Article

Independent Predictors and a Nomogram for Postoperative Urethral Stricture After TURP in Elderly Patients: A Real-World Study

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AIM: Postoperative urethral stricture is an important complication after transurethral resection of the prostate (TURP). This study aimed to identify independent predictors of urethral stricture within 3 months after TURP in elderly patients and to develop a nomogram for predicting this complication.

METHODS: This retrospective study consecutively included 300 elderly patients who underwent transurethral resection of the prostate at Deqing County People's Hospital between June 2024 and November 2025. Patients were divided into a stricture group and a non-stricture group according to whether a urethral stricture occurred within 3 months after surgery. Demographic, clinical, and laboratory data were collected, and the controlling nutritional status (CONUT) score, prognostic nutritional index (PNI), and neutrophil-to-lymphocyte ratio (NLR) were calculated. Univariate and multivariable logistic regression analyses were performed to identify independent predictors of postoperative urethral stricture. A nomogram was subsequently constructed with variables of statistical significance. Model discrimination was assessed using the receiver operating characteristic (ROC) curve, and internal validation was performed by bootstrap resampling. Model performance was further evaluated using calibration and decision curve analyses.

RESULTS: Among the 300 elderly patients included in the final cohort, 84 were identified as having urethral stricture within 3 months after TURP. Multivariate logistic regression analysis showed that a higher CONUT score was an independent risk factor for postoperative urethral stricture (odds ratio [OR] = 2.41, 95% confidence interval [CI]: 1.43–4.04). Higher fasting glucose (OR = 1.56, 95% CI: 1.11–2.21), lower body mass index (BMI) (OR = 0.80, 95% CI: 0.70–0.91), alcohol use (OR = 3.02, 95% CI: 1.33–6.88), acute urinary retention (OR = 2.15, 95% CI: 1.07–4.31), longer catheterization duration (OR = 1.34, 95% CI: 1.03–1.74), and longer operative time (OR = 1.04, 95% CI: 1.02–1.07) were also independently associated with an increased risk of postoperative urethral stricture. The nomogram based on these variables demonstrated good discriminative ability, with an area under the curve (AUC) of 0.836 (95% CI: 0.789–0.882), a sensitivity of 76.2%, and a specificity of 75.0%. After 1000 bootstrap resamples for internal validation, the optimism-corrected AUC was 0.810 (95% CI: 0.731–0.878). Calibration analysis showed good agreement between predicted and observed probabilities, and decision curve analysis indicated that the model provided a certain net benefit.

CONCLUSIONS: Preoperative CONUT score, fasting glucose, BMI, alcohol use, acute urinary retention, catheterization duration, and operative time were associated with postoperative urethral stricture in elderly patients undergoing TURP. The nomogram based on these variables showed good discriminative performance, although further validation in larger samples and multicenter studies is still required.

Keywords: transurethral resection of the prostate; urethral stricture; controlling nutritional status; nomogram

Introduction

Benign prostatic hyperplasia (BPH) is one of the most common benign urological diseases in elderly men, and its histological prevalence increases progressively with age. The histological prevalence of BPH has been reported in approximately 50%–60% of men aged 60 years and in up to 80%–90% of those older than 70 years [1]. Transurethral resection of the prostate (TURP) remains the standard surgical treatment for BPH-related bladder outlet obstruction. Urethral stricture is one of the postoperative complications that warrants long-term attention after transurethral prostatic endoscopic surgery. Its clinical manifestations include decreased urinary flow rate, recurrent urinary retention, recurrent infections, and the need for repeated dilation or reoperation, all of which increase the medical burden and patient suffering [2].

Urethral stricture results from abnormal wound healing following injury to the urethral mucosa and corpus spongiosum, a typical fibrotic process characterized by fibroblast activation, collagen deposition, extracellular matrix remodeling, and reduced tissue compliance [3,4]. The wound repair process involves the participation of immune cells and

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inflammatory mediators, and dysregulation of this process may tip the balance toward scar formation with reduced extent of healing via physiological reconstruction [5]. Previous studies on urethral stricture after TURP have mainly identified local or procedure-related risk factors, including prolonged operative time, catheter-related factors, prior lower urinary tract instrumentation, and periurethral inflammatory changes, while more recent studies have further explored host-related variables and predictive approaches for postoperative stricture risk [6,7,8].

However, the occurrence of urethral stricture is not fully attributed to local injury or procedural factors. The outcome of wound healing depends not only on the injury itself, but also on the host's nutritional reserves, immune status, and metabolic milieu [9,10]. Malnutrition, chronic hyperglycemia, and immune-inflammatory imbalance may all interfere with epithelial repair, angiogenesis, and collagen remodeling, thereby increasing the likelihood that tissue repair shifts from normal healing to pathological fibrosis [11,12]. The controlling nutritional status (CONUT) score is derived from serum albumin, total cholesterol, and peripheral lymphocyte count, and reflects malnutrition, impaired immune function, and inflammation-related status [13]. Its associations with adverse postoperative outcomes and increased infection risk have been demonstrated in multiple disease settings [14,15]. Nevertheless, the value of such composite nutritional-inflammatory indices in the risk assessment of urethral stricture after TURP has not been systematically investigated. Nomogram-based models have been increasingly applied in urology to predict postoperative outcomes and support perioperative risk stratification, highlighting the clinical relevance of individualized prediction tools in surgical decision-making [16]. Therefore, this study aimed to identify the independent predictors of postoperative urethral stricture in elderly patients undergoing TURP in a real-world cohort. We further developed a nomogram to support preoperative risk stratification and perioperative management.

