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Factors Associated with Urethral Stricture Post-Transurethral Resection of the Prostate for Benign Prostatic Hyperplasia: A Case-Control Study

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Abstract

Background: The clinical relevance of urethral stricture (US) as a late complication after transurethral resection of the prostate (TURP) underscores the need to better understand its associated factors in contemporary practice. The aim was to evaluate demographic, clinical, and perioperative factors associated with post-TURP US for benign prostate hyperplasia (BPH).

Materials and Methods: A case–control study was conducted including patients who underwent TURP for BPH between 2015 and 2024. From a cohort of 578 patients, 50 cases with confirmed US and 150 controls without stricture were randomly selected. Demographic variables, comorbidities, hematological markers, preoperative, perioperative, and postoperative factors were analyzed. Bivariate and multivariate logistic regression analyses were performed to estimate OR. The discriminative capacity of significant numerical variables was calculated using ROC curves

Results: The incidence of US was 10.9%. Multivariate analysis identified older age (aOR: 1.08; 95% CI: 1.01–1.15), larger prostate volume (aOR: 1.03; 95% CI: 1.01–1.05), history of urinary catheterization (aOR: 2.96; 95% CI: 1.05–8.32), monopolar TURP (aOR: 4.38; 95% CI: 1.59–12.08), postoperative urinary tract infection (aOR: 6.98; 95% CI: 2.57–19.01), and longer postoperative catheterization duration (aOR: 1.46; 95% CI: 1.19–1.80) as independent associated factors. Postoperative catheter duration showed the highest discriminative ability (AUC: 0.724), with an optimal cutoff ≥8.5 days.

Conclusions: Post-TURP US is associated with multiple clinical and surgical factors. Postoperative catheterization duration emerged as the most clinically useful and potentially modifiable factor, highlighting the importance of optimizing catheter management and preventing postoperative urinary tract infections.

Introduction

Benign prostatic hyperplasia (BPH) is a public health problem in the male population, especially in men over 60 years of age [1]. Transurethral resection of the prostate (TURP) remains the treatment of choice for symptomatic cases and is one of the most frequently performed urological procedures worldwide. However, despite being a safe and effective technique, it is not without complications, with urethral stricture (US) being one of the most significant. This is a late complication that can cause urinary obstruction, undoubtedly affecting quality of life [2]. In the Peruvian context, BPH represents the main demand for urology services in the country, being a significant cause of hospitalization. Therefore, the appearance of a concomitant complication prolongs hospital stay and increases healthcare costs [3].

The incidence of US after TURP varies widely in the literature, with reported rates between 1.5% and 19% [4]. Several studies have proposed prolonged operative time, comorbidities [5], resection ratio [6, 7, 8], prior catheterization [9] and duration of postoperative catheterization as possible risk factors [2, 10]. However, the heterogeneity of results prevents reaching a definitive consensus on the risk factors involved.

Despite the clinical relevance of this complication, the available evidence in Peru is limited, with few studies associating risk factors with the development of this complication, which hinders clinical decision-making at the local level. Therefore, the objective of this study was to determine the factors associated with the development of post-TURP US due to BPH.

Materials and Methods

Type and Design

A case–control study was conducted including patients who underwent TURP for BPH between 2015 and 2024 in a tertiary-level hospital in Peru. This study was reported in accordance with the STROBE statement for observational studies.

Population and Sample

The study population consisted of 578 patients. The sample size was determined using the formula proposed by Díaz et al. [11], based on previous catheterization as the exposure variable [12]. Assuming an exposure prevalence of 16.33%, an odds ratio (OR) of 2.98, 80% statistical power, and a 5% margin of error, a 1:3 case–control ratio was established. Fifty cases and 150 controls were selected through simple random sampling.

Eligibility criteria

Cases were defined as patients who underwent TURP and developed US confirmed by cystoscopy, with pathology-confirmed BPH and complete medical history. Controls were defined as patients who underwent the same procedure and did not develop US during follow-up. For both group, exclusion criteria were history of malignancy, US of other etiologies, follow-up of less than 3 months, and patients who underwent laser TURP.

Variables and Operational Definition

The variables were extracted from the medical records and grouped as follows:

1. Demographic factors: geographic origin and age
2. Comorbidities: hypertension, diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), and anemia
3. Hematological markers: neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and prostate-specific antigen (PSA)

4. Preoperative factors: prostate volume (PV), use of nonsteroidal anti-inflammatory drugs (NSAIDs), and prior catheterization
5. Perioperative factors: energy type (monopolar or bipolar), operative time
6. Postoperative factors: postoperative urinary tract infection (UTI) and catheter duration.

