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ORIGINAL RESEARCH

Construction of logistic regression model and ROC curve analysis on influencing factors of urogenic infection after benign prostatic hyperplasia surgery

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Abstract

Background: This study aimed to construct a logistic regression model to identify factors influencing urogenic infection following benign prostatic hyperplasia (BPH) surgery and to analyze the Receiver Operating Characteristic (ROC) curve for predictive evaluation. **Methods**: The clinical data from 205 patients with simple BPH admitted to our hospital between January 2019 and June 2024 were retrospectively analyzed after categorizing them into an infection group (n = 35) and an uninfected group (n = 170) based on the occurrence of urogenic infection. Their general clinical data, relevant medical history, and surgical details, including indwelling urinary catheter use, operation duration, prophylactic use of antibacterial drugs, intraoperative blood loss and other factors, were compared between the two groups. **Results**: Among the 205 patients, 35 were identified as having a urogenic infection, defined by a urine culture colony count of $\geq 10^5$ CFU/mL. Factors such as advanced age, diabetes, absence of preoperative prophylactic antibacterial drug use, prostate size >55 g, and postoperative indwelling urinary catheter were found to significantly influence the likelihood of urogenic infection. The binary logistic multivariate regression model was established as follows: $\text{Logit(P)} = \ln[P/(1-P)] = 18.428 + 0.185X_1 + 2.378X_2 + 1.999X_3 + 1.298X_4 + 2.176X_5$. The model's goodness-of-fit was confirmed through the Hosmer and Lemeshow test ($\chi^2 = 3.612$, $p = 0.890$). The ROC curve analysis demonstrated a high area under the curve (AUC = 0.935), with a 95% confidence interval (CI) ranging from 0.895 to 0.975. In conclusion, advanced age, diabetes mellitus, lack of preoperative antibiotic prophylaxis, prostate size exceeding 55 g, and postoperative indwelling urinary catheter use were identified as key factors influencing the occurrence of urogenic infection after BPH surgery in patients with simple BPH. **Conclusions**: The constructed logistic regression model offers a high predictive value and provides valuable guidance for clinical practice.

Keywords

Simple benign prostatic hyperplasia surgery; Urogenic infection; Factors; Regression model

1. Introduction

Benign prostatic hyperplasia (BPH) is a common condition affecting middle-aged and elderly men, leading to significant challenges for the patients [1] due to frequent urination, urgency, nocturia and dysuria. As the disease progresses, it not only severely impacts patients' quality of life but also leads to serious complications. For instance, prolonged difficulty in urination can result in bladder dysfunction [2], urinary retention, bladder stones, and other complications. In severe cases, it may compromise kidney function, causing renal insufficiency [3].

Among the various treatment methods for BPH, transurethral laser enucleation of the prostate has emerged as a preferred approach due to its distinct advantages as it offers benefits such as minimal trauma and bleeding, rapid recovery, and effective removal of hyperplastic prostate tissue. It can alleviate urethral obstruction, improve urination symptoms, and significantly enhance patients' quality of life and overall health. Despite the remarkable outcomes achieved with transurethral laser enucleation, complications can still arise postoperatively, with urogenic infection [4] being a common issue. In addition, these infections may not only extend the duration of hospital stay and increase medical expenses but may also hinder the rehabilitation process [5] and, in severe cases, may even pose life-threatening risks. Thus, identifying the factors influencing the occurrence of urogenic infection after BPH surgery is of critical importance.

This study aims to investigate the influencing factors of urogenic infection in patients with simple BPH who underwent surgery at our hospital, construct a logistic regression model, and perform ROC curve analysis to evaluate its predictive performance.

2. Materials and methods

2.1 Clinical data

The clinical data of 205 patients with simple BPH admitted to our hospital between January 2019 and June 2024 were retrospectively analyzed. Based on the occurrence of urogenic infection after the surgery, the cases were classified into an infected group and an uninfected group.

