

Association between metabolic syndrome score and systemic immune-inflammatory index in patients with benign prostatic hyperplasia: a retrospective study

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Research Article

Keywords: MetS, MetS score, BPH, SII, Cross-sectional study

Posted Date: August 31st, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10640031/v1>

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Additional Declarations: No competing interests reported.

Abstract

Purpose

Although metabolic syndrome (MetS) and systemic immune-inflammation index (SII) have been clearly associated with the occurrence and development of benign prostatic hyperplasia (BPH), the predictive value of MetS score for the severity of BPH in middle-aged and elderly Chinese is still unclear, and the association between MetS score and SII is also unclear. This study aims to study the severity of the MetS score of hyperplasia of prostate volume prediction performance and MetS score and the link between the SII.

Patients and methods:

We retrospectively analyzed 339 BPH patients (141 with severe hyperplasia and 198 with mild-to-moderate hyperplasia). Data on age, smoking history, laboratory findings, urinary examination results, and MetS score were collected. The predictive factors of BPH severity were analyzed by Spearman correlation and logistic regression. ROC curve/area under curve (AUC) was used to analyze the predictive performance of MetS score for the severity of BPH. Logistic regression and restricted cubic spline analysis were used to study the relationship between MetS score and SII in patients with BPH.

Results

We found that the receiver operating characteristic (ROC) curve of MetS score was superior to MetS in predicting PV. The area under the curve (AUC) of MetS score was 0.842, and MetS was 0.743. DeLong test showed that there was a statistically significant difference in discrimination ($Z = 3.936, p < 0.001$), and the 95% confidence interval of the AUC difference ranged from 0.047 to 0.140. At the same time, multivariate logistic regression analysis showed that MetS score was significantly positively associated with high SII risk [OR: 2.79(95% CI: 1.75–4.54)]. Stratified analysis showed consistent associations between diabetes and hypertension subgroups. Nonlinear analysis identified an inflection point for MetS score of 0.7. On the left side of the inflection point, the increased risk of high SII was more significant (OR = 5.073; 95%CI 2.053–12.53). Above this threshold, the risk increase rate slowed down (OR = 1.603; 95% CI 1.008–2.552).

Conclusions

MetS score was superior to binary MetS classification in predicting PV severity. At the same time, there was a significant and nonlinear relationship between MetS score and high SII. This suggests that metabolic syndrome may promote the occurrence and development of BPH by increasing systemic inflammatory response.

Introduction

Benign prostatic hyperplasia (BPH) is one of the most common urological diseases affecting elderly men, often resulting in lower urinary tract symptoms (LUTS) and decreased(1). Its prevalence increases dramatically after the age of 50, due to a complex interplay(2). Numerous epidemiological studies have identified components of MetS as potential risk factors(3–5). The increasing coexistence of BPH and MetS in the aging population has sparked interest in the study of their potential pathophysiological link.

MetS refers to a range of metabolic abnormalities, including elevated blood pressure, central obesity, dyslipidemia, and hyperglycemia(6). Several studies have shown that MetS may contribute to prostate overgrowth and LUTS through a variety of mechanisms, including hyperinsulinemia-driven stromal proliferation, chronic inflammation, endothelial dysfunction, and alterations(7, 8). Multiple epidemiological studies have reported higher PV and international prostate symptom score (IPSS) in men with MetS, as well as a higher likelihood of BPH progression(9). However, the binary classification of MetS does not accurately reflect the severity of metabolic disorders, and it cannot evaluate the relationship between the severity of metabolic syndrome and the progression of BPH. To better quantify the severity of MetS, Yang et al. developed a MetS scoring system for the Chinese population based on age, sex, and ethnic group specificity. The scoring system assigns weights to five common metabolic abnormalities: triglycerides, high-density lipoprotein, fasting blood glucose, waist circumference, and mean arterial pressure to quantitatively assess the severity of MetS(10).

In addition, systemic inflammatory markers based on complete blood cell counts have attracted attention in recent years due to their low cost and ease of use. A large number of studies have found that systemic inflammatory markers or their combination are associated with benign prostatic hyperplasia (BPH), showing predictive value(11, 12). Neutrophil-to-lymphocyte ratio (NLR), systemic inflammatory response index (SIRI) and systemic immune inflammation index (SII) have significant roles(13). SII has the best predictive ability for the severity of BPH, and $SII \geq 564.92$ is a risk factor(14).

