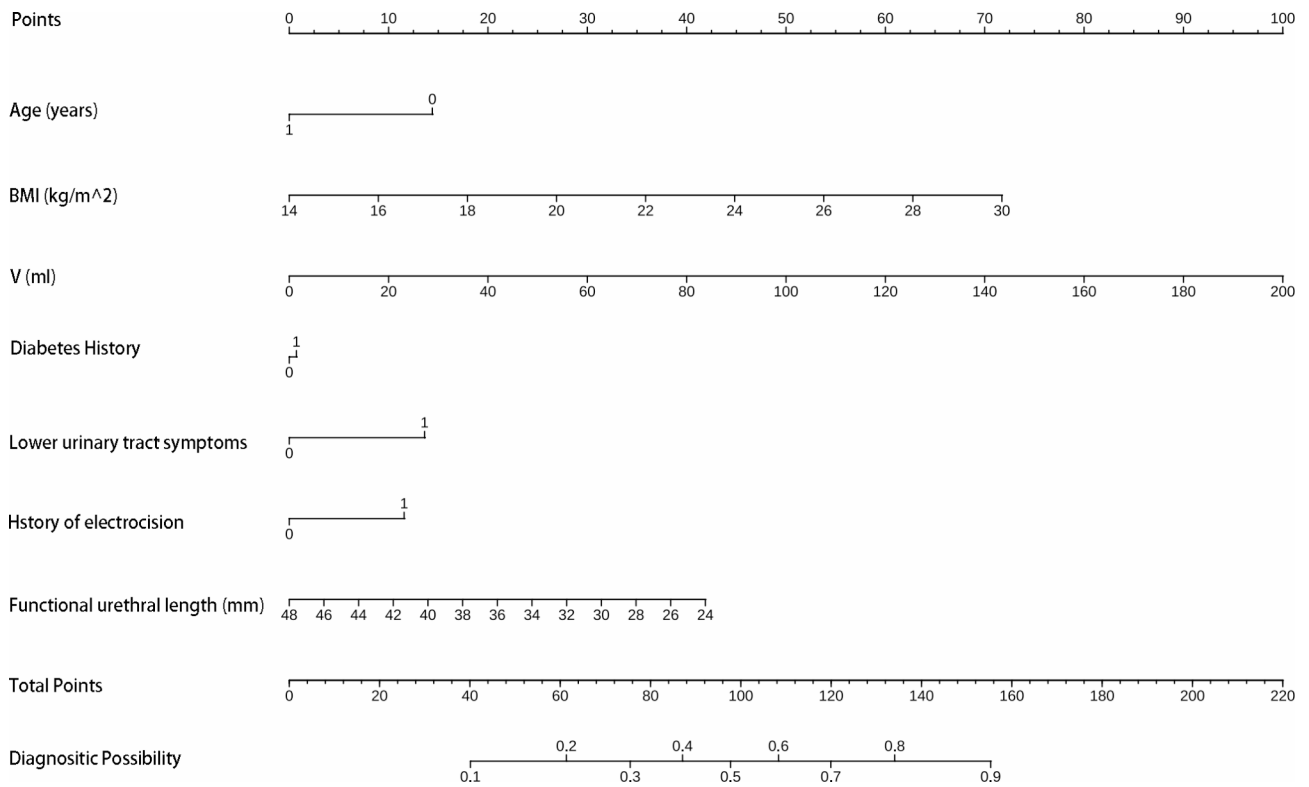
Fig. 3 A nomogram to forecast the likelihood of RP's early PPI. By drawing a line upward from the corresponding values to the "points line," points were assigned for each variable. The total of the individual scores for each of