2.1.1 Inclusion criteria

① Diagnosed with BPH according to the "Chinese Guidelines for the Diagnosis and Treatment of Urological Diseases" [6], confirmed through imaging, urodynamics and other examinations; ② No urogenic infection before surgery; ③ Undergoing first-time treatment; ④ Strict adherence to aseptic procedures for indwelling catheterization; ⑤ Patients voluntarily provided informed consent.

2.1.2 Exclusion criteria

Presence of ① severe neurological dysfunction; ② preoperative urinary infection; ③ prostate cancer, urethral stricture or urinary retention; ④ complications such as urinary retention, bladder stones, or secondary upper urinary tract hydrops.

2.2 Study protocol

2.2.1 Identification of urogenic infection

Within 1 to 3 days after transurethral laser enucleation of the prostate, 10–15 mL of urine was collected under aseptic conditions and submitted for examination within 1 hour. The urine samples were cultured at 35–37 °C for 18–24 hours, and bacterial growth was observed. Then, the colonies were counted and identified, and a urine culture colony count of $\geq 10^5$ CFU/mL was considered clinically significant, leading to the diagnosis of urogenic infection.

2.2.2 Clinical data

Clinical data collected from the two groups included general characteristics (*e.g.*, age, gender, body mass index (BMI), history of drinking and smoking), medical history (*e.g.*, hypertension, hyperlipidemia, coronary heart disease), details of surgery (*e.g.*, use of an indwelling urinary catheter, duration of surgery, prophylactic use of antibacterial drugs), and intraoperative blood loss.

2.3 Statistical analysis

Data analyses were performed using SPSS version 27.0 (International Business Machines Corporation, Armonk, NY, USA). Measurement data were analyzed using the *t*-test, enumeration data were analyzed using the χ^2 test, and a *p*-value of < 0.05 was considered statistically significant. Logistic regression analysis was applied to identify relevant influencing factors, and the predictive value of these factors was assessed using the receiver operating characteristic (ROC) curve.

3. Results

3.1 Urinary infection after simple BPH surgery

Urine culture analysis indicated that 35 of the 205 patients developed urogenic infection following simple BPH surgery.

3.2 Univariate analysis

Univariate analysis demonstrated significant differences between the infected and uninfected groups in terms of age, diabetes status, preoperative prophylactic use of antibacterial drugs, prostate size, and postoperative use of an indwelling urinary catheter ($p < 0.05$). The detailed results are shown in Table 1.

3.3 Multivariate logistic regression analysis

Multivariate logistic regression analysis was performed with urogenic infection following BPH surgery as the dependent variable. Variables, such as age, diabetes status, preoperative prophylactic use of antibacterial drugs, prostate size, and postoperative use of an indwelling urinary catheter (the assigned values are listed in Table 2), were incorporated into the logistic regression model, and the results revealed that age, diabetes, preoperative prophylactic use of antibacterial drugs, prostate size, and postoperative indwelling urinary catheter were significantly associated with urogenic infection ($p < 0.05$). Additionally, the odds ratios (ORs) for these variables were greater than 1, indicating increased risks associated with these factors (Table 3).

3.4 Probability model for urinary infection following surgery for BPH

Based on the results presented in Table 3, a binary logistic multivariate regression analysis model was constructed to predict the likelihood of urinary infection following BPH surgery. The model was expressed as:

$$\mathrm{Logit(P)} = \ln[\mathrm{P}/(1-\mathrm{P})] = -18.428 + 0.185X_1 + 2.378X_2 + 1.999X_3 + 1.298X_4 + 2.176X_5.$$

3.5 Goodness of fit test

The goodness-of-fit of the probability model was evaluated using the Hosmer-Lemeshow test. The results demonstrated a χ^2 value of 3.612 with a *p* value of 0.890, indicating a good fit for the model (Table 4).

3.6 ROC curve analysis

The ROC curve analysis further validated the predictive value of the model, showing statistically significant results ($p < 0.05$) (Fig. 1). The area under the curve (AUC) was 0.935, with a 95% confidence interval (CI) ranging from 0.895 to 0.975.

TABLE 1. Factors significantly affecting infection via univariate analysis.

