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Non-invasive Diagnosis of Bladder Outlet Obstruction in Men with Lower Urinary Tract Symptoms Using Clinical Variables and Urinary Biomarkers

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Research Article

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Abstract

Purpose

To determine whether adding urinary biomarkers to clinical, prostatic, and uroflowmetry parameters improves diagnostic accuracy for bladder outlet obstruction (BOO) in men with lower urinary tract symptoms (LUTS).

Methods

This study included 140 men with LUTS. Clinical parameters with < 40% missingness were imputed using random forest-based multiple imputation (m = 60). Patients were randomly divided into training (80%) and test (20%) cohorts. Three logistic regression models were developed: clinical parameters only (Model 1), urinary biomarkers only (Model 2), and both combined (Model 3). Discrimination, accuracy, and clinical utility, assessed by decision curve analysis (DCA), were compared. A nomogram was developed from Model 3.

Results

Model 1 achieved a mean area under the curve (AUC) of 0.74 ± 0.03 in the training cohort and 0.63 ± 0.07 in the test cohort. Model 2 yielded AUCs of 0.62 and 0.76, respectively. Model 3, incorporating the IPSS-storage subscore (IPSS-Storage), total prostate volume (TPV), transitional zone index (TZI), and urinary 8-OHdG, showed the most consistent performance, with mean AUCs of 0.75 ± 0.02 and 0.76 ± 0.06 in the training and test cohorts, respectively. In the test cohort, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value were 0.82, 0.77, 0.87, 0.83, and 0.81, respectively. DCA demonstrated a consistent net benefit in both cohorts.

Conclusion

Integrating urinary 8-OHdG with IPSS-Storage, TPV, and TZI improved diagnostic discrimination and clinical utility for BOO compared with clinical or biomarker data alone. This model may serve as an initial non-invasive tool to reduce unnecessary video-urodynamic studies.

Introduction

Bladder outlet obstruction (BOO) is the most common form of lower urinary tract dysfunction (LUTD) in men. The causes of male BOO include bladder neck dysfunction (BND), prostatic obstruction, urethral sphincter dysfunction, and urethral stricture [1]. Among these conditions, prostatic obstruction due to benign prostatic hyperplasia (BPH) is the most common. Men with LUTD and an enlarged prostate are often clinically presumed to have BOO secondary to BPH, termed benign prostatic obstruction (BPO). However, lower urinary tract symptoms (LUTS) are not synonymous with BOO, and not all men with LUTS and an enlarged prostate have obstruction attributable to BPH. Bladder neck dysfunction, urethral sphincter dysfunction, and bladder sensory disorders may also contribute to male LUTS [2].

Consequently, some men experience unsatisfactory outcomes after prostatic surgery and require continued medical treatment. Accurate baseline identification of BOO is therefore essential for optimizing treatment selection and surgical outcomes.

The clinical diagnosis of BPO currently relies on LUTS assessment and objective measures, including total prostatic volume (TPV), transitional zone index (TZI), maximum urinary flow rate (Qmax), voided volume, uroflowmetry pattern, and post-void residual (PVR) volume [1, 3]. A composite prostatic score incorporating several prostatic and uroflowmetry parameters has been developed to improve the sensitivity and specificity of BOO diagnosis [4]. Nevertheless, accurate diagnosis of BPO remains challenging without video-urodynamic study (VUDS) [5]. Although VUDS can precisely characterize LUTD, its routine use in the initial assessment of men with LUTS is limited by its invasive nature and radiation exposure. Consequently, recent research has focused on urinary biomarkers associated with inflammation and oxidative stress as potential indicators of the inflammatory and ischemic pathophysiological changes associated with BOO [6]. Men with clinically diagnosed BOO have been reported to have elevated urinary levels of biomarkers such as 8-hydroxy-2'-deoxyguanosine (8-OHdG) [7].

This study aimed to investigate whether incorporating urinary biomarkers into clinical symptom assessment and prostatic and uroflowmetry parameters can improve the diagnostic accuracy for BOO in men with LUTS.

Materials and Methods

A total of 140 men with LUTS were included in this study. All patients had moderate LUTS and were clinically considered to have BOO. At baseline, LUTS were assessed using the International Prostate Symptom Score (IPSS). Transrectal prostate ultrasonography was performed to determine the TPV and TZI. Uroflowmetry was also performed at baseline, and the Qmax, flow pattern, voided volume, and PVR were recorded. All clinical assessments were performed according to standardized procedures. Uroflowmetry was considered valid only when the voided volume exceeded 200 mL; otherwise, the examination was repeated.