Methods

Study Population

In this retrospective real-world study, clinical data of patients who underwent TURP at Deqing County People's Hospital between June 2024 and November 2025 were consecutively collected. The database was locked in February 2026 to ensure that all included patients had completed at least 3 months of postoperative follow-up, and only patients with sufficient follow-up data for outcome assessment were included in the final analysis. All case data were obtained from the hospital electronic medical record system and follow-up database. The inclusion criteria were as follows: (1) age ≥60 years; (2) undergoing TURP for BPH-related lower urinary tract symptoms or bladder outlet obstruction; (3) availability of complete preoperative clinical data, laboratory test results, and perioperative data; and (4) availability of definite postoperative follow-up records that allowed determination of whether urethral stricture had occurred. The exclusion criteria were as follows: (1) preexisting urethral stricture, bladder neck contracture, or other definite organic diseases affecting urethral patency before surgery; (2) concomitant prostate cancer, bladder cancer, or other urinary tract malignancies; (3) a history of major lower urinary tract reconstruction/surgery affecting urethral structure or voiding function; (4) severe active infection, hematologic disease, or other conditions during the perioperative period that could significantly affect key laboratory indices; (5) missing key clinical variables, laboratory indices, or outcome information; and (6) loss to follow-up after surgery or insufficient follow-up data to determine the outcome. Given the retrospective nature of the study and the anonymization of all clinical data, the ethics committee waived the requirement for written informed consent.

Data Collection and Variable Definitions

Clinical data were collected through the electronic medical record system. Demographic and clinical characteristics included age, body mass index (BMI), smoking history, alcohol use, and comorbidities, such as hypertension, diabetes, acute urinary retention, evidence of prostatitis, prior lower urinary tract instrumentation, preoperative renal dysfunction, preoperative urethral dilation, and preoperative cystostomy. Perioperative variables included preoperative maximum urinary flow rate (Qmax), difficult endoscope insertion, intraoperative perforation, operative time, estimated blood loss, and postoperative catheterization duration. Preoperative Qmax was obtained from preoperative urodynamic or uroflowmetry examinations. Difficulties in endoscope insertion and intraoperative perforation were determined according to operative records. Operative time was defined as the duration from the start to the end of surgery. Catheterization duration was defined as the total number of days from postoperative urinary catheter placement to catheter removal. Laboratory variables included fasting glucose, blood urea nitrogen (BUN), creatinine (Cr), uric acid (UA), alanine aminotransferase (ALT), aspartate aminotransferase (AST), globulin (GLB), white blood cell count (WBC), hemoglobin (Hb), platelet count (PLT), C-reactive protein (CRP), triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Results of serum albumin (ALB), peripheral neutrophil count, and peripheral lymphocyte count were also extracted for the calculation of composite indices. The composite indices included in this study were the neutrophil-to-lymphocyte ratio (NLR), prognostic nutritional index (PNI), and CONUT. They were calculated using formulas as follows:

NLR = neutrophil count/lymphocyte count;

PNI = ALB (g/L) + 5 × lymphocyte count ($\times 10^9$/L).

The CONUT score was calculated by summing the component scores for serum albumin, peripheral lymphocyte count, and total cholesterol according to the original scoring system proposed by Ignacio de Ulibarri et al. [17]. Albumin was scored as '0' for ≥3.50 g/dL, '2' for 3.00–3.49 g/dL, '4' for 2.50–2.99 g/dL, and '6' for <2.50 g/dL; total lymphocyte count was scored as '0' for ≥1600/mm^3, '1' for 1200–1599/mm^3, '2' for 800–1199/mm^3, and '3' for <800/mm^3; total cholesterol was scored as '0' for ≥180 mg/dL, '1' for 140–179 mg/dL, '2' for 100–139 mg/dL, and '3' for <100 mg/dL. The sum of these three components yielded the final CONUT score.

Outcome Definition

The study outcome was urethral stricture identified within 3 months after TURP. Urethral stricture was defined as postoperative obstructive voiding symptoms, such as dysuria, a weakened urinary stream, or decreased urinary flow, together with objective evidence of urethral luminal narrowing on urethroscopy and/or imaging examinations. Uroflowmetry was used as an auxiliary assessment, but was not considered sufficient alone for diagnosis. Isolated bladder neck contracture, isolated meatal stenosis, and nonspecific voiding difficulty without objective evidence of urethral narrowing were not classified as urethral stricture. Similarly, cases requiring catheterization or dilation were included in the stricture group only when urethral stricture was objectively confirmed.