the seven variables that make up the nomogram was used to get the "total points." By calculating the likelihood that corresponds to the "total points," we may determine the patient's early PPI risk. BMI, Prostate Health Index
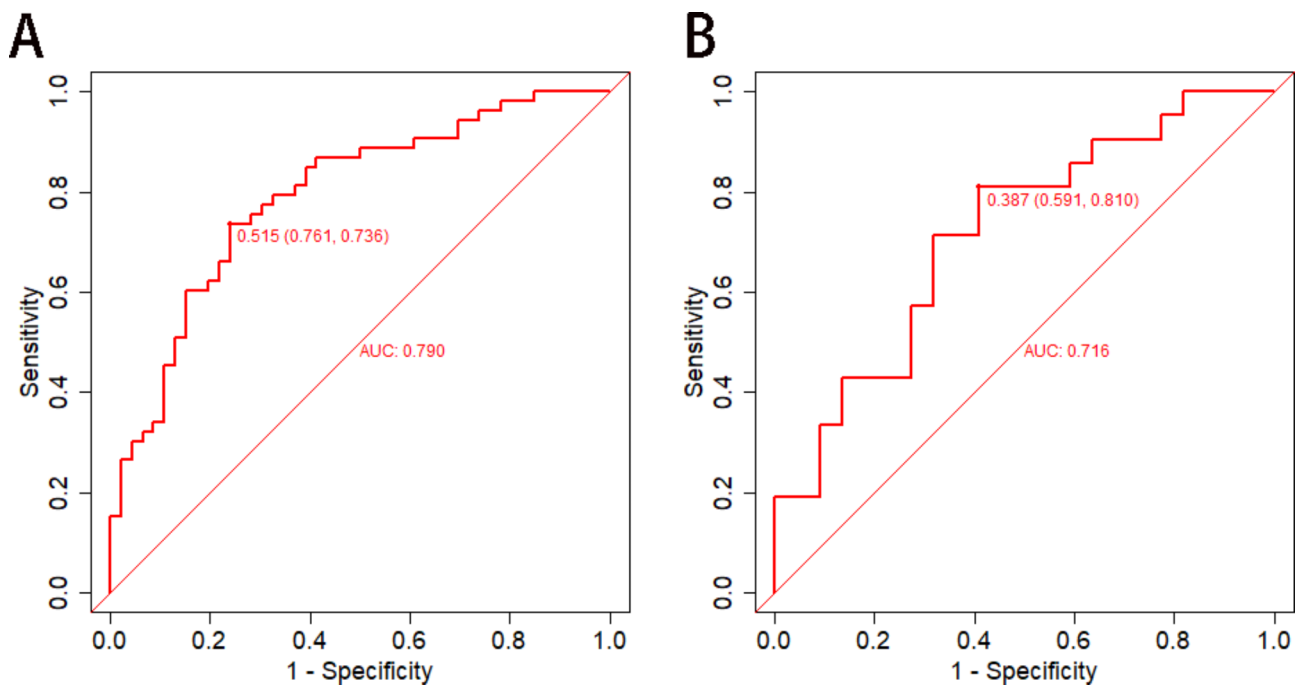