The exclusion criteria were age < 40 years; acute or chronic urinary retention; BOO secondary to central nervous system disease or detrusor-sphincter dyssynergia; a history of lower urinary tract surgery; a previous diagnosis of urological malignancy; subsequent pathological diagnosis of prostate or bladder cancer; and failure to undergo VUDS. The Research Ethics Committee of Hualien Tzu-Chi Hospital, Buddhist Tzu-Chi Medical Foundation, approved the study (**approval number: 111-132-B**). Given the retrospective nature of the study, the requirement for informed consent was waived.

Video-urodynamic study

VUDS was performed according to the standard operating procedures and terminology recommended by the International Continence Society for the assessment of the adult male lower urinary tract [8]. During

the filling phase, the first sensation of filling, normal desire to void, urgency sensation, and cystometric bladder capacity were recorded. During the voiding phase, detrusor pressure during voiding, Qmax, voided volume, and PVR volume were recorded. Cinefluoroscopy with simultaneous voiding cystourethrography was performed, and the subtype of LUTD was determined based on the integrated assessment of the fluoroscopic findings and urodynamic parameters. Patients were classified into the following LUTD subtypes according to the VUDS findings: detrusor overactivity (DO) without BOO; DO with BND; DO with BPO; and dysfunctional voiding (DV) without BOO [9]. In the present study, BOO was defined as the presence of either BND or BPO on VUDS and was used as the primary outcome for the diagnostic analysis.

Urinary biomarker analysis

A 50 mL urine sample was collected at baseline for the urinary biomarker analysis. The biomarkers assessed included interleukin (IL)-6, IL-8, tumor necrosis factor-α (TNF-α), nerve growth factor (NGF), 8-OHdG, 8-isoprostane, total antioxidant capacity (TAC), and prostaglandin E2 (PGE2). Inflammatory and oxidative stress biomarkers were quantified using the MILLIPLEX® Human Cytokine/Chemokine Magnetic Bead Panel (Millipore, Darmstadt, Germany), according to previously described protocols [7, 10].

Statistical analysis

Data preprocessing

The total cohort was randomly divided into a training cohort (n = 112, 80%) and a test cohort (n = 28, 20%). No significant differences were observed between the two cohorts in clinical parameters and urinary biomarker levels ($p \geq 0.05$), indicating comparable baseline characteristics for model development and validation **(Table S1)**. All urinary biomarker data were complete, with no missing values. For clinical parameters with a missingness rate < 40% [11], missing values were imputed using random forest-based multiple imputation (m = 60) [12] implemented with the mice package in R [13]. This approach was adopted to minimize potential selection bias and preserve the sample size that would otherwise be lost through complete-case analysis. To minimize the risk of data leakage, the imputation procedure was performed separately for the training and test cohorts. In the training cohort, the outcome variable was included as an auxiliary variable in the imputation model, whereas the outcome variable was excluded from the imputation model for the test cohort [14].

The robustness of the findings to the handling of missing data was assessed in a sensitivity analysis comparing pooled regression estimates from the multiply imputed datasets with estimates obtained from complete-case analysis. The direction and magnitude of the effect estimates for the key variables were similar between the two approaches **(Table S2)**, indicating that the findings were not materially influenced by the method used to handle missing data.

Descriptive and univariable analyses

Categorical variables are presented as numbers (percentages) and were compared between groups using the chi-square test; Fisher's exact test was used when the expected cell frequency was less than 5. Continuous variables are presented as mean ± standard deviation and were compared between groups using the independent samples *t*-test.

Model Derivation and Validation

Three logistic regression models were developed to evaluate the incremental predictive value of urinary biomarkers beyond conventional clinical parameters. Model 1 included clinical parameters only, Model 2 included urinary biomarkers only, and Model 3 integrated both clinical parameters and urinary biomarkers. To minimize the premature exclusion of potentially relevant predictors, variables with $p < 0.20$, based on the pooled regression coefficients and standard errors derived using Rubin's rules across the 60 imputed datasets, were considered candidate predictors [15]. Backward stepwise selection based on the Akaike information criterion (AIC) was then performed separately in each of the 60 imputed training datasets. Variables retained in at least 50% of the resulting models were included in the final multivariable model [16]. The final model was constructed using the pooled regression coefficients and presented as a nomogram to facilitate individualized risk estimation.

Model discrimination was assessed using the area under the receiver operating characteristic (ROC) curve (AUC), calculated separately for each of the 60 imputed training datasets and summarized as the mean ± standard deviation. The optimal probability threshold was determined using Youden’s index based on the pooled ROC analysis. Accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were then calculated using this threshold. The final model was evaluated in the test cohort.

Decision curve analysis was performed to assess the clinical utility of the three models by comparing their net benefit across a range of threshold probabilities. Predicted probabilities from the 60 imputed datasets were averaged for this analysis. Particular attention was given to whether the integrated model provided additional net benefit over the clinical-only and biomarker-only models.

All statistical tests were two-tailed, and $p < 0.05$ was considered statistically significant. Statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA) and R, version 4.2.0.