Statistical Analysis

All statistical analyses were performed using R software (version 4.5.2; R Foundation for Statistical Computing, Vienna, Austria), and a two-sided $p < 0.05$ was considered statistically significant. Normality of continuous variables was assessed using the Shapiro–Wilk test, with additional evaluation based on Quantile-Quantile (Q–Q) plots and histograms. Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range, IQR), as appropriate. The CONUT score was presented as median (IQR) because its mean ± SD presentation was less intuitive for this low-range discrete score. Categorical variables were expressed as frequencies and percentages. Baseline characteristics between the stricture and non-stricture groups were compared using the independent-samples *t*-test or Mann–Whitney *U* test for continuous variables and the chi-square test or Fisher's exact test for categorical variables, as appropriate. Univariate logistic regression analyses were performed on all variables included in the baseline analysis. Regression coefficients, standard errors, odds ratios (ORs), and 95% confidence intervals (CIs) were subsequently calculated. Variables with $p < 0.05$ in the univariate analysis were entered into the subsequent multivariate logistic regression model. To avoid information redundancy and potential multicollinearity caused by simultaneously entering composite indices and their component variables, when a composite index was included in the model, its corresponding original component variables were not entered simultaneously. Before model construction, variance inflation factors (VIF) were used to assess multicollinearity among candidate variables, and variables were further selected in combination with statistical results and clinical relevance. In the multivariate logistic regression analysis, independent predictors of postoperative urethral stricture were further identified, and adjusted ORs and their 95% CIs were calculated. A nomogram was developed based on statistically significant variables identified through multivariate logistic regression analysis. Model performance was evaluated using receiver operating characteristic (ROC) curves, bootstrap internal validation, calibration curve and decision curve analyses. The optimal cutoff value of the model was determined using the Youden index, and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were also calculated to comprehensively evaluate the predictive performance of the model.

Results

Baseline Characteristics of Participants Stratified by Postoperative Urethral Stricture Status

Among the 300 patients who underwent TURP included in this study, 84 developed urethral stricture within 3 months after surgery. Compared with the non-stricture group, patients in the stricture group had higher CONUT scores and fasting glucose levels, but lower BMI, preoperative Qmax, and PNI (all $p < 0.05$). Compared to the non-stricture group, the stricture group had higher proportions of patients with prostatitis, intraoperative perforation, alcohol use, acute urinary retention, diabetes, and difficulties in endoscope insertion, as well as longer catheterization duration and operative time, with all differences reaching statistical significance (all $p < 0.05$). No significant between-group differences were observed in age, uric acid, creatinine, white blood cell count, CRP, NLR, triglycerides, or HDL-C (all $p > 0.05$) (Table 1).

Univariate Logistic Regression Analysis of the Risk of Postoperative Urethral

As shown in Table 2, univariate logistic regression analysis demonstrated that a higher CONUT score was significantly associated with an increased risk of postoperative urethral stricture (OR = 2.88, 95% CI: 1.91–4.33). Higher fasting glucose (OR = 1.68, 95% CI: 1.30–2.16), alcohol use (OR = 2.94, 95% CI: 1.61–5.34), intraoperative perforation (OR = 4.48, 95% CI: 1.92–10.43), evidence of prostatitis (OR = 5.83, 95% CI: 2.11–16.11), acute urinary retention (OR = 2.32, 95% CI: 1.38–3.89), longer catheterization duration (OR = 1.33, 95% CI: 1.10–1.60), diabetes (OR = 2.14, 95% CI: 1.18–3.90), longer operative time (OR = 1.02, 95% CI: 1.00–1.04), difficult endoscope insertion (OR = 2.60, 95% CI: 1.14–5.96), and hypertension (OR = 1.69, 95% CI: 1.02–2.82) were all significantly associated with a higher risk of urethral stricture (all $p < 0.05$). In con-

Table 1. Baseline characteristics of patients with and without postoperative urethral stricture.