Indicator	Infected group (n = 35)	Uninfected group (n = 170)	χ^2/t	p value
Age (yr, $\bar{x} \pm s$)	73.86 ± 7.38	66.62 ± 6.30	6.008	<0.001
BMI (kg/m^2, $\bar{x} \pm s$)	22.86 ± 2.37	22.92 ± 2.29	−0.140	0.889
Disease duration (n, %)				
>3 yr	22, 62.86	106, 62.35	0.003	0.955
≤3 yr	13, 37.14	64, 37.65		
Hypertension (n, %)				
Yes	18, 51.43	88, 51.76	0.001	0.971
No	17, 48.57	82, 48.24		
Hyperlipidemia (n, %)				
Yes	21, 60.00	105, 61.76	0.038	0.845
No	14, 40.00	65, 38.24		
Diabetes (n, %)				
Yes	28, 80.00	35, 20.59	48.127	<0.001
No	7, 20.00	135, 79.41		
Nephrosis (n, %)				
Yes	14, 40.00	69, 40.59	0.004	0.949
No	21, 60.00	101, 59.41		
Coronary heart disease (n, %)				
Yes	11, 31.43	53, 31.18	0.138	0.710
No	24, 68.57	117, 68.82		
Prostate size (n, %)				
≤55 g	9, 25.71	106, 62.35	15.820	<0.001
>55 g	26, 74.29	64, 37.65		
Preoperative prophylactic antimicrobial use (n, %)				
Yes	11, 31.43	120, 70.59	19.295	<0.001
No	24, 68.57	50, 29.41		
Indwelling catheter before operation (n, %)				
Yes	19, 54.29	92, 54.12	0.000	0.986
No	16, 45.71	78, 45.88		
Procedure time (n, %)				
≤1 h	23, 65.71	113, 66.47	0.007	0.931
>1 h	12, 34.29	57, 33.53		
Indwelling urinary catheter after operation (n, %)				
>96 h	21, 60.00	60, 35.29	7.413	0.006
≤96 h	14, 40.00	110, 64.71		
Physician Experience (n, %)				
Beginners	5, 14.29	24, 14.12	0.001	0.979
Skilled	30, 85.71	146, 85.88		
Length of stay (d, $\bar{x} \pm s$)	7.34 ± 0.80	7.38 ± 0.77	−0.274	0.784
Lavage Fluid Volume (L, $\bar{x} \pm s$)	40.27 ± 4.22	40.29 ± 4.18	−0.013	0.990
Postoperative bladder irrigation time (h, $\bar{x} \pm s$)	48.34 ± 2.81	48.42 ± 2.75	−0.146	0.884
Preoperative albumin (g/L, $\bar{x} \pm s$)	34.85 ± 3.57	34.92 ± 3.51	−0.092	0.927
Systolic blood pressure on admission (mmHg, $\bar{x} \pm s$)	141.86 ± 14.43	141.96 ± 14.36	−0.041	0.967
Diastolic blood pressure at admission (mmHg, $\bar{x} \pm s$)	84.39 ± 8.54	84.42 ± 8.36	−0.013	0.990

BMI: body mass index.

TABLE 2. Variable assignment.

Variables		Value assignment
Urinary infection developed postoperatively	Y	Dichotomous variable: Occurrence: Assign Value 1; Absent: Assign Value 0
Age	X_1	Continuous variable
Diabetes	X_2	Binary variables: No: assigned value 0; Yes: assigned value 1
Large and small bacteria drugs for prostate	X_3	Binary variables: >55 g: assigned value 1; ≤55 g: assigned value 0
Preoperative prophylactic use of antimicrobial agents	X_4	Binary variables: No: assigned value 1; Yes: assigned value 0
Indwelling urinary catheter after operation	X_5	Binary variables: ≤96 h: assigned value 0; >96 h: assigned value 1

TABLE 3. Multivariate logistic regression analysis for independent factors affecting infection after simple BPH surgery.