Results

A total of 140 men were enrolled. Baseline demographic characteristics, IPSS scores, prostate and uroflowmetry parameters, and urine biomarker levels are presented in Table 1. Based on VUDS findings, 73 patients were classified as having no BOO, whereas 67 were classified as having BOO, including 34 with BND and 33 with BPO. Compared with patients without BOO, those with BOO had significantly higher

mean TPV and TZI. The urinary level of the oxidative stress biomarker 8-OHdG was also significantly higher in patients with BOO.

Table 1
Baseline characteristics and urinary biomarker levels in patients with and without BOO before imputation

Parameter **Missing data (n, %)**	**Total enrollment** **(n = 140)**	**Non-BOO** **(n = 73)**	**BOO** **(n = 67)**	***p* value**
Clinical characteristics				
Age (years) (0, 0%)	62.9 ± 14.5	61.2 ± 13.6	64.7 ± 15.3	0.151
IPSS-Voiding (28, 20%)	7.7 ± 6.3	8.4 ± 6.3	7.1 ± 6.4	0.266
IPSS-Storage (28, 20%)	8.1 ± 3.9	7.4 ± 3.5	8.7 ± 4.1	0.069
TPV (mL) (44, 31.4%)	39.4 ± 38.7	28.0 ± 11.6	48.3 ± 49.0	0.005
TZI (53, 37.9%)	0.37 ± 0.16	0.29 ± 0.12	0.42 ± 0.17	< 0.001
Qmax (mL/s) (23, 16.4%)	13.3 ± 7.2	14.3 ± 7.2	12.4 ± 7.1	0.157
Volume (mL) (23, 16.4%)	219.4 ± 109.6	225.1 ± 112.5	213.9 ± 107.3	0.582
PVR (mL) (20, 14.3%)	44.4 ± 69.5	38.1 ± 77.8	50.6 ± 60.0	0.324
Urine biomarkers				
IL-6 (pg/ml)	2.43 ± 4.34	2.27 ± 4.94	2.61 ± 3.60	0.647
IL-8 (pg/ml)	37.72 ± 296.46	58.43 ± 408.8	15.16 ± 44.72	0.390
TNFα	1.47 ± 5.88	1.91 ± 7.91	1.00 ± 2.00	0.360
NGF	0.21 ± 0.31	0.24 ± 0.42	0.19 ± 0.09	0.322
8-OHdG	79.00 ± 45.55	67.70 ± 43.95	91.31 ± 44.36	0.002
8-isoprostane	43.34 ± 48.88	44.92 ± 52.97	41.61 ± 44.34	0.691
TAC	655.54 ± 906.05	714.72 ± 958.41	591.05 ± 847.80	0.422
PGE2	323.85 ± 320.39	341.24 ± 354.01	304.92 ± 280.66	0.505

BOO: bladder outlet obstruction; IPSS : international prostate symptom score; TPV: total prostate volume; TZI: transition zone index; Qmax: maximum flow rate; PVR: post-void residual; IL: interleukin; TNF-α: tumor necrosis factor-α; NGF: nerve growth factor; 8-OHdG: 8-hydroxydeoxyguanosine; TAC total antioxidant capacity; PGE2: prostaglandin E2.

Univariable logistic regression analysis in the training cohort identified six variables with p ≤ 0.2 as candidate predictors: age (*p* = 0.101), IPSS-Storage (*p* = 0.069), TPV (*p* = 0.141), TZI (*p* = 0.005), 8-OHdG (*p* = 0.033), and TAC (*p* = 0.173) **(**Table 2**)**.

Table 2
Predictors of BOO in the training cohort identified by univariable and multivariable analysis using multiply imputed data

	Univariable		**Multivariable**		**Multivariable**	
	OR (95% CI)	***p* -value**	**OR (95% CI)**	***p* -value**	**OR (95% CI)**	***p* -value**
Clinical characteristics			Model 1: Only clinical parameters		Model 3: Integration of clinical parameters and urine biomarkers	
Age (years)	1.02 (0.99–1.05)	0.101	-	-	-	-
IPSS-Voiding	0.96 (0.91–1.03)	0.257	-	-	-	-
IPSS-Storage	1.11 (0.99–1.23)	0.069	1.10 (0.97–1.25)	0.121	1.12 (0.98–1.26)	0.101
TPV (mL)	1.03 (0.99–1.08)	0.141	1.02 (0.98–1.07)	0.303	1.02 (0.98–1.07)	0.291
TZI	81.56 (3.87-1721.3)	0.005	22.84 (0.40–1319)	0.128	18.76 (0.33–1066)	0.151
Qmax (mL/s)	0.97 (0.92–1.03)	0.282	-	-	-	-
Volume (mL)	1.00 (0.99-1.00)	0.540	-	-	-	-
PVR (mL)	1.00 (0.99–1.01)	0.370	-	-	-	-
Urine biomarkers			Model 2: Only urine biomarkers		-	-
IL-6 (pg/ml)	1.03 (0.94–1.14)	0.528	-	-	-	-
IL-8 (pg/ml)	1.00 (0.99-1.00)	0.523	-	-	-	-