Variable	Total (n = 300)	Non-stricture group (n = 216)	Stricture group (n = 84)	$t/\chi^2/Z$	p-value
CONUT, median (IQR)	0 (0, 1)	0 (0, 1)	1 (0, 1)	−5.72	<0.001
Fasting glucose (mmol/L)	6.03 ± 1.00	5.87 ± 1.04	6.41 ± 0.76	−4.94	<0.001
BMI (kg/m^2)	25.90 ± 2.70	26.25 ± 2.84	24.99 ± 2.06	4.26	<0.001
Preoperative Qmax (mL/s)	7.29 ± 1.44	7.46 ± 1.57	6.88 ± 0.94	3.92	<0.001
Evidence of prostatitis, *n* (%)	18 (6.00%)	6 (2.78%)	12 (14.29%)	14.20	<0.001
Intraoperative perforation, *n* (%)	25 (8.33%)	10 (4.63%)	15 (17.86%)	13.85	<0.001
Alcohol use, *n* (%)	57 (19.00%)	30 (13.89%)	27 (32.14%)	13.09	<0.001
Catheterization duration (days)	6.56 ± 1.45	6.40 ± 1.52	6.96 ± 1.17	−3.46	<0.001
Acute urinary retention, *n* (%)	104 (34.67%)	63 (29.17%)	41 (48.81%)	10.30	0.001
PNI	52.19 ± 3.19	52.48 ± 3.44	51.44 ± 2.29	3.02	0.003
Operative time (min)	60.86 ± 13.53	59.70 ± 14.53	63.82 ± 10.03	−2.79	0.006
Diabetes, *n* (%)	58 (19.33%)	34 (15.74%)	24 (28.57%)	6.38	0.012
Difficult endoscope insertion, *n* (%)	25 (8.33%)	13 (6.02%)	12 (14.29%)	5.41	0.020
Blood urea nitrogen (mmol/L)	6.93 ± 1.32	7.02 ± 1.39	6.70 ± 1.06	2.14	0.033
Hypertension, *n* (%)	136 (45.33%)	90 (41.67%)	46 (54.76%)	4.19	0.041
Globulin (g/L)	26.94 ± 2.37	26.80 ± 2.45	27.32 ± 2.12	−1.82	0.071
Age (years)	71.31 ± 5.06	71.62 ± 5.29	70.54 ± 4.34	1.81	0.071
ALT (U/L)	31.51 ± 10.50	32.17 ± 10.40	29.80 ± 10.61	1.75	0.082
Preoperative renal dysfunction, *n* (%)	47 (15.67%)	29 (13.43%)	18 (21.43%)	2.93	0.087
Smoking history, *n* (%)	108 (36.00%)	84 (38.89%)	24 (28.57%)	2.79	0.095
Uric acid (μmol/L)	351.79 ± 67.57	347.82 ± 67.72	361.98 ± 66.47	−1.65	0.102
LDL-C (mmol/L)	2.86 ± 0.50	2.89 ± 0.50	2.79 ± 0.51	1.57	0.120
Estimated blood loss (mL)	175.23 ± 56.73	178.39 ± 55.39	167.12 ± 59.63	1.50	0.136
Total cholesterol (mmol/L)	5.17 ± 0.53	5.20 ± 0.53	5.10 ± 0.55	1.48	0.141
Creatinine (μmol/L)	85.33 ± 11.98	85.96 ± 11.55	83.70 ± 12.96	1.39	0.165
Prior lower urinary tract instrumentation, *n* (%)	80 (26.67%)	53 (24.54%)	27 (32.14%)	1.79	0.181
WBC (×10^9/L)	7.37 ± 1.34	7.31 ± 1.35	7.53 ± 1.34	−1.27	0.205
Positive urine culture, *n* (%)	44 (14.67%)	29 (13.43%)	15 (17.86%)	0.95	0.330
AST (U/L)	26.07 ± 7.80	26.30 ± 7.91	25.50 ± 7.51	0.81	0.418
Preoperative cystostomy, *n* (%)	20 (6.67%)	13 (6.02%)	7 (8.33%)	0.52	0.470
NLR	2.13 ± 0.73	2.11 ± 0.72	2.17 ± 0.73	−0.67	0.506
Hemoglobin (g/L)	138.51 ± 9.29	138.68 ± 9.48	138.07 ± 8.82	0.53	0.600
CRP (mg/L)	10.39 (5.91, 14.78)	10.49 (6.01, 14.48)	10.01 (5.87, 15.02)	0.71	0.720
Triglycerides (mmol/L)	1.95 ± 0.79	1.94 ± 0.79	1.97 ± 0.80	−0.36	0.720
Preoperative urethral dilation, *n* (%)	39 (13.00%)	29 (13.43%)	10 (11.90%)	0.12	0.725
HDL-C (mmol/L)	1.35 ± 0.23	1.35 ± 0.24	1.36 ± 0.19	−0.14	0.889
Platelet count (×10^9/L)	213.86 ± 44.78	213.95 ± 45.95	213.63 ± 41.88	0.06	0.954

Notes: Unless otherwise stated, all parameters are expressed as mean ± SD.

Abbreviations: ALT, alanine aminotransferase; AST, aspartate aminotransferase; BMI, body mass index; CONUT, controlling nutritional status; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NLR, neutrophil-to-lymphocyte ratio; PNI, prognostic nutritional index; Qmax, maximum urinary flow rate; WBC, white blood cell count; IQR, interquartile range; SD, standard deviation.

trast, higher BMI (OR = 0.83, 95% CI: 0.75–0.92), higher preoperative Qmax (OR = 0.74, 95% CI: 0.61–0.90), and higher PNI (OR = 0.90, 95% CI: 0.83–0.98) were significantly associated with a lower risk of postoperative urethral stricture (all $p < 0.05$).

Multivariate Logistic Regression Analysis of the Risk of Postoperative Urethral Stricture After TURP

Variables with statistically significant differences in the univariate analysis were entered into the multivariate logistic regression model. Collinearity diagnostics showed that the VIF values of the candidate variables ranged from 1.07 to 1.37, indicating no obvious multicollinearity (**Supplementary Table 1**). As shown in Table 3, after ad-

Table 2. Univariate logistic regression analysis.