Fig. 4 The evaluation and internal validation of the nomogram. (**A**) The AUC of the training group (AUC = 0.790) and (**B**) the validation group (AUC = 0.716) showed that the model had a high discrimination ability
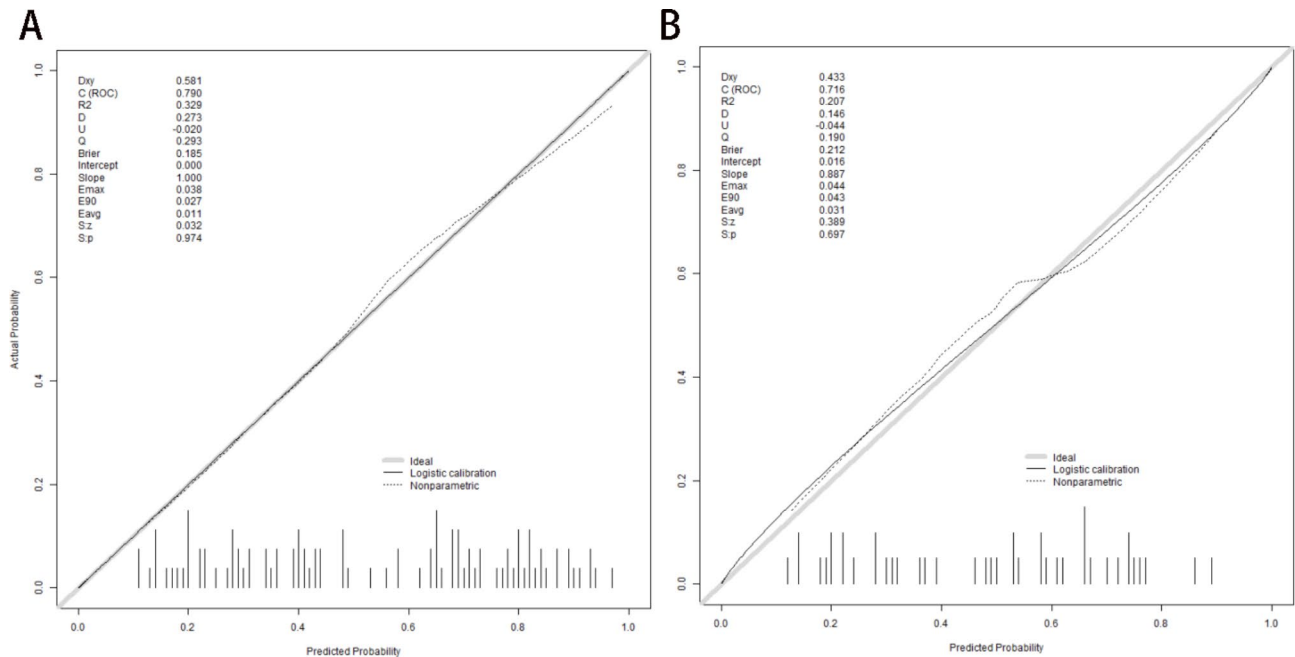
Fig. 5 A calibration curve is used to assess the concordance between predicted risk and actual risk of PPI in the early postoperative period. (**A**) The Calibration curve of the training group and (**B**) the validation group
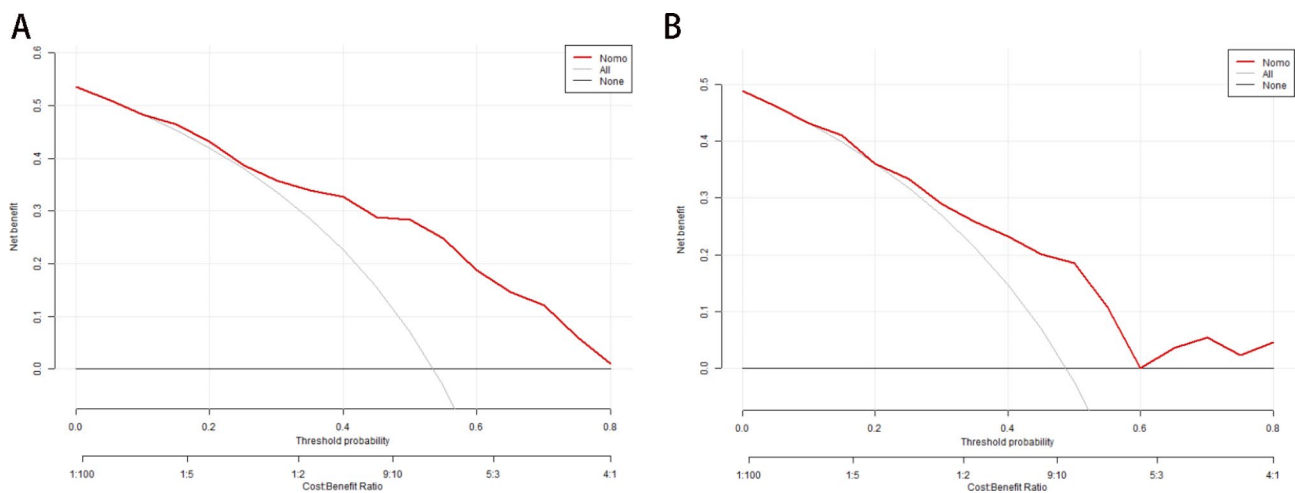