OR: odds ratio; IPSS : international prostate symptom score; TPV: total prostate volume; TZI: transition zone index; Qmax: maximum flow rate; PVR: post-void residual; IL: interleukin; TNF-α: tumor necrosis factor-α; NGF: nerve growth factor; 8-OHdG: 8-hydroxydeoxyguanosine; TAC total antioxidant capacity; PGE2: prostaglandin E2.

	Univariable		Multivariable		Multivariable	
	OR (95% CI)	***p* -value**	**OR (95% CI)**	***p* -value**	**OR (95% CI)**	***p* -value**
TNFα	0.95 (0.81–1.11)	0.477	-	-	-	-
NGF	0.19 (0.002–17.19)	0.467	-	-	-	-
8-OHdG	1.01 (1.00-1.02)	0.033	1.01 (1.00-1.02)	0.033	1.01 (1.00-1.02)	0.084
8-isoprostane	0.99 (0.99-1.00)	0.227	-	-	-	-
TAC	1.00 (0.99-1.00)	0.173	-	-	-	-
PGE2	1.00 (0.99-1.00)	0.567	-	-	-	-

OR: odds ratio; IPSS : international prostate symptom score; TPV: total prostate volume; TZI: transition zone index; Qmax: maximum flow rate; PVR: post-void residual; IL: interleukin; TNF-α: tumor necrosis factor-α; NGF: nerve growth factor; 8-OHdG: 8-hydroxydeoxyguanosine; TAC total antioxidant capacity; PGE2: prostaglandin E2.

After backward stepwise selection, the predictors included in the three multivariable models differed. Model 1, comprising clinical parameters only, included IPSS-Storage ($p = 0.121$), TPV ($p = 0.303$), and TZI ($p = 0.128$). Model 2, comprising urinary biomarkers only, included 8-OHdG ($p = 0.033$). Model 3, which integrated clinical parameters and urinary biomarkers, included IPSS-Storage ($p = 0.101$), TPV ($p = 0.291$), TZI ($p = 0.151$), and 8-OHdG ($p = 0.084$).

The performance metrics of the three predictive models in the training and test cohorts are summarized in Table 3. In the training cohort, Model 1 demonstrated moderate discrimination, with a mean AUC of 0.74 ± 0.03 and an accuracy of 0.78. However, its performance was lower in the independent test cohort (mean AUC = 0.63 ± 0.07; accuracy = 0.61), suggesting limited generalizability of the clinical-only model. Model 2 showed modest discrimination in the training cohort (AUC = 0.62), whereas its AUC increased to 0.76 in the test cohort. Model 3 demonstrated the most consistent performance. In the training cohort, Model 3 achieved a mean AUC of 0.75 ± 0.02 and an accuracy of 0.76. In the test cohort, it maintained an AUC of 0.76 ± 0.06, with high accuracy (0.82), sensitivity (0.77), specificity (0.87), PPV (0.83), and NPV (0.81). Overall, the integrated model demonstrated more consistent discrimination across the training and test cohorts than the clinical-only model and showed favorable predictive performance compared with either the clinical or biomarker-only model.

Table 3
Performance metrics of predictive models incorporating clinical parameters and urinary biomarkers for BOO

Training cohort	**Model 1:** **Only clinical parameters**	**Model 2:** **Only urine biomarkers**	**Model 3:** **Integration clinical parameters and urine biomarkers**
AUC	0.74 ± 0.03	0.62[a]	0.75 ± 0.02
Accuracy	0.78	0.63	0.76
Sensitivity	0.67	046	0.57
Specificity	0.88	0.79	0.93
PPV	0.84	0.68	0.89
NPV	0.74	0.61	0.70
Test cohort			
AUC	0.63 ± 0.07	0.76 [a]	0.76 ± 0.06
Accuracy	0.61	0.68	0.82
Sensitivity	0.62	0.54	0.77
Specificity	0.60	0.80	0.87
PPV	0.57	0.70	0.83
NPV	0.64	0.67	0.81

[a] Model 2 AUC is presented as a single value rather than mean ± SD, as urinary biomarker data had no missing values, and therefore no between-imputation variability existed. AUC: area under curve; PPV: positive predictive value; NPV: negative predictive value;

ROC Analysis of Model 3

The discrimination and consistency of Model 3 were evaluated using ROC curves generated across the 60 multiply imputed datasets (Fig. 1). In the training cohort, the optimal probability threshold was 0.55 (mean AUC: 0.75 ± 0.02) (Fig. 1A). In the test cohort, the mean AUC was 0.76 ± 0.06 (Fig. 1B), indicating that the model demonstrated comparable discriminative performance in the test cohort.