Variable	β	S.E	Z	*p*-value	OR (95% CI)
CONUT, median (IQR)	1.06	0.21	5.07	<0.001	2.88 (1.91–4.33)
Fasting glucose (mmol/L)	0.52	0.13	3.98	<0.001	1.68 (1.30–2.16)
BMI (kg/m^2)	−0.19	0.05	−3.57	<0.001	0.83 (0.75–0.92)
Alcohol use, *n* (%)	1.08	0.31	3.53	<0.001	2.94 (1.61–5.34)
Intraoperative perforation, *n* (%)	1.50	0.43	3.48	<0.001	4.48 (1.92–10.43)
Evidence of prostatitis, *n* (%)	1.76	0.52	3.40	<0.001	5.83 (2.11–16.11)
Acute urinary retention, *n* (%)	0.84	0.26	3.17	0.002	2.32 (1.38–3.89)
Preoperative Qmax (mL/s)	−0.30	0.10	−3.08	0.002	0.74 (0.61–0.90)
Catheterization duration (days)	0.28	0.09	3.00	0.003	1.33 (1.10–1.60)
PNI	−0.11	0.04	−2.49	0.013	0.90 (0.83–0.98)
Diabetes, *n* (%)	0.76	0.31	2.49	0.013	2.14 (1.18–3.90)
Operative time (min)	0.02	0.01	2.35	0.019	1.02 (1.00–1.04)
Difficult endoscope insertion, *n* (%)	0.96	0.42	2.26	0.024	2.60 (1.14–5.96)
Hypertension, *n* (%)	0.53	0.26	2.04	0.042	1.69 (1.02–2.82)
Blood urea nitrogen (mmol/L)	−0.19	0.10	−1.89	0.059	0.83 (0.68–1.01)
ALT (U/L)	−0.02	0.01	−1.75	0.079	0.98 (0.96–1.00)
Preoperative renal dysfunction, *n* (%)	0.56	0.33	1.70	0.090	1.76 (0.92–3.37)
Globulin (g/L)	0.09	0.05	1.70	0.090	1.10 (0.99–1.22)
Smoking history, *n* (%)	−0.46	0.28	−1.66	0.096	0.63 (0.36–1.09)
Age (years)	−0.04	0.03	−1.65	0.098	0.96 (0.91–1.01)
Uric acid (μmol/L)	0.00	0.00	1.63	0.104	1.01 (0.99–1.03)
LDL-C (mmol/L)	−0.40	0.26	−1.56	0.118	0.67 (0.40–1.11)
Estimated blood loss (mL)	−0.00	0.00	−1.54	0.123	1.00 (0.99–1.00)
Total cholesterol (mmol/L)	−0.36	0.24	−1.50	0.134	0.70 (0.43–1.12)
Creatinine (μmol/L)	−0.02	0.01	−1.46	0.144	0.98 (0.96–1.01)
Prior lower urinary tract instrumentation, *n* (%)	0.38	0.28	1.33	0.182	1.46 (0.84–2.53)
WBC (×10^9/L)	0.12	0.10	1.27	0.205	1.13 (0.94–1.37)
Positive urine culture, *n* (%)	0.34	0.35	0.97	0.332	1.40 (0.71–2.77)
AST (U/L)	−0.01	0.02	−0.80	0.427	0.99 (0.96–1.02)
Preoperative cystostomy, *n* (%)	0.35	0.49	0.72	0.472	1.42 (0.55–3.69)
NLR	0.12	0.18	0.67	0.502	1.13 (0.80–1.59)
Hemoglobin (g/L)	−0.01	0.01	−0.51	0.610	0.99 (0.97–1.02)
Triglycerides (mmol/L)	0.06	0.16	0.36	0.717	1.06 (0.77–1.46)
CRP (mg/L)	−0.01	0.02	−0.36	0.721	0.99 (0.94–1.04)
Preoperative urethral dilation, *n* (%)	−0.14	0.39	−0.35	0.725	0.87 (0.40–1.88)
HDL-C (mmol/L)	0.07	0.57	0.13	0.899	1.07 (0.35–3.29)
Platelet count (×10^9/L)	−0.00	0.00	−0.06	0.956	1.01 (0.99–1.02)

S.E, standard error; OR, odds ratio; CI, confidence interval; IQR, interquartile range.

justment for potential confounders, a higher CONUT score (OR = 2.41, 95% CI: 1.43–4.04), higher fasting glucose (OR = 1.56, 95% CI: 1.11–2.21), lower BMI (OR = 0.80, 95% CI: 0.70–0.91), alcohol use (OR = 3.02, 95% CI: 1.33–6.88), acute urinary retention (OR = 2.15, 95% CI: 1.07–4.31), longer catheterization duration (OR = 1.34, 95% CI: 1.03–1.74), and longer operative time (OR = 1.04, 95% CI: 1.02–1.07) were all independently associated with postoperative urethral stricture.

Nomogram Construction and Model Performance Assessment for Postoperative Urethral Stricture After TURP

Based on the variables with statistical significance in the multivariate logistic regression analysis, a nomogram for postoperative urethral stricture after TURP was established (Fig. 1). As shown in Fig. 2, ROC curve analysis demonstrated that this model demonstrated satisfactory performance in differentiating postoperative urethral stricture after TURP, with an area under the curve (AUC) of 0.836 (95% CI: 0.789–0.882). At the optimal cutoff value of 0.260, the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the model were

Table 3. Multivariate logistic regression analysis of significant predictors.

Variable	β	S.E	Z	p-value	OR (95% CI)
CONUT, median (IQR)	0.88	0.26	3.33	<0.001	2.41 (1.43–4.04)
Fasting glucose (mmol/L)	0.45	0.18	2.53	0.011	1.56 (1.11–2.21)
BMI (kg/m^2)	−0.22	0.07	−3.31	<0.001	0.80 (0.70–0.91)
Alcohol use, n (%)	1.11	0.42	2.63	0.008	3.02 (1.33–6.88)
Acute urinary retention, n (%)	0.77	0.35	2.16	0.031	2.15 (1.07–4.31)
Catheterization duration (days)	0.29	0.13	2.19	0.028	1.34 (1.03–1.74)
Operative time (min)	0.04	0.01	3.03	0.002	1.04 (1.02–1.07)