Fig. 6 Model's decision curve. Decision curve of the training group and (**B**) the validation group. The red line represents the nomogram net clinical benefit of early PPI; the net clinical benefit of early PPI, corrected for optimism using fivefold cross-validation, is defined by the blue line of the cross-validated curve. The fine solid black line suggests that no patient had early PPI, but the solid grey line shows that every patient had early PPI. There could be a higher net benefit from this DCA, between 8 and 50%. The nomogram model will benefit more from therapy than either no treatment (assuming all patients were non-early PPI) or all treatment (assuming all patients were early PPI) if the risk threshold is less than 50%

The model was well corrected according to the Hosmer-Lemeshow goodness-of-fit test for the training cohort ($\chi 2 = 3.6026$, $P = 0.8911$) and the validation cohort ($\chi 2 = 4.8152$, $P = 0.7771$). The calibration analysis of the model is shown in Fig. 5, which demonstrates the model calibration after 500 Bootstrap internal sampling. The Brier score of the training set was 0.185 with a *p*-value of 0.974 (>0.05), and the Brier score of the validation set was 0.212 with a *p*-value of 0.9697 (>0.05). The

calibration curve showed a strong correlation between the predicted and actual probability of occurrence.

Analysis of clinical practicability and rationality of prediction model

To assess the clinical utility of nomogram, we used the predicted probability of the calibration plot as a test variable and the incidence of early PPI in patients after RP as a state variable. We constructed a clinical decision curve (DCA) for the nomogram model as shown in Fig. 6.

In the DCA curve, two dashed lines represent two extreme cases, and the grey horizontal line indicates that the model predicts no early incontinence in all RP patients and zero clinical benefits. Another grey line with a negative slope indicates that the model predicts early incontinence in all RP patients, and the clinical benefit curve is a negative slope line. The red curve represents the benefit for patients using the predictive model for this study. When the predicted probability was more significant than the 0.05 threshold (wide range), the red curve was higher than the grey horizontal line and the grey negative tilt line, indicating that patients could benefit from the prediction model of this study.

In addition, as shown in the clinical impact curves (Fig. 7A-B), when this prediction model was used to risk stratify a population of 1000 people, the two curves closely overlapped, indicating that it performs well in clinical applications.

Discussion

Urinary incontinence (UI) is a common RP consequence that negatively affects patients' quality of life (QoL), frequently necessitates follow-up care, and adds to the financial load on the health care system [23, 24]. With the application of multi-parameter magnetic resonance imaging and in vivo optical imaging, the detection rate of cancer, including prostate cancer, has increased [25, 26]. However, imprecise estimates of recovery duration and intensity may also impact RP decisions. Lowering post-prostatectomy urine incontinence (PPI) duration or severity will improve patient outcomes and save related medical expenses. As a result, developing prediction models and determining the characteristics of patients who experience early onset of urine incontinence and those who do not follow RP are crucial for clinical diagnosis and prompt PPI intervention.

We examined the clinical information and easily accessible laboratory and anthropological parameters, such as age, gender, BMI, prostate-specific antigen, diabetes, and urodynamic parameters, of 142 patients who experienced early urinary incontinence following radical prostatectomy. We used several statistical techniques to determine the independent variables contributing to developing early PPI in RP patients. These variables were age, body mass index, prostate volume, history of diabetes, lower urinary tract symptoms, history of transurethral resection of the prostate, and functional urethral length. We created a straightforward and precise nomogram, verified it within the model, and demonstrated its clinically solid applicability and efficacy.