Decision Curve Analysis and Nomogram

Decision curve analysis (DCA) was performed to evaluate the clinical utility of the three predictive models (Fig. 2). Although the clinical-only model demonstrated a net benefit comparable to that of the integrated model in the training cohort, its net benefit was less consistent across threshold probabilities in the test cohort. In contrast, the integrated model demonstrated a relatively stable net benefit across both cohorts and generally provided greater net benefit than the clinical-only and urinary biomarker-only models in the test cohort.

An integrated predictive nomogram incorporating IPSS-Storage, TPV, TZI, and 8-OHdG was developed using the training cohort to estimate the individualized probability of BOO, with the optimal probability threshold of 0.55 indicated on the nomogram scale (Fig. 3A). The calibration curve demonstrated good agreement between the nomogram-predicted probabilities and the observed outcomes, with a mean absolute error of 0.069 (Fig. 3B).

Discussion

The present study demonstrated that urinary 8-OHdG may provide additional diagnostic information for identifying BOO in men with LUTS. Integrating 8-OHdG with clinical parameters, including IPSS-Storage, TPV, and TZI, improved the consistency of BOO prediction across the training and test cohorts. These findings suggest that urinary 8-OHdG may complement conventional clinical assessment and provide a non-invasive approach to identifying men who are more likely to have BOO.

BOO is a urodynamic diagnosis characterized by increased resistance to urinary flow in patients with LUTS. BOO may result from anatomical or functional abnormalities [2]. Anatomical obstruction may occur at the bladder neck, prostatic urethra, urethral sphincter, or anterior urethra [1, 3]. Because BPH is not the sole cause of male BOO, assessment based primarily on prostate and uroflowmetry parameters may not accurately distinguish BOO from other causes of LUTS. Bladder hypersensitivity, overactive bladder, and impaired relaxation of the urethral sphincter can produce storage or voiding symptoms that overlap with those of BOO, especially in men with a small prostate volume [2]. In such cases, accurate diagnosis of BOO may be difficult without VUDS.

Recent studies have suggested that bladder hypersensitivity, overactive bladder, and other LUTDs may be associated with chronic inflammation involving the bladder, prostate, or urethra [17]. Inflammation in the lower urinary tract may activate sensory afferents, increase bladder sensation, and increase sympathetic activity, potentially impairing relaxation of the urethral smooth muscle during voiding [18]. In ageing men with BPH and BOO, chronic bladder ischemia may contribute to bladder dysfunction, including detrusor underactivity and voiding LUTS [19, 20]. Consistent with these mechanisms, urinary inflammatory and oxidative stress biomarkers have been reported to be elevated in both BOO and non-BOO men with LUTS compared with controls. These findings suggest that chronic inflammation and oxidative stress may contribute to LUTD in men with LUTS, irrespective of the presence of BOO [7, 21].

In this study, urinary biomarkers alone did not provide sufficient discrimination between men with and without BOO. Rather, their diagnostic value appeared to be enhanced when combined with conventional

clinical parameters. In particular, integrating 8-OHdG with IPSS-Storage, TPV, and TZI provided a more informative approach to BOO prediction than either clinical parameters or urinary biomarkers alone. Men with larger TPV and TZI are more likely to have BOO due to BPO or BND. Chronic BOO increases voiding pressure, which may compromise bladder perfusion and consequently increase oxidative stress in the bladder wall [22, 23]. Although the levels of other urinary inflammatory proteins were also elevated, 8-OHdG showed the strongest association with BOO among the urinary biomarkers examined. Human BPH tissues have been reported to contain significantly higher levels of 8-OHdG than control transition-zone tissues, with 8-OHdG levels correlating with prostate weight [24]. Therefore, increased urinary 8-OHdG levels may reflect oxidative stress associated with both BOO and prostatic enlargement, which may explain the added diagnostic value of incorporating this biomarker into the integrated model. DCA indicated that the integrated model provided a relatively consistent net benefit across the training and test cohorts, whereas the relative performance of the clinical-only and biomarker-only models varied more substantially between cohorts, supporting the potential clinical utility of the integrated model.

This study also developed a nomogram for estimating the probability of BOO in men with LUTS using noninvasive clinical parameters, including IPSS-Storage, TPV, TZI, and urinary 8-OHdG. By integrating these variables into a cumulative point-based score, the nomogram may help identify men with a higher probability of BOO who may benefit from further diagnostic evaluation or targeted treatment. In men with persistent LUTS despite medical therapy who are being considered for surgical intervention, incorporating urinary 8-OHdG into the clinical assessment may improve identification of underlying BOO and potentially reduce the risk of inappropriate surgical treatment.