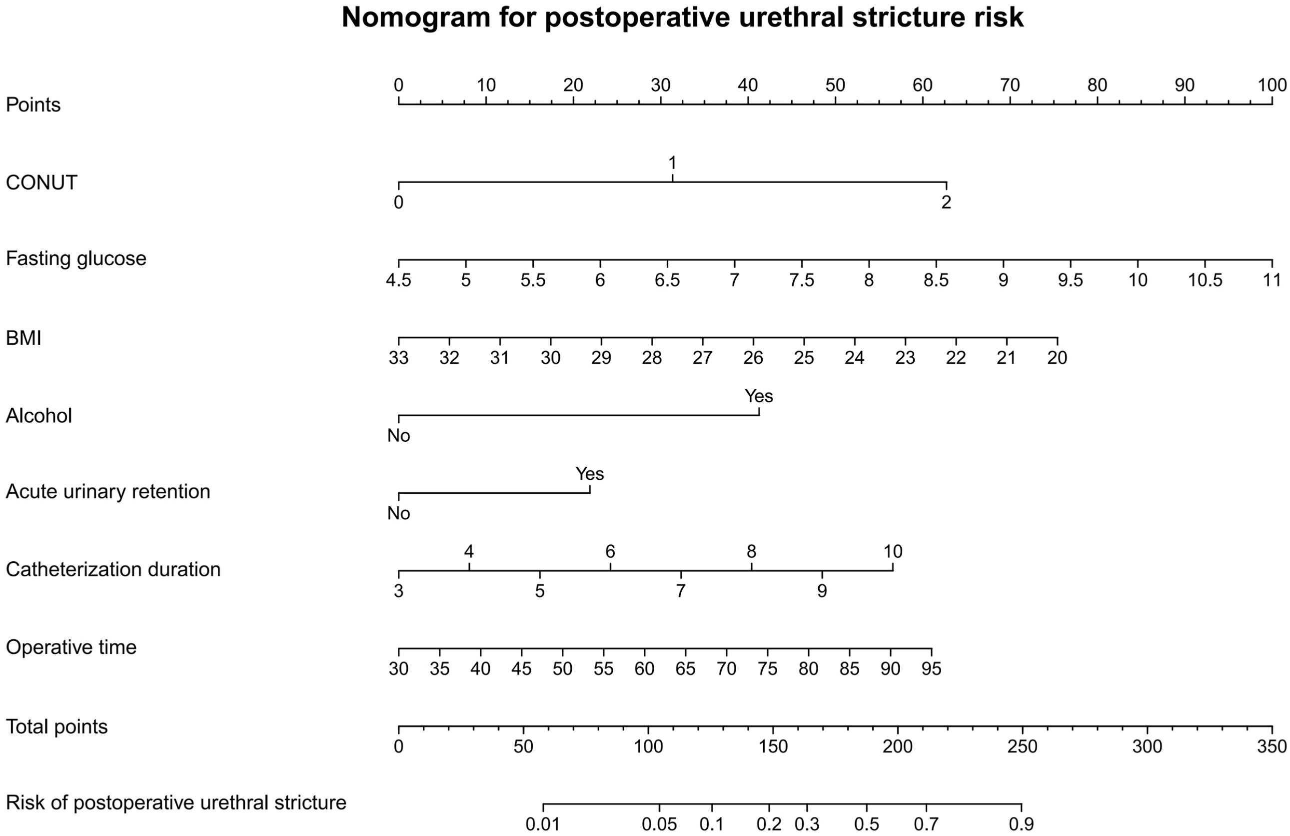

Fig. 1. Nomogram for predicting postoperative urethral stricture after transurethral resection of the prostate (TURP).

76.2%, 75.0%, 54.2%, 89.0%, and 75.3%, respectively (**Supplementary Table 2**). After 1000 bootstrap resamples for internal validation, the optimism-corrected AUC was 0.810 (95% CI: 0.731–0.878) (Fig. 2B). The calibration curve showed that the predicted probabilities were generally consistent with the observed probabilities (Fig. 2C). Decision curve analysis indicated that, across a wide range of threshold probabilities, use of this model for clinical decision-making provided a greater net benefit than either the "treat all" or "treat none" strategy (Fig. 2D).

Discussion

After case screening based on the inclusion and exclusion criteria, 300 elderly patients who underwent TURP were included in the final analysis, of whom 84 were identified as having urethral stricture within 3 months after surgery. The results showed that a higher CONUT score, elevated fasting glucose, lower BMI, alcohol use, acute urinary retention, prolonged catheterization duration, and longer operative time were independently associated with postoperative urethral stricture. The nomogram established using these variables demonstrated good discriminative performance, with an AUC of 0.836, indicating that the model may have potential utility in identifying patients at increased risk of postoperative urethral stricture.

Potential Mechanisms Linking CONUT to Postoperative Urethral Stricture

The CONUT score is derived from serum albumin level, total cholesterol level, and peripheral lymphocyte count, and provides a relatively comprehensive reflection of nutritional reserve, immune status, and chronic inflammatory