For hematological markers and PV, the most recent blood test and ultrasound prior to surgery were used, respectively. For NSAID and prior catheterization, one month and one year prior to surgery were considered, respectively. For energy type, were considered: monopolar (M-TURP) and bipolar (B-TURP). Postoperative UTI was defined as a positive urine culture (> 10^5 CFU/mL) within one month after surgery.

Data Processing and Analysis

Statistical analysis was performed using STATA 19.5®. For descriptive analysis, categorical variables were expressed as number and percentage. Numerical variables were expressed as mean and standard deviation (SD), and the median and interquartile range (IQR) depending on their normality distribution. Bivariate logistic regression was performed to estimate crude ORs. Multivariate analysis was performed on those variables that were significant. Furthermore, to determine the relationship between the variables, the OR was used, with a 95% confidence interval (95% CI), values not including 1 were considered statistically significant. Subsequently, cut-off points with their respective sensitivity and specificity were calculated using Receiver Operating Characteristic (ROC) curves and Area Under the Curve (AUC), only for those significant numerical variables.

AI-assisted technologies statement

During the preparation of this manuscript, ChatGPT (version 5.2) was used solely to assist with language editing, grammar refinement, and improvement of clarity and coherence of the text. This tool was not used for data analysis, statistical analysis, data interpretation, or generation of results. All authors critically reviewed and edited the content generated with the assistance of this tool and take full responsibility for the integrity, accuracy, and originality of the work.

Results

Among 578 patients undergoing TURP, 63 developed US, yielding an incidence of 10.9%. The final analytical sample included 200 patients (Fig. 1).

As shown in Table 1, the mean age was 67.9 ± 8.2 years, and most patients were from Lima (84.5%). Hypertension was the most frequent comorbidity (34.5%). The median NLR was 1.9 (IQR: 1.5–2.4); while PLR was 130.7 (IQR: 105.1–159.6). The medians of PSA and PV were 2.8 ng/mL (IQR: 1.6–4.3) and 58.5 cm^3 (IQR: 43.0–80.0), respectively. Additionally, only 29 patients (14.5%) received any NSAID regimen at least one month before surgery; while a history of catheter use within the year prior to surgery was observed in only 51 patients (25.5%). Furthermore, the use of bipolar energy (B-TURP) was slightly higher

than monopolar (M-TURP), at 56% versus 44%, respectively. The median operative time was 85 minutes (IQR: 60–105) and the median catheter duration was 7 days (IQR: 6–9). Finally, 42 patients (21%) experienced UTI as a postoperative complication.

Table 1
Descriptive analysis

	Frequency	Percentage
Urethral stricture		
No	150	75.0%
Yes	50	25.0%
Geographic origin		
Lima	169	84.5%
Provinces	31	15.5%
Age (y)	67.9	± 8.2
HT		
No	131	65.5%
Yes	69	34.5%
DM		
No	161	80.5%
Yes	39	19.5%
COPD		
No	196	98.0%
Yes	4	2.0%
Anemia		
No	167	83.5%
Yes	33	16.5%
NLR	1.9	(1.5–2.4)
PLR	130.7	(105.1–159.6)
PSA (ng/mL)	2.8	(1.6–4.3)

Values are presented as number (%), mean ± SD, or median (IQR).

HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, NLR: neutrophil-to-lymphocyte ratio, PLR: platelet-to-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, NSAIDs: non-steroidal anti-inflammatory drugs, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.

	Frequency	Percentage
Urethral stricture		
PV (cm^3)	58.5	(43.0–80.0)
Use of NSAIDs		
No	171	85.5%
Yes	29	14.5%
Prior catheterization		
No	149	74.5%
Yes	51	25.5%
Energy		
B-TURP	112	56.0%
M-TURP	88	44.0%
Operating time (min)	85	(60.0 – 105.0)
Postoperative UTI		
No	158	79.0%
Yes	42	21.0%
Catheter duration (d)	7	(6.0–9.0)
Values are presented as number (%), mean ± SD, or median (IQR).		
HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, NLR: neutrophil-to-lymphocyte ratio, PLR: platelet-to-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, NSAIDs: non-steroidal anti-inflammatory drugs, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.		

In the bivariate analysis, significant differences were observed between cases and controls for age, NLR, PLR, PSA, PV, operative time, energy type, postoperative UTI, prior catheterization, and catheter duration ($p < 0.05$). These variables showed significant associations in the unadjusted analysis (Table 2).