Several limitations must be acknowledged. First, the sample size was small, particularly in the independent test cohort, which may limit the precision and generalizability of the predictive model. Second, men with a large TPV or urinary retention were excluded, which may have introduced selection bias and limited the applicability of the model to these clinically important populations. Third, the non-BOO group did not comprise healthy controls but included men with various forms of LUTD involving the bladder or bladder outlet. Consequently, men with completely normal lower urinary tract function were not represented. This heterogeneity may have influenced the observed biomarker levels and the ability of the model to distinguish BOO from other forms of LUTD. Further studies involving larger, multicenter cohorts and broader patient populations are warranted to externally validate the nomogram and establish its clinical utility.

Conclusion

The use of clinical parameters or urinary inflammatory and oxidative stress biomarkers alone provided limited diagnostic discrimination for BOO in men with LUTS. In contrast, the integrated predictive model combining IPSS-Storage, TPV, TZI, and urinary 8-OHdG demonstrated good and reasonably consistent diagnostic performance, with DCA indicating greater and more consistent clinical net benefit than either the clinical-only or biomarker-only model. This non-invasive approach may facilitate the identification of men with a higher probability of BOO and help guide the selection of patients for further urodynamic

evaluation or treatment, potentially reducing unnecessary invasive urodynamic testing and inappropriate surgical intervention in men unlikely to have BOO. External validation in larger, prospective cohorts is warranted before its routine clinical application.

Declarations

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Author Contribution

Tian JH, Hsieh TC, and Kuo HC wrote the main manuscript textTian JH prepared figures 1-3 and TablesHsieh TC made critical comments and statistical analysisKuo HC made the final revisionAll authors reviewed the manuscript

Ethics statement:

The study protocol was approved by the Research Ethics Committee of Hualien Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation, IRB code: 111-132-B, dated June/15/2022.