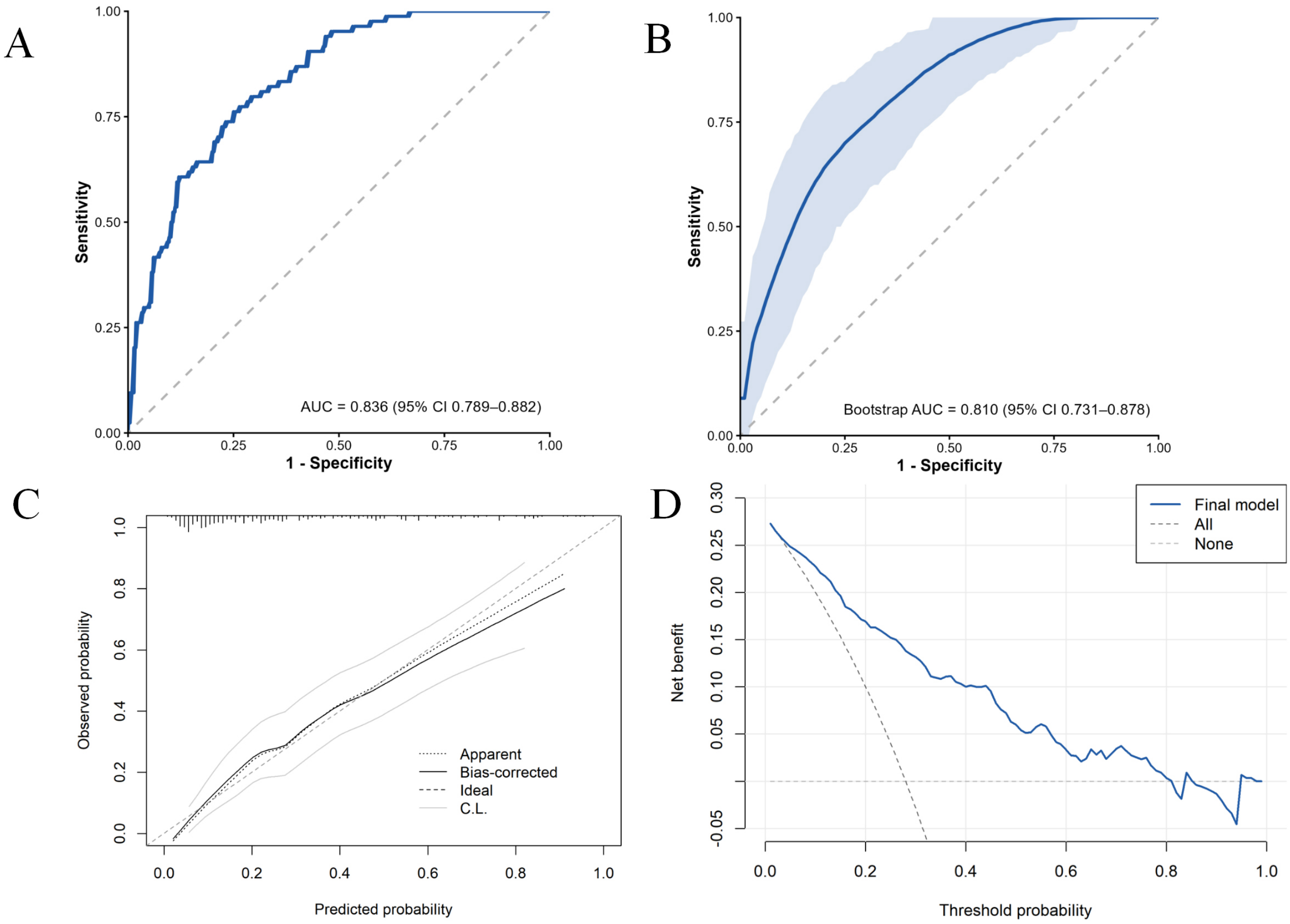

Fig. 2. Performance assessment and validation of the urethral stricture prediction model. (A) Receiver operating characteristic (ROC) curve; (B) bootstrap-validated ROC curve; (C) calibration curve; (D) decision curve analysis (DCA). AUC, area under the curve.

consumption [13]. In the present study, a higher CONUT score was independently associated with an increased risk of urethral stricture after TURP, suggesting that impaired nutritional status and chronic inflammatory state potentially provide fundamental conditions for the development of postoperative urethral stricture. Urethral stricture is a pathological process characterized by persistent inflammation, aberrant repair, and fibrotic remodeling [4]. Sustained or dysregulated inflammation after injury may activate profibrotic pathways by upregulating transforming growth factor-beta (TGF-β) expression, thereby promoting myofibroblast differentiation and collagen deposition, reducing tissue elasticity, and ultimately leading to luminal narrowing [3,4]. Normal wound healing requires the orderly transition through the inflammatory, proliferative, and remodeling phases. In the presence of impaired immunonutritional status and chronic inflammatory consumption, inflammatory resolution may be delayed, which in turn may disrupt epithelial repair, angiogenesis, and extracellular matrix remodeling, thereby shifting tissue repair from physiological regeneration toward scar-forming healing [5,12]. In this context, low albumin not only indicates inadequate protein reserve but also often reflects persistent inflammation and a negative acute-phase response. It may impair normal healing by limiting amino acid availability for tissue repair, reducing antioxidant capacity, and affecting fibroblast proliferation, angiogenesis, and collagen remodeling [5,18]. Cholesterol is essential for cell membrane stability, receptor-mediated signaling, and cellular proliferation and repair. Reduced cholesterol levels may therefore impair epithelial regeneration, membrane repair, and the maintenance of immune cell function, further hindering the orderly transition of local tissues from the inflammatory phase to the proliferative and remodeling phases [19]. In addition, lymphopenia, as a marker of impaired immune regulation, may hamper the resolution of inflammation and disrupt the maintenance of immune homeostasis during tissue repair [15]. Accordingly, the immunonutritional impairment reflected by an elevated CONUT score may prolong the inflammatory phase after transurethral injury to the urethral mucosa and corpus spongiosum. It may also interfere with the subsequent proliferative and remodeling phases, rendering local tissues more susceptible to persistent inflammation and scar remodeling [12]. Previous studies have likewise accumulated evidence that CONUT, as a risk factor, is associated with adverse postoperative outcomes across multiple fields, including gastrointestinal surgery and urological surgery [15,19]. These studies suggest that immunonutritional impairment may be associated with infectious complications, delayed recovery, and unfavorable short-term functional outcomes [15]. Although the specific endpoints differ across surgical settings, they all share a common dependence on effective post-injury inflammatory control, tissue regeneration, and structural remodeling. In this context, the association between CONUT and postoperative urethral stricture is consistent with previous findings that immunonutritional status influences postoperative recovery.