The aim of our study was to retrospectively analyze the association between MetS score and the severity of BPH using clinically collected data. And the relationship between MetS score and SII. To understand the role of MetS in the clinical progression of BPH, so as to provide a reference basis for the early intervention and effect evaluation of patients.

Materials and Methods

Patients and data collection

The retrospective study received ethical approval from the Ethics Committee of The First Affiliated Hospital of Wenzhou Medical University, complied with the ethical approval reference, and was conducted in accordance with the Declaration of the World Medical Association of Helsinki. Written informed consent was obtained from all participants. We retrospectively analyzed medical records from 2023 to 2025 and enrolled 339 eligible patients with BPH (141 with severe hyperplasia and 198 with mild-to-moderate hyperplasia). Patients with comorbidities including acute/chronic inflammation, history of previous lower urinary tract surgery, malignancy, autoimmune disease, major organ dysfunction, infectious disease, or severe neuropsychiatric disorders were excluded. Baseline data including age, smoking history, MetS score, laboratory results, prostate volume measured by abdominal ultrasound, and postoperative pathological results were recorded to exclude patients with prostate cancer. Figure 1 displays a flowchart of the participant selection process.

Assessment and Grouping of BPH

All participants were diagnosed with BPH by comprehensive evaluation including medical history, color Doppler ultrasound of the urinary system, and postoperative pathological testing. The PV was calculated as the prostate height × width × length ×π/6. The prostate volume of more than 80ml was divided into the severe group, and the prostate volume between 25ml and 80ml was divided into the mild-to-moderate group(15).

Assessment of MetS Score

Referring to the MetS scoring model developed by Yang et al. for Chinese adults, we constructed MetS scores according to standard procedures. The MetS score was calculated as follows: MetS score =-3.1436+0.0258× waist circumference +0.361× triglycerides -0.9348× high-density lipoprotein +0.0128× mean arterial pressure +0.1224× fasting blood glucose(10).

Definition of Immune-inflammatory Indexes

On the second morning post-admission, peripheral venous blood samples were collected while patients were fasting. An automated Hematology Analyzer (Mindray Auto Hematology Analyzer BC6800) was used to measure lymphocyte, neutrophil, monocyte, and platelet counts, which are expressed as ×10⁹ per liter. The immune-inflammatory indexes in this study were calculated as SII= platelets × neutrophils/lymphocytes(16).

Statistical Analysis

All analyses were performed using SPSS version 27.0 (IBM Corporation, Armonk, NY, USA) and R version 4.5.0 (R Statistical Computing Foundation, Vienna, Austria). Normality was assessed by the Kolmogorov-Smirnov test. Normally distributed continuous variables were subjected to independent t-test, chi-square test for categorical variables, and Mann-Whitney U test for non-parametric data. Univariate and multivariate logistic regression were used to calculate odds ratio (OR) and 95% confidence interval (CI) to locate the association of hyperplasia severity. Predictive performance was quantified by receiver operating characteristic (ROC) curves and area under the curve (AUC) using R software packages such as "rms", "ggplot2", "cart", and "dplyr". Prior to dichotomy, optimal cutoff values for continuous variables (survminer, survival package) have been determined. All analyses were performed with the use of a two-tailed test, and statistical significance was defined as P < 0.05.

Results

1. Predictive power of MetS and MetS score for PV

Characteristics of Participants

A total of 339 patients with benign prostatic hyperplasia were included in our cohort: 198 (58.41%) had moderate to severe benign prostatic hyperplasia and 141 (41.59%) had severe benign prostatic hyperplasia. Baseline characteristics and MetS score differed significantly between groups. As shown in Table 1, PV was significantly associated with age (P<0.001), weight (P<0.001), BMI (P<0.001), mean arterial pressure (P<0.001), waist circumference (P<0.001), blood glucose (P<0.001), triglyceride (P<0.001), high density lipoprotein (P<0.001) in patients with severe hyperplasia < 0.001), MetS score (P < 0.001) and MetS (P < 0.001) showed statistically significant variation. There was no significant difference in smoking (P = 0.658).