Factors	β	Standard Error	wald	p	OR value	95% Confidence Interval for OR value	
						Lower Limit	Upper Limit
Age	0.185	0.054	11.923	0.001	1.203	1.083	1.337
Diabetes	2.378	0.567	17.608	<0.001	10.778	3.550	32.722
Prostate size	1.999	0.644	9.642	0.002	7.380	2.090	26.058
No preoperative prophylactic use of antimicrobial agents	1.298	0.551	5.551	0.018	3.664	1.244	10.789
Indwelling urinary catheter after operation	2.176	0.647	11.325	0.001	8.811	2.481	31.289
Constant	−18.428	4.086	20.338	<0.001	0.000		

OR: odds ratios.

TABLE 4. Hosmer Lemeshow test for probability models.

χ^2	Degrees of freedom	p
3.612	8	0.890

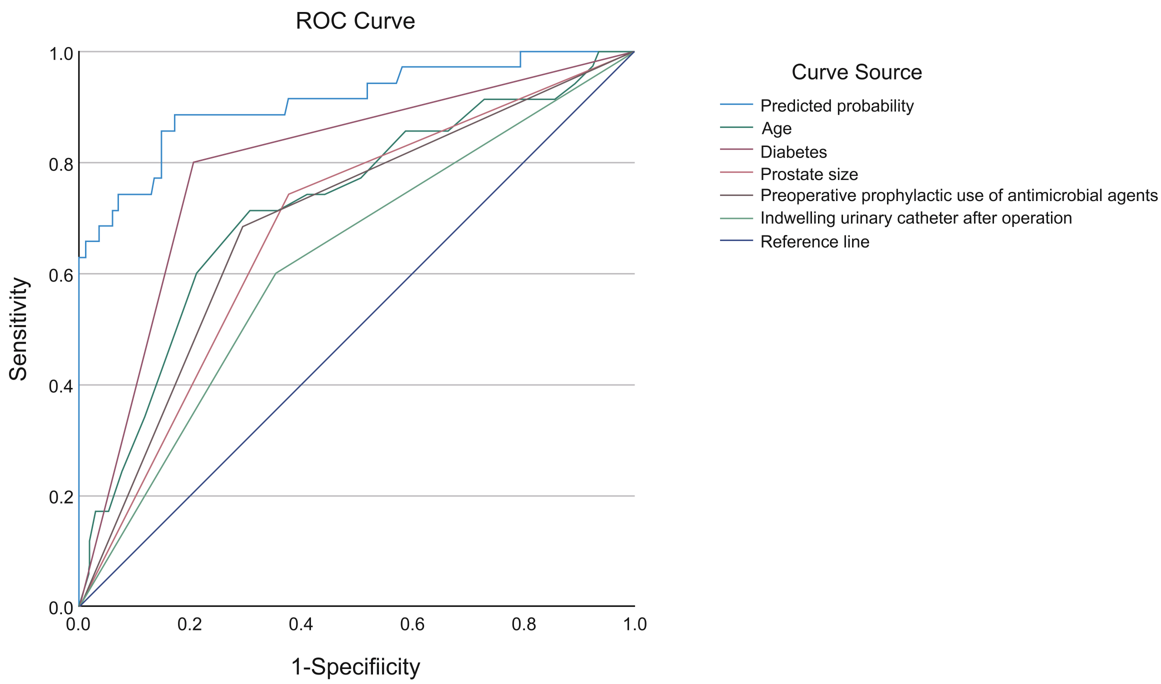

FIGURE 1. ROC curve. ROC: receiver operating characteristic.

4. Discussion

In modern medicine, transurethral laser enucleation of the prostate [7] is considered an effective treatment for simple BPH [8] as it is associated with significant advantages, including minimal trauma, rapid recovery, and a marked improvement in patients' quality of life. However, postoperative urogenic infections remain a challenging complication as these infections not only prolong hospital stays and increase medical expenses but also adversely impact patient prognosis [9]. The occurrence of urogenic infections is influenced by multiple factors [10], highlighting the importance of identifying and addressing these variables to prevent and control infections effectively. Herein, we identified age, diabetes, preoperative prophylactic use of antimicrobial agents, prostate size, and postoperative indwelling urinary catheter as significant factors contributing to urogenic infections after simple BPH surgery.