Table 2
Bivariate analysis

	Urethral stricture				
	Yes	**No**	**Total**	**OR [95% IC]**	***p***
Geographic origin					
Lima	43 (86.0%)	126 (84.0%)	169	Ref	
Provinces	7 (14.0%)	16 (16.0%)	31	0.85 [0.34–2.12]	0.735
Age (y)	70.7 ± 8.6	66.9 ± 7.8	67.9 ± 8.2	1.06 [1.01–1.10]	**0.005**
HT					
No	33 (66.0%)	98 (65.3%)	131	Ref	0.932
Yes	17 (34.0%)	52 (34.7%)	69	0.97 [0.49–1.90]	
DM					
No	38 (76.0%)	123 (82.0%)	161	Ref	0.354
Yes	12 (24.0%)	27 (18.0%)	39	1.43 [0.67–3.11]	
COPD					
No	49 (98.0%)	147 (98.0%)	196	Ref	1.000
Yes	1 (2.0%)	3 (2.0%)	4	1.00 [0.10–9.84]	
Anemia					
No	38 (76.0%)	129 (86.0%)	167	Ref	0.099
Yes	12 (24.0%)	21 (14.0%)	33	1.93 [0.87–4.30]	

Values are presented as number (%), mean ± SD, or median (IQR)

OR was calculated by univariate logistic regression; the *p*–value corresponds to the test of comparison between groups.

OR: odds ratio, 95% IC: 95% confidence level, *p*: *p*–value, HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, NLR: neutrophil-lymphocyte ratio, PLR: platelet-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, NSAIDs: non-steroidal anti-inflammatory drugs, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.

	Urethral stricture				
	Yes	**No**	**Total**	**OR [95% IC]**	***p***
Geographic origin					
NLR	2.30 (1.7–2.7)	1.85 (1.4–2.2)	1.9 (1.5–2.4)	2.18 [1.44–3.30]	**< 0.001**
PLR	144.4 (113.6–182.5)	128.8 (103.8–154.9)	130.7 (105.1–159.6)	1.01 [1.00–1.02]	**0.020**
PSA (ng/mL)	3.6 (2.0–5.7)	2.5 (1.4–4.1)	2.8 (1.6–4.3)	1.11 [1.03–1.21]	**0.009**
PV (cm^3)	69 (53–93)	56 (42–76)	59 (43–80)	1.02 [1.00–1.03]	**0.012**
Use of NSAIDs					
No	44 (88.0%)	127 (84.7%)	171	Ref	0.562
Yes	6 (12.0%)	23 (15.3%)	29	0.75 [0.29–1.97]	
Prior catheterization					
No	25 (50.0%)	124 (82.7%)	149	Ref	**< 0.001**
Yes	25 (50.0%)	26 (17.3%)	51	4.80 [2.38–9.58]	
Energy					
B-TURP	19 (38.0%)	93 (62.0%)	112	Ref	**0.003**
M-TURP	31 (62.0%)	57 (38.0%)	88	2.66 [1.38–5.15]	
Operating time (min)	95 (75–100)	80 (55–100)	85 (60–105)	1.02 [1.01–1.03]	**0.001**
Postoperative UTI					
No	23 (46.0%)	135 (90.0%)	158	Ref	**< 0.001**

Values are presented as number (%), mean ± SD, or median (IQR)

OR was calculated by univariate logistic regression; the *p*–value corresponds to the test of comparison between groups.

OR: odds ratio, 95% IC: 95% confidence level, *p*: *p*–value, HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, NLR: neutrophil-lymphocyte ratio, PLR: platelet-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, NSAIDs: non-steroidal anti-inflammatory drugs, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.

	Urethral stricture				
	Yes	**No**	**Total**	**OR [95% IC]**	***p***
Geographic origin					
Yes	27 (54.0%)	15 (10.0%)	42	10.56 [4.89–22.83]	
Catheter duration (d)	7 (6–8)	9 (7–11)	7 (6–9)	1.47 [1.25–1.72]	**< 0.001**
Values are presented as number (%), mean ± SD, or median (IQR)					
OR was calculated by univariate logistic regression; the *p*–value corresponds to the test of comparison between groups.					
OR: odds ratio, 95% IC: 95% confidence level, *p*: *p*–value, HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, NLR: neutrophil-lymphocyte ratio, PLR: platelet-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, NSAIDs: non-steroidal anti-inflammatory drugs, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.					