Table 1 Baseline Characteristics of Participants

Variables	overall(N=339)	Mild to moderate (N=198)	Severe (N=141)	P-value
Age	60.0 (51.0, 69.0)	59.0 (51.0, 69.0)	63.0 (54.0, 69.0)	<0.001
Weight	70.0 (42.0, 96.5)	66.0 (42.0, 96.5)	71.5 (50.0, 95.0)	<0.001
BMI	24.2 (16.4, 33.1)	23.5 (16.4, 31.8)	25.4 (19.5, 33.1)	<0.001
Mean arterial pressure	96.7 (73.7, 135)	93.7 (73.7, 135)	100 (74.7, 133)	<0.001
Waist circumference	88.0 (64.0, 114)	85.5 (64.0, 110)	91.0 (74.0, 114)	<0.001
Fasting blood glucose	5.70 (3.80, 27.7)	5.60 (3.90, 17.6)	5.90 (3.80, 27.7)	<0.001
Triglycerides	1.69 (0.430, 12.8)	1.50 (0.430, 7.35)	2.25 (0.680, 12.8)	<0.001
High-density lipoprotein	1.17 (0.600, 2.30)	1.24 (0.600, 2.30)	1.06 (0.610, 1.60)	<0.001
MetS score	0.694 (-0.972, 7.29)	0.395 (-0.972, 3.14)	1.06 (-0.0931, 7.29)	<0.001
Smoking				0.658
No	214 (63.1%)	129 (65.2%)	85 (60.3%)	
Yes	125 (36.9%)	69 (34.8%)	56 (39.7%)	
MetS				<0.001
No	219 (64.6%)	168 (84.8%)	51 (36.2%)	
Yes	120 (35.4%)	30 (15.2%)	90 (63.8%)	

Notes: Normally distributed continuous variables are described as means $\pm$ SEs, and continuous variables without a normal distribution are presented as medians [P25, P75].

Abbreviations: BMI, body mass index; MetS, metabolic syndrome.

Prediction of PV severity by MetS score

Table 1 Correlation analysis showed that age ($P<0.001$), MetS score ($P<0.001$), and MetS ($P<0.001$) were significantly associated with the severity of PV. Subsequent univariate logistic regression analysis (Table 2) showed that age (OR=1.459, 95%CI: 1.335-1.594), MetS (OR=9.882, 95%CI: 5.884-16.599) and MetS score (OR=6.735, 95%CI: 4.195-10.813) had a significant impact on the severity of PV.

To assess diagnostic performance, we constructed a receiver operating characteristic (ROC) curve and calculated the area under the curve (AUC) value (FIG. 2). Excellent MetS score (AUC=0.837) and good MetS performance (AUC=0.743). To compare the predictive performance of MetS score and MetS, DeLong test was performed on their ROC curves. The area under the line (AUC) was 0.842 for MetS score and 0.743 for MetS, and the AUC gap was large, and the difference value was 0.094. DeLong test showed that there was a statistically significant difference in discrimination ability ($Z = 3.936, p<0.001$), and the 95% confidence interval of the AUC difference ranged from 0.047 to 0.140.

Table 2 Univariate logistic regression of PV severity

Variables	B	Standard error	Wald	p	OR	95% CI
Age	0.377	0.045	69.519	<0.001	1.459	1.335-1.594
MetS	2.291	0.265	74.960	<0.001	9.882	5.884-16.599
MetS score	1.907	0.242	62.345	<0.001	6.735	4.195-10.813

Abbreviations: OR, odds ratio; CI, confidence interval

2. Association between MetS score and elevated SII

Basic characteristics of MetS score participants

In terms of baseline characteristics, the final sample of the study totaled 339 BPH patients, including 165 patients (48.7%) with high SII and 174 patients (51.3%) with normal SII. The analysis showed that patients with high MetS score were older ($p<0.001$), weight ($p<0.001$), body mass index ($p<0.001$), platelet count ($p<0.001$), and neutrophil count ($p<0.001$) were higher than those with low MetS score. There was also a significant increase in the incidence of hypertension and diabetes ($P<0.001$) (Table 3).