Comparison With Previous Studies and Interpretation of Other Significant Variables

Previous research has also shown that lower BMI is associated with an increased risk of urethral stricture after TURP [20], which is consistent with our findings. In elderly surgical patients, a lower BMI often indicates inadequate energy reserve, chronic and excessive use of energy, or impaired maintenance of body composition. Given that tissue repair, angiogenesis, and collagen remodeling all require sufficient metabolic substrates and protein synthesis capacity, low BMI may reflect poor nutritional reserve and thus constitute a critical factor for abnormal postoperative repair [12].

The multivariate model showed that elevated fasting glucose, prolonged catheterization duration, longer operative time, acute urinary retention, and alcohol use were independent risk factors of urethral stricture. These variables may reflect the combined influence of host metabolic status and local injury burden. A hyperglycemic environment may lead to microcirculatory dysfunction, persistent inflammation, abnormal fibroblast function, and delayed epithelial regeneration, thereby impairing normal healing and potentially promoting fibrotic remodeling [21,22]. The associations of prolonged catheterization duration and longer operative time with urethral stricture are also broadly consistent with previous TURP studies. Longer instrument exposure and prolonged transurethral catheterization may increase local friction, mucosal compression, and ischemic injury, thereby promoting subsequent scar formation [7,23]. Acute urinary retention was also a significant variable in this study. Although it may not directly cause stricture, it is more likely to reflect more severe preexisting obstruction and increased susceptibility to the risks of perioperative catheterization and instrumentation, thereby predisposing patients to adverse postoperative outcomes. The association between alcohol use and postoperative urethral stricture should be interpreted with caution, as alcohol may dysregulate immune and inflammatory responses and increase the risk of postoperative complications, including wound complications and infections [24,25]. Therefore, compared with the immunonutritional vulnerability reflected by CONUT, these variables may provide complementary explanations for the occurrence of postoperative urethral stricture from the perspectives of metabolic abnormalities, the intensity of tissue injury, and the burden of repair.

From a clinical perspective, the CONUT score can be calculated from routine laboratory tests and is easy to obtain at a relatively low cost. It may therefore serve as a useful adjunct for preoperative risk stratification in patients undergoing TURP. In addition, a nomogram for predicting postoperative urethral stricture constructed with statistically significant predictors, such as CONUT, fasting glucose, BMI, alcohol use, acute urinary retention, catheterization duration, and operative time, demonstrated good discriminative performance, suggesting that integrating host immunonutritional status with perioperative injury-related factors may improve early identification of high-risk patients.

Clinical Implications and Study Limitations

Several limitations of this study should be acknowledged. First, this was a single-center retrospective observational study, and the final analysis was restricted to patients with complete clinical information and definite follow-up records, which may have introduced selection bias and restricted the generalizability of the findings. In addition, the relatively high observed proportion of urethral stricture may be partly related to the elderly study population, the enrichment of perioperative risk factors, and the detection of early or mild stricture events during follow-up; therefore, it should not be interpreted as a population-level incidence estimate. Second, although several perioperative variables were included in the analysis, some potentially relevant confounding factors, such as differences in surgical technique, instrument handling, energy settings, and surgeon experience, were not specifically measured or adjusted for, and these factors may also have influenced postoperative outcomes. Third, the outcome was defined as urethral stricture occurring within 3 months after surgery, which is generally considered an early stricture event. Since late-onset urethral stricture may also occur beyond this time window, the present follow-up duration may therefore have led to an underestimation of the true overall incidence. Finally, histopathological data, inflammatory cytokine profiles, and external validation were not available in this study. Future multicenter prospective studies with longer follow-up and external validation are warranted to confirm the robustness and generalizability of the present findings.

Conclusions

This study demonstrates that an elevated preoperative CONUT score is independently associated with an increased risk of urethral stricture after TURP. Elevated fasting glucose, lower BMI, acute urinary retention, prolonged catheterization duration, longer operative time, and alcohol use were also associated with the occurrence of postoperative urethral stricture. These findings suggest that, in addition to perioperative local injury-related factors, postoperative urethral stricture after TURP may also be associated with the patient's preoperative nutritional status, immune status, and inflammatory state. The nomogram constructed based on these variables showed good discriminative performance. These findings suggest that integrating host immunonutritional status with perioperative factors may improve early identification of postoperative urethral stricture risk.

Availability of Data and Materials

The data and materials in the current study are available from the corresponding author on reasonable request.

Author Contributions

Conception and design: YPW, DD. Administrative support: YPW, HJ, GC. Provision of study materials: YPW, DD, LYS, HFC. Collection and assembly of data: HJ, GC, HFC, HZC. Data analysis and interpretation: YPW, LHZ, LYS. All authors drafted the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was carried out in strict accordance with the ethical guidelines of the Declaration of Helsinki. It has been reviewed and approved by the Ethics Committee of Deqing County People's Hospital, with the approval number (LL2026-DRY-K17). Given the retrospective nature of the study and the anonymization of all clinical data, the Ethics Committee waived the requirement for written informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.4668.

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