The results of this study showed that the following variables were independent risk factors for early PPI: prostate volume, age, BMI, diabetes, history of transurethral resection of the prostate, and lower urinary tract
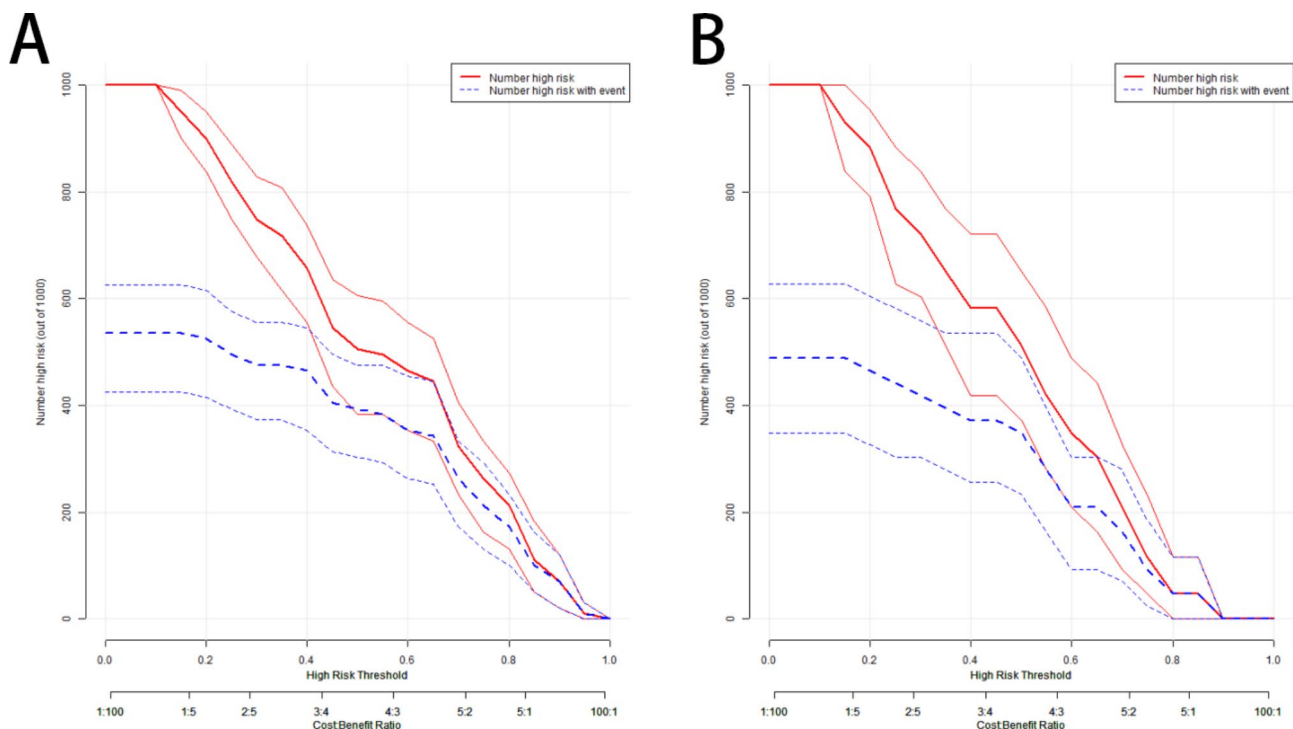

Fig. 7 Clinical impact curve. The model's clinical impact curve during training (**A**) and validation (**B**) was observed. The number of people that the model determines to be at high risk under various probability criteria is shown by the red line. The number of participants that the model deems to be at high risk but who in reality have an outcome event falling beneath certain probability criteria is represented by the blue line

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symptoms. The length of the membranous urethra protects early PPI. One of the best indicators of a less successful recovery from urine incontinence after a year is reportedly age. In a prospective investigation of 206 patients, Licht et al. [27] discovered that age greater than 65 was an independent predictor of inadequate recovery of urine function following RP. An earlier study by Eastham et al. [28] examined 581 consecutive 2-year patients to identify risk factors for urine incontinence following RP and to identify characteristics that predicted an early recurrence of urinary incontinence. Age was the most significant risk factor in the multivariate study. Obesity or body mass index is linked to a delayed recovery from postpartum voiding incontinence. Mulholland et al. [29] delivered voiding function questionnaires to 268 patients over two years to examine the impact of BMI on post-RP urine incontinence. However, the number of respondents in this study was restricted. It relied on the correlation between the degree of leakage and BMI. Of the 182 replies, they did not detect a link between urinary function and BMI. Similarly, obese patients experienced a delayed recovery from urine incontinence, according to research by Ahlering et al. [30] on 100 patients who had robotic RP. Delays in recovering from incontinence have also been linked to increases in prostate volume. The impact of prostate volume on urine incontinence in participants included in the CaPSURE registry was examined by Konety et al. [31]. After adjusting for patient age and BMI, the authors discovered that RP in patients with prostate volumes more significant than 50 ml was linked to decreased rates of urine incontinence at 6 and 12 months. Of these patients, 2097 possessed data on their prostate sizes. Urinary incontinence recovery after RP may also be prolonged in patients with medical comorbidities, especially diabetic mellitus (DM). To determine how comorbidities affected men undergoing RP for localized prostate cancer in terms of their sexual, urological, and health-related quality of life, Karakiewicz et al. [32]. carried out a survey-based study. For the 2415 males who responded to the survey, the authors discovered a significant correlation between the incidence of lifetime comorbidities and declining urine performance. According to a more focused investigation, individuals with type 2 diabetes recover from urine incontinence following LRP more slowly than individuals without the disease [7]. Urinary incontinence is also thought to be adversely affected by transurethral resection of the prostate, or TURP. Elder et al. [33] assessed thirty individuals who had undergone radical prostatectomy of the perineum following TURP and discovered that RP administered four weeks to four months following TURP exacerbated the patient's urine incontinence. Urinary incontinence in the past or symptoms related to the lower urinary tract are deemed to be unfavourable risk factors for urine incontinence