Table 3 Baseline Characteristics of participants in quartiles of MetS score

Variables	Overall (N=339)	MetS-IR quartiles				P-value
		Q1(N=85)	Q2(N=85)	Q3(N=84)	Q4(N=85)	
Age	60.0 (51.0, 69.0)	60.0(51.0, 65.0)	59.0(51.0, 65.0)	62.0(52.0, 65.0)	62.0 (51.0, 69.0)	<0.001
Smoking(%)						0.573
No	214 (63.1%)	54 (63.5%)	58 (68.2%)	47 (56.0%)	55 (64.7%)	
Yes	125 (36.9%)	31 (36.5%)	27 (31.8%)	37 (44.0%)	30 (35.3%)	
Weight	70.0 (42.0, 96.5)	61.5 (42.0, 86.0)	67.5 (51.0, 80.0)	71.0(55.0, 88.0)	74.0 (50.0, 96.5)	<0.001
BMI	24.2 (16.4, 33.1)	22.0(16.4, 27.1)	24.1(19.2, 30.5)	24.9(19.3, 33.1)	25.5 (18.8, 32.0)	<0.001
Total cholesterol	5.20(2.64, 8.88)	5.41(2.89, 8.88)	5.12(3.23, 7.53)	5.13 (3.13, 7.58)	5.24 (2.64, 8.57)	0.695
Low-density lipoprotein	3.30 (1.45, 6.10)	3.37 (1.45, 5.63)	3.33 (1.71, 4.87)	3.24 (1.70, 5.34)	3.27 (1.54, 6.10)	0.855
High SII(%)						<0.001
no	174 (51.3%)	64 (75.3%)	47 (55.3%)	35 (41.7%)	28 (32.9%)	
is	165 (48.7%)	21 (24.7%)	38 (44.7%)	49 (58.3%)	57 (67.1%)	
Hypertension(%)						<0.001
no	180 (53.1%)	70 (82.4%)	48 (56.5%)	36 (42.9%)	26 (30.6%)	
is	159 (46.9%)	15 (17.6%)	37 (43.5%)	48 (57.1%)	59 (69.4%)	
Diabetes(%)						<0.001
No	233 (68.7%)	72 (84.7%)	65 (76.5%)	50 (59.5%)	46 (54.1%)	
Yes	106 (31.3%)	13 (15.3%)	20 (23.5%)	34 (40.5%)	39 (45.9%)	
Monocytes count	0.370 (0.0800, 1.23)	0.350 (0.180, 0.990)	0.350 (0.160, 0.820)	0.390 (0.0800, 0.750)	0.380 (0.180, 1.23)	0.088
Lymphocyte count	1.57 (0.450, 3.19)	1.67 (0.620, 2.82)	1.54 (0.660, 3.06)	1.55 (0.450, 3.17)	1.56 (0.600, 3.19)	0.686
Platelet count	219 (97.0, 523)	198 (109, 350)	227 (103, 523)	221 (106, 393)	226 (97.0, 494)	0.006
Neutrophil count	4.06 (1.37, 13.6)	3.40 (1.37, 12.7)	4.02 (1.63, 8.82)	4.53 (2.25, 13.6)	4.59 (2.40, 12.0)	<0.001

Abbreviations: BMI, body mass index; SII, systemic immune-inflammation index.

Association of MetS score with high SII risk

The association between MetS score and high SII risk was analyzed using crude and adjusted logistic regression models (Table 4). For baseline MetS score, Model 1 showed a significant association with high SII risk (OR 2.92 [95% CI, 2.02-4.30], $P < 0.001$). The association remained significant after adjustment for covariates in models 2 and 3 (OR 2.90 [95% CI, 1.88-4.56], $P < 0.001$) and (OR 2.79 [95% CI, 1.75-4.54], $P < 0.001$). For MetS score quartile, the risk of high SII increased across quartiles, showing a clear dose-response relationship. In model 1, the OR for high SII risk for Q2, Q3, and Q4 compared with Q1 (the reference group) was 2.46 (95% CI, 1.24-4.79), 4.27 (95% CI, 2.24-8.36), and 6.20 (95% CI, 3.23-12.34), respectively. Similar patterns were observed in adjusted model 2, with ORs of 2.82 (95% CI, 1.42-5.73), 4.33 (95% CI, 2.11-9.16), and 6.66 (95% CI, 3.10-14.90). In adjusted model 3, the odds ratios were 2.67 (95% CI, 1.32-5.50), 4.15 (95% CI, 1.95-9.09), and 6.24 (95% CI, 2.74-14.75). Trend tests confirmed a significant trend between increasing MetS quartile and high SII risk (P for trend < 0.01 in all models).