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Figures

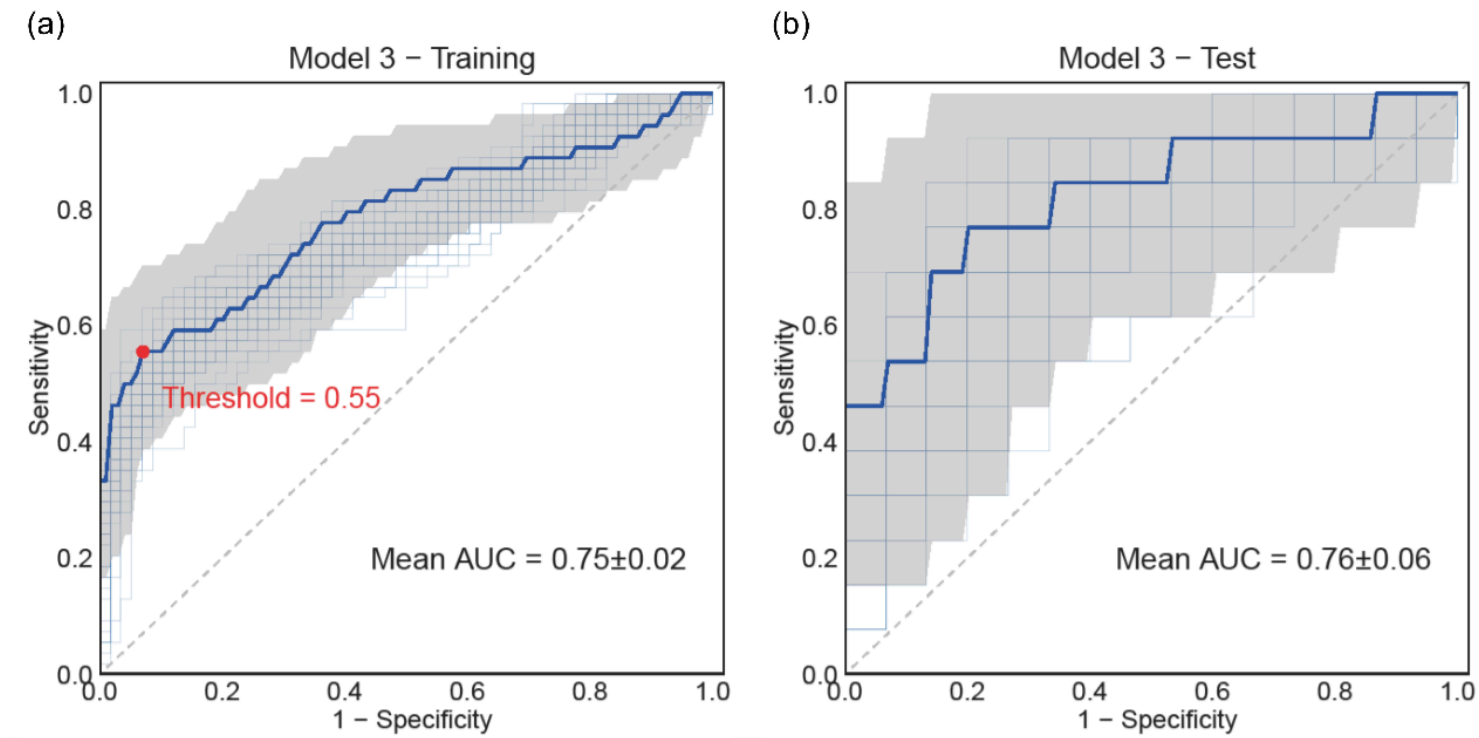


Figure 1

Diagnostic performance of the integrated model incorporating clinical parameters and urine biomarkers (Model 3) in (a) the training cohort and (b) the test cohort. ROC curves were derived from 60 multiply imputed datasets. The blue line indicates the mean ROC curve, and the gray band indicates the 95% confidence interval. The red point indicates the optimal probability threshold of 0.55, determined using Youden's index in the training cohort (a). ROC, receiver operating characteristic; AUC, area under the curve.

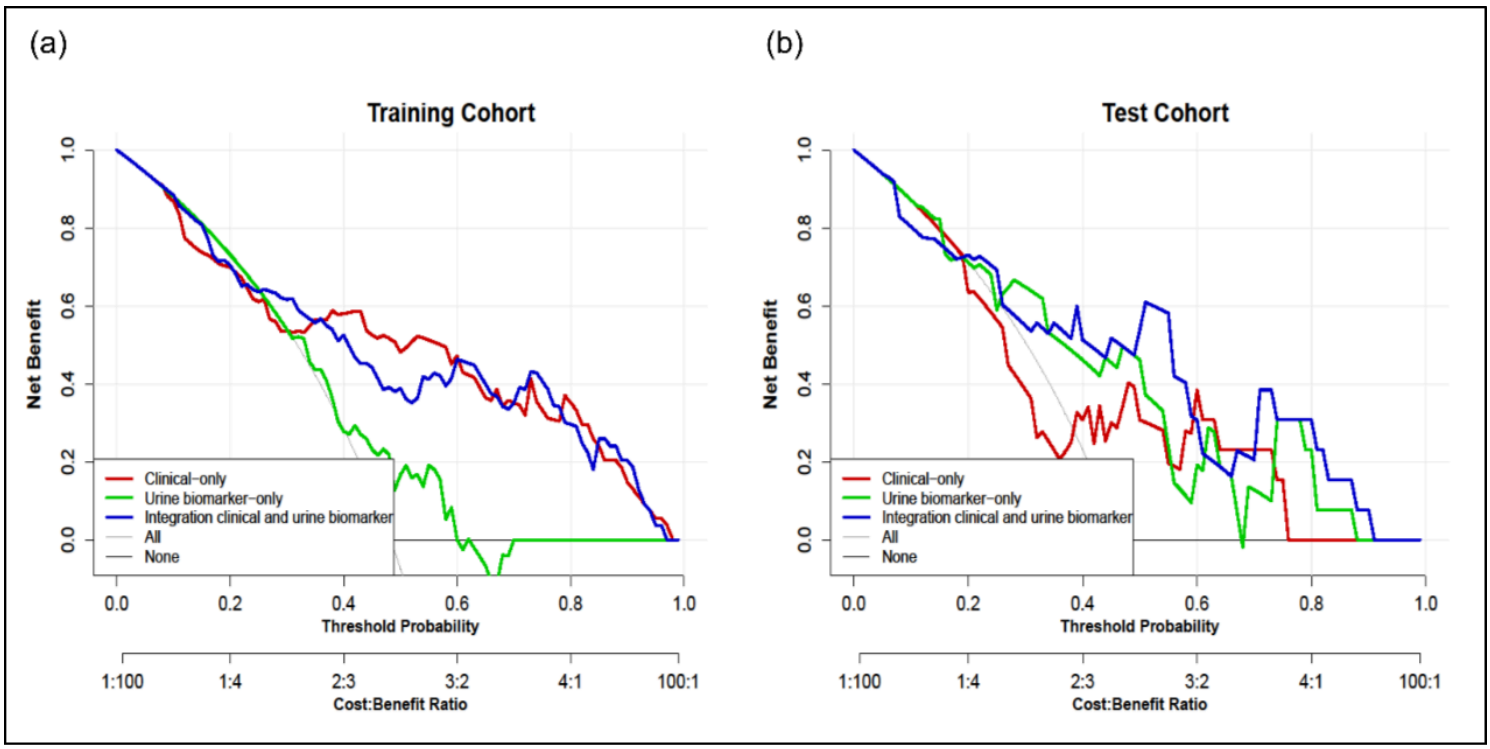


Figure 2

Decision curve analysis of the clinical net benefit of predicting bladder outlet obstruction (BOO) in (a) the training cohort and (b) the test cohort. The curves show the net clinical benefit of the integrated model incorporating clinical parameters and urinary biomarkers compared with the clinical-only and urine biomarkers-only models, as well as the “treat-all” and “treat-none” strategies, across a range of threshold probabilities.