following RP. Urine incontinence before RP was an unfavourable risk factor for urine incontinence following RP, according to a prospective evaluation of 482 RP patients by Wei et al. [34]. Urinary incontinence recovery from RP is also linked to delayed recovery of membrane urethral length. Preoperative functional urethral length (FUL) is also associated with delayed recovery of urinary incontinence after RP. Functional urethral length can be measured during urodynamic testing. Hammerer and Huland [35] evaluated urodynamics in 82 men before and after prostatectomy and found that urethral closure pressure, functional urethral length, and bladder stability were important urodynamic factors affecting continence after radical prostatectomy. Similarly, Mirko Bakula et al. [8] found that preoperative assessment of FUL and MUCP were valuable prognostic factors for early incontinence recovery after open retropubic RP (ORRP).

This work aimed to establish nomograms to forecast the risk rate of early PPIs and identify risk variables for developing early PPIs. After screening, seven predictors were added to the nomogram. The nomogram's risk prediction ability for the validation set was 0.792 and 0.719, respectively. Three things make up this study's main advantages: first, prediction models were constructed using straightforward, objective clinical data; second, the variables needed to build the models are easily obtained, which significantly improves the model's universality and makes it easier to apply in clinical practice. Finally, with a sensitivity of 0.761 and a specificity of 0.736, our nomograms demonstrated significant distinction, consistency, and calibration.

The current study has some limitations; this is a single-centre cross-sectional study with a limited sample size that may introduce selection bias. Second, urethral length was not included as a predictor in the prediction model since many of the patients in the sample had lost their MRI pictures. Furthermore, a trained observer measured each instance, and in order to guarantee high reliability across ratings, two or more scorers will be used in our next investigation. In addition, we only performed internal validation on nomogram models, and subsequent studies also required external validation. A large sample, multicenter, prospective study can be conducted to find more risk factors for early PPI complications in RP patients so that relevant measures can be taken early to accelerate the recovery of urinary incontinence after RP and improve patients' quality of life.

Conclusion
In conclusion, age, body mass index, prostate volume, history of transurethral resection of the prostate, diabetes mellitus, symptoms related to the lower urinary tract, and functional urethral length are independent risk factors for early urine incontinence following radical

prostatectomy. To avoid the development of early urine incontinence, early management is recommended, particularly for patients with several risk factors. Our team has developed a simple and workable early PPI prediction model that can be used in primary carver, it can also serve as a reminder for urologists to sharpen their surgical techniques and focus on maintaining the functional urethra to fulfil the goal of passive prevention for patients having a radical prostatectomy. Early urine incontinence following prostatectomy can be prevented more successfully by addressing high-risk factors for the condition early on in the course of managing prostate cancer and implementing both active and passive preventative techniques.

Abbreviations
BMI	Body mass index
RP	Radical prostatectomy
PPI	post-prostatectomy incontinence
PHI	Prostate Health Index
LUTS	lower urinary tract symptoms
MUCP	Maximal urethral closure pressure
FUL	Functional urethral length
DCA	Decision curve analysis
SPECT/CT	Single-photon emission computed tomography/computed tomography

Supplementary Information
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Supplementary Material 1

Author contributions
CS wrote the first draft of the manuscript. CS, XZ, XZ, ZC, XFC, WZ and BZ collected and analyzed the data. DHG supervised the work.

Data availability
Data are provided in the Supplementary Information files.

Declarations

Ethics approval and consent to participate
The research involving human subjects was reviewed and approved by the Medical Ethics Review Committee of the First People's Hospital of Nantong, in strict adherence to the principles of the Declaration of Helsinki, and informed consent was obtained from all subjects.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors report no conflicts of interest in this work.

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