Table 4 Association of MetS score with high SII risk

Exposure	Model 1 (OR (95%CI) P-value)	Model 2 (OR (95%CI) P value)	Model 3 (OR (95%CI) P-value)
MetS score	2.92 (2.02,4.30) <0.001	2.90 (1.88, 4.56) <0.001	2.79 (1.75, 4.54) <0.001
MetS score quantiles			
Q1	References	Reference	Reference
Q2	2.46 (1.24, 4.79) <0.001	2.82 (1.42, 5.73) <0.001	2.67 (1.32, 5.50) 0.007
Q3	4.27 (2.24, 8.36) <0.001	4.33 (2.11, 9.16) <0.001	4.15 (1.95, 9.09) <0.001
Q4	6.20 (3.23, 12.34) <0.001	6.66 (3.10, 14.90) <0.001	6.24 (2.74, 14.75) <0.001
P trend	<0.001	<0.001	0.009

Model specifications are as follows: Model 1 not adjusted. Model 2 includes age and BMI adjustment. Model 3 included adjustment for age, BMI, hypertension, and diabetes.

Curve fitting and threshold effect analysis

Threshold effect analysis showed a nonlinear association between MetS score and high SII risk (Figure 3). When MetS score was lower than 0.7, the increased rate of high SII risk was more significant (OR = 5.073;95% CI 2.053-12.53;p< 0.0001). Above this threshold, the rate of increased risk slowed down (OR = 1.603;95% CI 1.008-2.552;p = 0.0396). This finding was further corroborated by a likelihood-ratio test (p =0.041), which showed a significant improvement in the model fit (Table 5).

Table 5 MetS Score and high SII risk threshold effect analysis

Threshold effect analysis	High SII OR (95% CI) p value
Inflection point for MetS Score (K-value)	0.7
<K slope	5.073 (2.053, 12.53) < 0.001
>K slope	0.0396 1.603 (1.008, 2.552)
Log likelihood ratio test	0.041

Abbreviations: OR, odds ratio; CI, confidence interval;Mets,metabolic syndrome;SII,systemic immune-inflammation index.

Subgroup analysis

Subgroup analyses were performed to explore the stability of the association between MetS score and high SII risk, combined with tests for interaction effects. In Model 3, all potential confounders were included in the analysis along with the variables defining the study subgroups. Results consistently showed a stable association between MetS score and age and BMI, as well as diabetes and hypertension in all groups. As all interaction p values exceeded 0.05, no significant interaction effects were found (Table 6).

Table 6 Subgroup analyses for the association between MetS Score and the risk of BPH.

Subgroups	OR (95%CI) P value	P -interaction
Hypertension		0.629
No	2.27(1.43, 3.59) <0.001	
Yes	1.93(1.2,3.08) 0.006	
Diabetes		0.691
No	2.54 (1.67, 3.86) < 0.001	
Yes	0.005 2.21 (1.27, 3.84)	

Abbreviations: OR, odds ratio; CI, confidence interval

Discussion

Increasing evidence suggests that BPH is an immune-mediated inflammatory disease in which chronic and low-grade inflammatory inflammation significantly contributes to disease progression and pathogenic mechanisms(17). Almost all surgical specimens from patients with BPH show inflammatory cell infiltration, mainly including lymphocytes, macrophages and mast cells(18-20). Therefore, immune-inflammatory markers are expected to serve as biomarkers for assessing disease severity and predicting prognosis. SII represents a novel comprehensive inflammatory marker based on complete blood cell count. These indicators integrate parameters such as lymphocytes, neutrophils, monocytes, and platelets, providing a more cost-effective, comprehensive, and accessible alternative to traditional inflammatory biomarkers. According to Yifan Wu et al., SII may serve as a valuable clinical indicator(21).

Potential causes of prostatitis include infections (bacterial or viral), hormonal changes, dietary or environmental factors, autoimmune responses, urinary reflux within the prostatic aggregation duct, and systemic inflammation associated with metabolic syndrome (MetS). The mechanism by which SII assesses BPH risk may be due to the promotion of prostate growth by oxidative stress, inflammatory mediators, and insulin-like growth factors. Studies have found that the stimulation of exogenous or endogenous antigens may induce the prostate to initiate an inflammatory response.

Prostate stromal cells activate Toll-like receptors (TLRs) as targets of infectious agents, and subsequently act as antigen presenting cells to activate the immune response of T cells and macrophages, releasing more inflammatory factors and chemokines (such as IL-6, IL-8, etc.). They respond to cytokine γ , IL-2, and IL-17 by increasing the production of IL-6 and IL-8, leading to overgrowth(22). Obese men with lower urinary tract symptoms/benign prostatic hyperplasia who have elevated insulin resistance or who have hypertension and hypercholesteatemia may experience persistent prostanosis. Metabolic syndrome may be an independent risk factor for prostatitis and fibrosis(23, 24). Therefore, it is of great significance to closely monitor the related indicators of metabolic syndrome for controlling the occurrence and development of inflammation and prostatic hyperplasia.