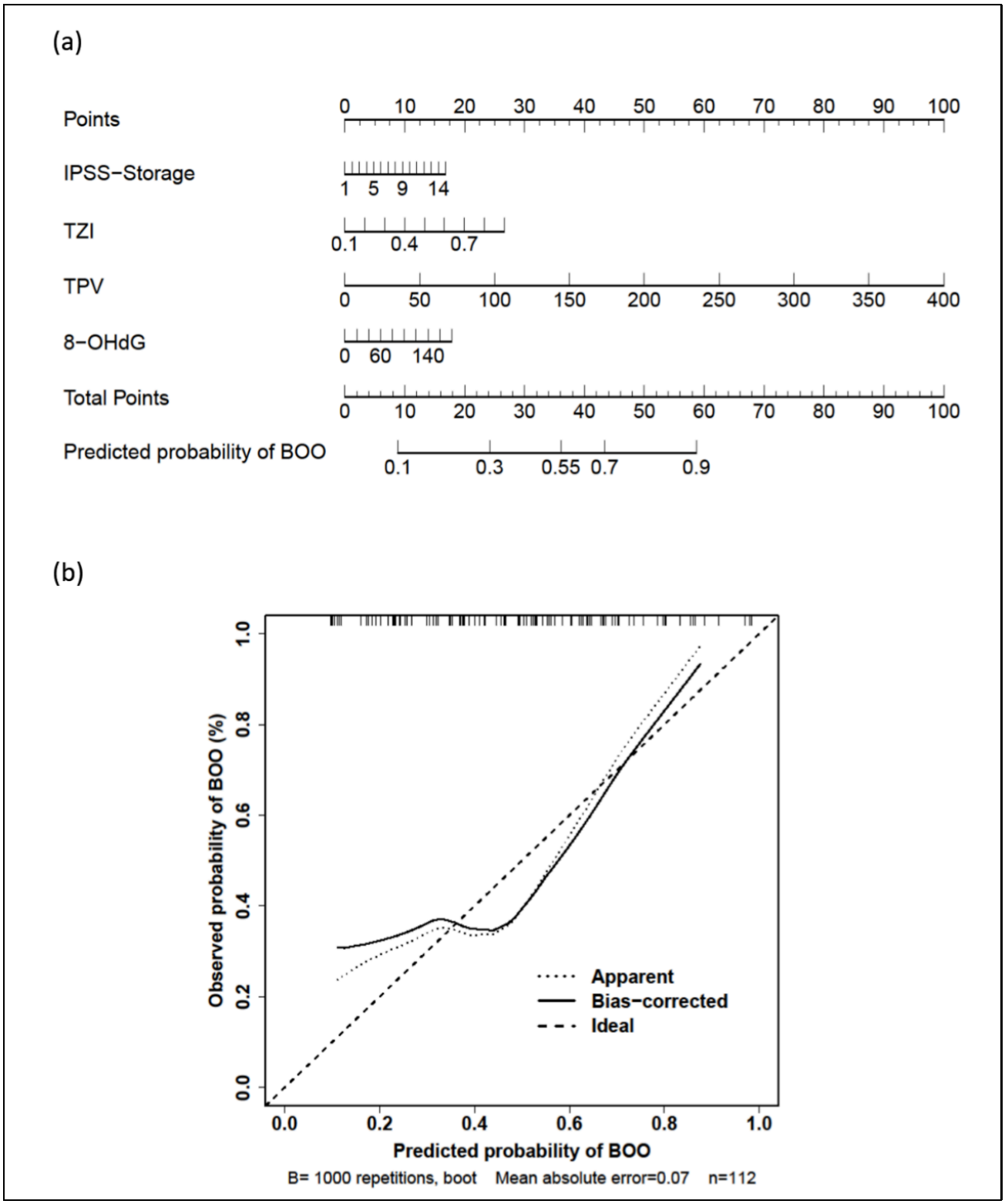


Figure 3

Nomogram and calibration curve for the integrated model predicting BOO. (a) Nomogram incorporating IPSS-Storage, TPV, TZI, and urinary 8-OHdG to estimate the probability of BOO. (b) Calibration curve showing the agreement between predicted and observed probabilities of BOO. IPSS, international prostate symptom score; TPV, total prostate volume; TZI, transition-zone index; 8-OHdG, 8-hydroxydeoxyguanosine; BOO, bladder outlet obstruction.

Supplementary Files

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- TableSupp..docx