4.1 Relationship between age and urogenic infection after BPH surgery

The findings of this study indicate that elderly patients are at a higher risk of developing urogenic infections after surgery, consistent with previous reports, and this increased susceptibility could be explained by several factors. In elderly patients, diminished immune cell activity and a progressive decline in immune system function render the body more vulnerable to pathogens, thereby increasing the risk of infection. Additionally, aging is often associated with a decline in urinary system organ function, including reduced kidney filtration capacity and weakened bladder contractility. These functional impairments can lead to inadequate excretion of metabolic waste and bacteria, resulting in urinary retention and creating a favorable environment for bacterial proliferation. Furthermore, elderly patients often exhibit lower surgical tolerance, which can exacerbate the risk of urogenic infection. Postoperative complications such as urinary retention and bladder spasm may arise, further increasing the likelihood of infection [11].

4.2 Relationship between diabetes and urogenic infection after BPH surgery

Relevant studies suggest that underlying conditions, particularly diabetes, significantly increase the risk of urogenic infection following BPH surgery, especially in elderly patients [12]. Several mechanisms may account for this heightened risk. Chronic hyperglycemia suppresses the phagocytic activity of white blood cells, weakening the body's defense against pathogens such as bacteria and thus elevating the likelihood of infection. Elevated blood glucose levels also impair vascular function, leading to insufficient local tissue perfusion, disrupted nutrient delivery, and delayed wound healing, which collectively create favorable conditions for bacterial invasion and proliferation.

Diabetes-induced neuropathy [13] further contributes to an increased infection risk by impairing bladder function. Patients with bladder hypoesthesia and reduced detrusor contractility are prone to urinary retention, heightened intravesical pressure, and an increased risk of urine reflux to the kidneys. Residual urine creates an optimal environment for bacterial growth. Additionally, diabetes alters normal urination patterns, with the urinary tract mucosa remaining in a persistently moist state, making it more susceptible to bacterial colonization and invasion [14]. Moreover, metabolic disturbances in protein and fat often accompany diabetes, compromising tissue repair and regeneration after surgery. This impaired healing process further increases the risk of postoperative infection [15].

4.3 Relationship between preoperative prophylactic use of antibacterial drugs and urogenic infection after BPH surgery

The findings of this study indicate that the absence of preoperative prophylactic antibacterial drug use is associated with an increased risk of urogenic infection after BPH surgery. Although transurethral laser enucleation of the prostate is minimally invasive, it may damage the prostate and surrounding tissues, impairing local blood circulation and temporarily weakening immune defenses [16], creating an entry point for bacterial invasion, and increasing the risk of infection if prophylactic antibacterial drugs are not administered. Furthermore, the urethra harbors a normal microbiota that may be introduced into the surgical site during the procedure. Without prophylactic antibacterial drugs, these microorganisms can proliferate and cause infection. Postoperative activity restrictions, common among patients, can reduce urine flow and hinder excretion [17] and lead to prolonged urine retention within the urinary system, further facilitating bacterial growth and increasing the likelihood of infection. By contrast, the preoperative prophylactic use of antibacterial drugs significantly lowers the risk of infection by addressing these vulnerabilities and providing a critical defense against bacterial proliferation [18].

4.4 Relationship between prostate size and urogenic infection after BPH surgery

In this study, a larger volume of prostate was found to increase the risk of urogenic infection after surgery for BPH [19]. Several factors may explain this observation. For instance, a larger prostate volume complicates the surgical procedure, increasing its difficulty and prolonging the operation time. This extended duration of urethral exposure elevates the risk of bacterial contamination and subsequent infection. Additionally, a larger prostate often necessitates more complex enucleation procedures [20], resulting in greater traction and damage to surrounding tissues. This trauma can impair local blood circulation and tissue repair, reducing the body's ability to elicit an effective anti-infection response. The increased invasiveness associated with a larger prostate also exacerbates the systemic inflammatory response, which suppresses immune system function and makes patients more infection-prone. Furthermore, when the prostate volume exceeds 55 g, the repair and healing of local tissues after removal require a longer time. During this extended recovery period, particularly when the patient is in a weakened physiological state, reduced resistance to external pathogens increases the likelihood of bacterial invasion and urogenic infection [21].