In recent years, more and more studies have shown that metabolic syndrome is correlated with common indicators in blood routine examination. Compared with patients without MetS, patients with MetS have more lymphocytes(25). Weight gain in patients can affect the physiological state and function of neutrophils. Compared with healthy controls, the platelet level of MetS patients is increased(26). YangZhao et al. found a strong positive association between SII and abdominal obesity and hypertension, while HDL-C was inversely associated(27). Animal studies have shown that in mouse models of high-fat diet-induced obesity, macrophages in adipose tissue switch from an M2-polarized state to an M1 proinflammatory state, and the former can protect adipocytes from inflammatory attack. These macrophages with altered phenotypes also secrete large amounts of proinflammatory lipid-sensitive factors, which further aggravates systemic inflammation(28). The molecular mechanism between inflammation and hypertension is relatively complex. Most people believe that oxidative stress and vascular endothelial dysfunction are the main causes of elevated blood pressure in the state of systemic inflammation(29). HDL-C is considered to be a protective factor for cardiovascular and other metabolic diseases. The decrease of HDL-C level will lead to the accumulation of lipids in the blood, which will cause severe inflammatory response(30). Studies based on different populations have shown that HDL-C affects systemic inflammatory state(31). At the same time, antioxidants are also one(32).

Our study provides a new perspective on the correlation between metabolic health and inflammation in prostate cancer patients by systematically examining the relationship between MetS score, a comprehensive index covering multiple metabolic indicators, and systemic inflammatory response index (SII). Nonlinear analysis identified a significant nonlinear association between MetS score and high SII risk, with a critical threshold of 0.7. This finding is of great significance for the early detection and control of inflammation and the development of prostatic hyperplasia. Moreover, all the participants were from a clinical population, which makes the data more reliable. In addition, the study has several limitations. First, the population was small and from a single center, which could have introduced selection bias. Second, the study was cross-sectional, and no clear causal inferences can be made about the results. Third, although some covariates were adjusted, key potential confounders such as socioeconomic status were not accounted for, which could have biased the findings. Therefore, future studies should carry out multi-center, large-scale prospective studies to fully consider the impact of key potential confounders. Such studies can not only help to verify the reliability of existing research conclusions, but also further explore the relationship between metabolic syndrome score and a wider range of disciplines, so as to improve its applicability and universality in multiple Settings.

Conclusion

In conclusion, our study established that MetS score had better predictive power for the severity of prostate volume (PV) hyperplasia than MetS diagnosis based on binary classification. It also revealed a significant and nonlinear relationship between MetS score and the risk of high SII, which has important implications for the detection and control of the occurrence and development of BPH in middle-aged and elderly people.

Abbreviations

BPH, benign prostatic hyperplasia;

MetS, metabolic syndrome;

AUC, area under curve ;

ROC, receiver operating characteristic;

SII, systemic immune-inflammation index;

BMI, body mass index;

PV,prostate volume;

NLR, neutrophil-to-lymphocyte ratio;

SIRI, systemic inflammation response index;

LUTS,lower urinary tract symptoms;

IPSS,international prostate symptom score ;

TLR-5, Toll-like receptor .

Declarations

Ethics Approval and Informed Consent

The study has received ethical approval from the Ethics Committee Boards of The First Affiliated Hospital of Wenzhou Medical University. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. According to the declaration of Helsinki, all participants signed an informed consent form before participating in the study.

Consent for publication

All authors have approved the manuscript for submission.

Data availability statement

The datasets used and/or analyzed in the current study will be available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding Statement

No funding.

Author Contributions

S-CD: Writing – original draft. Y-FL: Data curation, Formal Analysis, Writing – review & editing. M-S-G: Data curation, Formal Analysis, Validation, Writing – review & editing. J-YW: Conceptualization, Methodology, Writing – review & editing. Z-JC: Resources, Supervision, Writing – review & editing. H-HJ: Methodology, Supervision, Writing – review & editing.

Acknowledgments

The authors thank the participating volunteers.

Clinical trial number

Not applicable.