4.5 Relationship between postoperative indwelling urinary catheter and urogenic infection after BPH surgery

The use of a postoperative indwelling urinary catheter has been widely reported to increase the risk of urogenic infection after simple BPH surgery and can be attributed to several interconnected factors. When inserted into the urethra, the urinary catheter acts as a foreign body that damages the mucosa [22], compromising its integrity and disrupting the natural barrier that protects against bacterial invasion, thereby creating an entry point for pathogens. Prolonged catheterization exacerbates this issue by providing a continuous route for bacteria to ascend along the catheter and invade the urinary tract, significantly increasing the risk of infection. Furthermore, the extended presence of the catheter facilitates bacterial adhesion, multiplication, and the formation of biofilms on its surface. These biofilms, which are resistant to the effects of antibiotics, continuously release bacteria into the urinary system, making infections challenging to treat [23]. In addition to these risks, the prolonged placement of a catheter can also irritate local tissues, triggering an inflammatory response that not only damages immune cell function but also suppresses the body's overall immune defense mechanisms. This combination of mechanical damage, bacterial colonization and immune suppression significantly heightens the likelihood of urogenic infection following surgery.

This study had several limitations. First, we only included patients with simple BPH from a single hospital, making the sample source relatively narrow, and geographical limitations may restrict the generalizability of the findings. Differences in medical standards and patients' living habits across regions could influence the study results, making it difficult to represent the broader population fully. Second, the sample size of the study is relatively small. Although the analysis of 205 patients provides some insights, the statistical power for multivariate analysis remains limited, particularly for less common influencing factors that may not have been accurately captured. Third, this study primarily employed a retrospective analysis method, which relies on existing clinical data. This approach introduces the potential for information bias, as the accuracy and completeness of the data cannot always be guaranteed. Finally, the study did not adequately address the clinical application of the predictive models in diverse healthcare settings. This limitation may reduce the generalizability of the models and restrict their ability to guide clinical practice effectively in varied environments.

This study's reliance on data from a single hospital introduces geographical limitations, potentially under-representing the broader patient population, and future research should adopt a multicenter design, including patients from diverse regions and healthcare settings. The small sample size further limits the statistical power of the analysis, making it challenging to capture less common influencing factors. Increasing the sample size in future studies would be essential for more comprehensive evaluations. The retrospective design, dependent on pre-existing clinical data, poses a risk of information bias. To address this, subsequent studies should standardize data collection processes and implement rigorous quality control measures, particularly in multicenter, large-scale studies. Additionally, the applicability of the predictive model across different healthcare settings was not fully evaluated. In addition, establishing an external validation cohort will allow for adjustments based on regional and environmental factors, enhancing the model's generalizability and its utility in improving clinical care.

5. Conclusions

In conclusion, advanced age, diabetes, absence of prophylactic use of antibacterial drugs before surgery, prostate volume exceeding 55 g, and prolonged duration of postoperative indwelling urinary catheter use were identified as significant influencing factors for urogenic infection following BPH surgery in patients with simple BPH. The probability model constructed based on these findings demonstrates high clinical predictive value and provides a practical tool for guiding early interventions and preventive measures in clinical practice.

AVAILABILITY OF DATA AND MATERIALS

All data supporting the findings of this study are included within the manuscript. Additional raw data can be provided by the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

ZZ, DHL—designed the study and carried them out; prepared the manuscript for publication and reviewed the draft of the manuscript. ZZ, DHL, SZC, and HBW—supervised the data collection; analyzed the data. ZZ, DHL, SZC—interpreted the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of Wenzhou TCM Hospital of Zhejiang Chinese Medical University (Approval no. WZY2019-X-025-01). Written informed consent was obtained from a legally authorized representatives for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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