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Figures

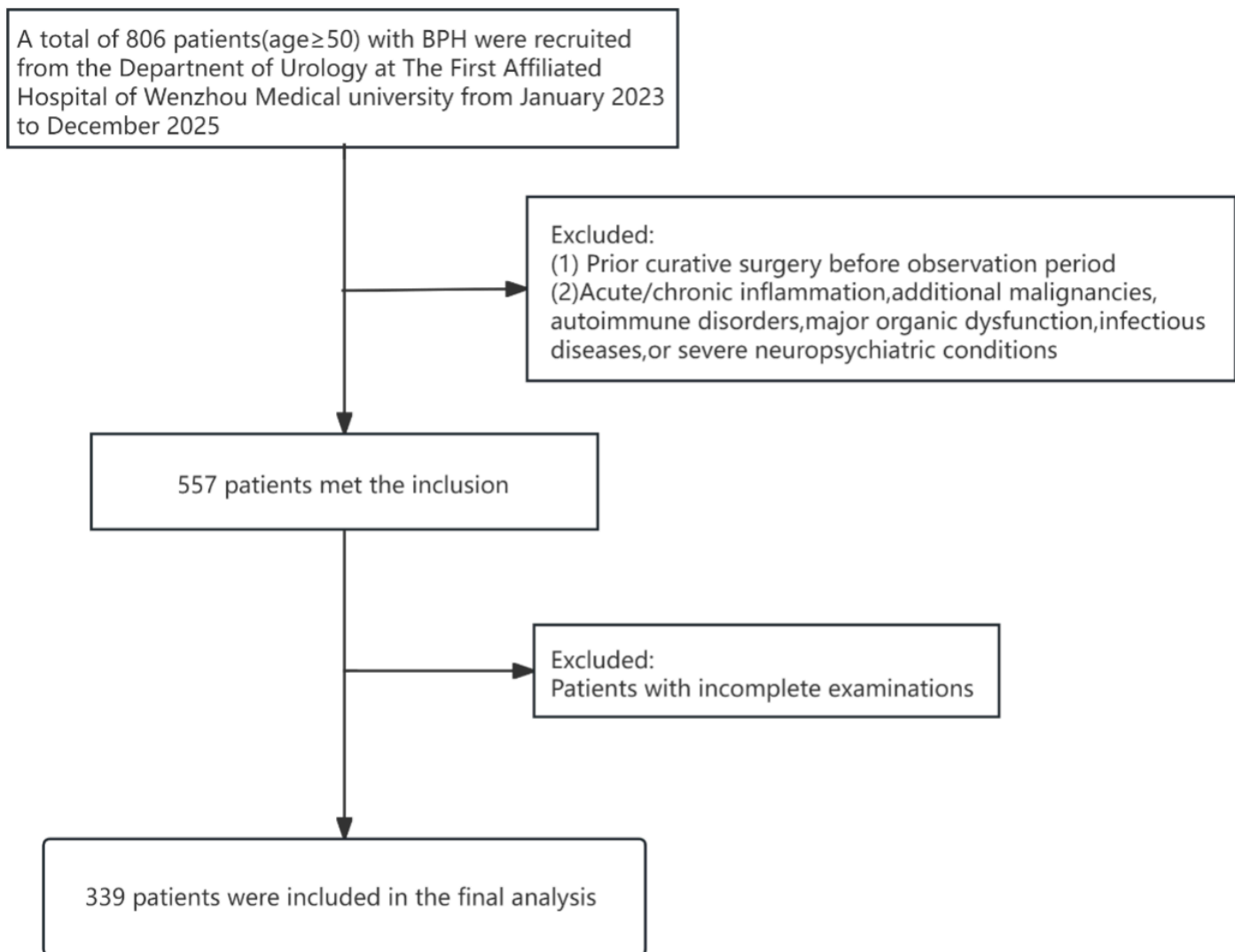


Figure 1

Research flowchart. Between January 2023 and December 2025, a total of 339 patients

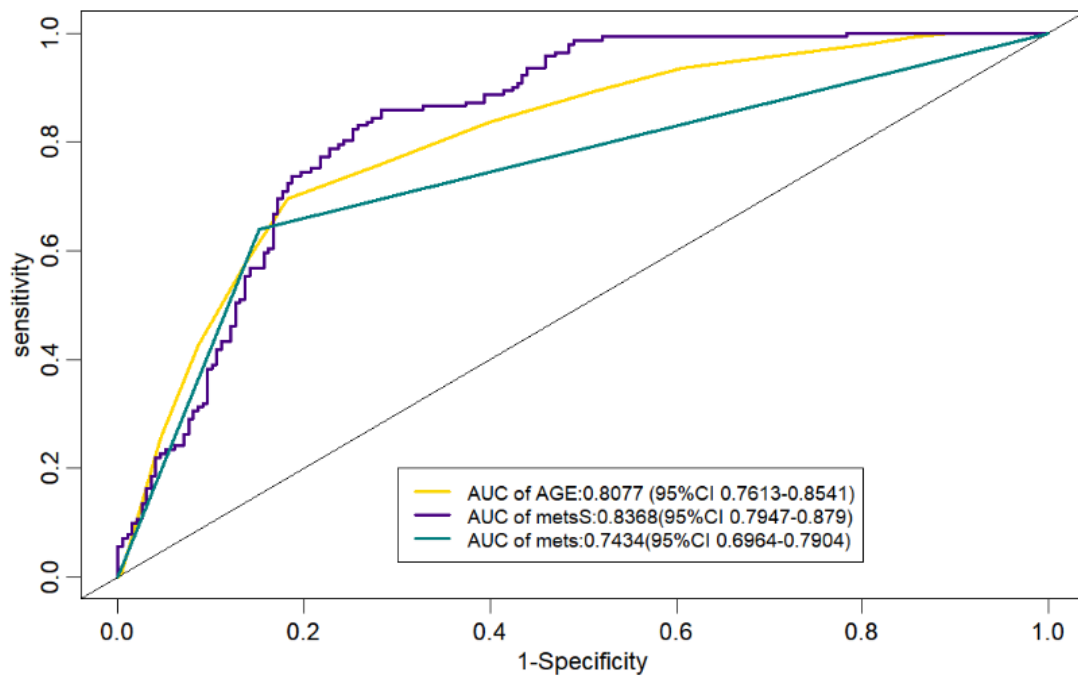


Figure 2

ROC curves comparing Mets, age, and Mets score with corresponding AUC values (95% CI).

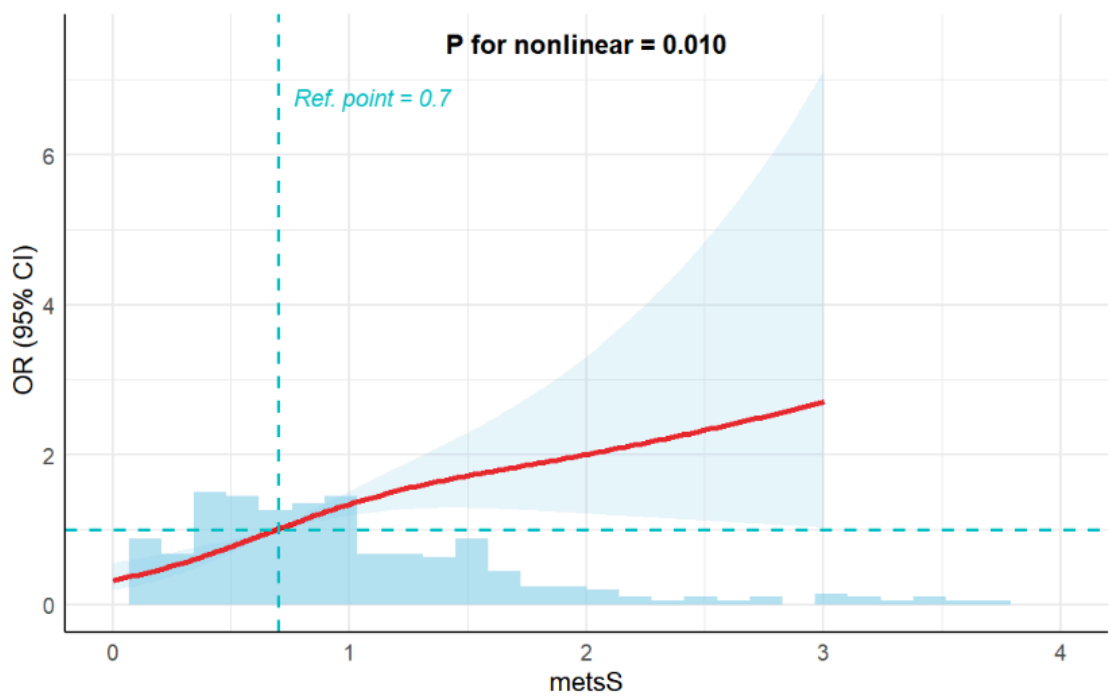


Figure 3

The red curve in the figure represents a smooth fit between variables, and the blue area Outlines the 95% confidence interval around the fit.