For multivariate analysis, logistic regression was used with the variables age, NLR, PLR, PSA, PV, prior catheterization, energy type, operative time, postoperative UTI, and catheter duration (Table 3). Independent factors associated with US were age (aOR: 1.08; 95% CI: 1.01–1.15), prostate volume (aOR: 1.03; 95% CI: 1.01–1.05), prior catheterization (aOR: 2.96; 95% CI: 1.05–8.32), monopolar TURP (aOR: 4.38; 95% CI: 1.59–12.08), postoperative UTI (aOR: 6.98; 95% CI: 2.57–19.01), and catheter duration (aOR: 1.46; 95% CI: 1.19–1.80). However, NLR showed a trend towards significance (p = 0.066) (Fig. 2).

Table 3
Multivariate analysis

	aOR	[95% CI]	*p*
Age	1.08	[1.01–1.15]	**0.017**
NLR	1.83	[0.96–3.49]	0.066
PLR	1.00	[0.99–1.01]	0.553
PSA	1.01	[0.90–1.14]	0.885
PV	1.03	[1.01–1.05]	**0.011**
Prior catheterization			
No	Ref		
Yes	2.96	[1.05–8.32]	0.040
Energy			
B-TURP	Ref		
M-TURP	4.38	[1.59–12.08]	**0.004**
Operating time	1.00	[0.98–1.01]	0.667
Postoperative UTI			
No	Ref		
Yes	6.98	[2.57–19.01]	**< 0.001**
Catheter duration	1.46	[1.19–1.80]	**< 0.001**

aOR: adjusted odds ratio, 95% CI: 95% confidence interval, *p*: *p*–value, NLR: neutrophil-to-lymphocyte ratio, PLR: platelet-to-lymphocyte ratio, PSA: prostate-specific antigen, PV: prostate volume, B-TURP: bipolar transurethral resection of the prostate, M-TURP: monopolar transurethral resection of the prostate, UTI: urinary tract infection.

The discriminative performance of the quantitative variables age, prostate volume, and catheter duration as predictors of post-TURP US was evaluated using ROC curves (Fig. 3). In Table 4, we observed that postoperative catheter duration showed the greatest discriminatory capacity, with an AUC of 0.724 (95% CI: 0.640–0.809), indicating good predictive power. The optimal cutoff point was ≥ 8.5 days, with a sensitivity of 56% and a specificity of 78%. Age had an AUC of 0.631 (95% CI: 0.543–0.720), with an optimal cutoff point of ≥ 66.5 years, achieving a sensitivity of 70% and a specificity of 51%. Prostate volume, meanwhile, reached an AUC of 0.619 (95% CI: 0.529–0.709). The optimal cutoff point was ≥ 57.5 cm^3, with a sensitivity of 66% and a specificity of 52%.

Table 4
Discriminative capacity of quantitative variables associated with post-TURP urethral stricture

	Cut-off	Sensitivity (%)	Specificity (%)	AUC	[95% IC of AUC]
Age	≥ 66.5	70	51	0.631	[0.543–0.720]
Prostate volume	≥ 57.5	60	52	0.619	[0.529–0.709]
Catheter duration	≥ 8.5	56	78	0.724	[0.640–0.809]

AUC: Area under the curve, 95% CI: 95% confidence interval

Discussion

This study included a total population of 578 patients who underwent TURP for BPH. The incidence of US was 10.9%. This is consistent with the incidence reported in other international studies, where the incidence was 9.8% [4] and 10.5% [2]. The incidence in the Peruvian population is still unknown; this is one of the few studies that reports a precise estimate of the incidence in a Peruvian hospital. However, in Mexico, a similar population, Garza-Montúfar et al. [9] reported an incidence of 29%; nevertheless, this study also included bladder neck stenosis (BNS), so that incidence does not explicitly correspond to US.

In our study, age was significantly associated with the development of US, with an increased risk directly proportional to increasing age. These results are consistent with the study by Wan Mokhter et al. [13], where this variable was included in their multivariate model, confirming the significant association (aOR: 1.121, 95% CI: 1.044–1.204). Similarly, Golomb et al. [14] conducted a retrospective cohort study of 43,525 patients who underwent M-TURP, identifying advanced age as an independent predictor of post-TURP US, even after adjusting for comorbidities and procedural characteristics ($p < 0.001$). Therefore, the observed association could be explained by age-related degenerative changes, such as decreased urethral vascularization, reduced tissue repair capacity, and increased susceptibility to iatrogenic trauma during endoscopic instrumentation; this, coupled with immunosenescence and a decrease in the urethral mucosal defense mechanism [15].

On the other hand, previous studies such as that by Venugopalan et al. [4] demonstrated a significant association between prostate volume and urethral stricture post-TURP in unadjusted models, but only in bivariate analyses. Our study expands on this analysis, demonstrating that after multivariate analysis this variable retains its significance, reinforcing the hypothesis that prostate volume acts as an independent risk factor. This finding is consistent with the study by Wan Mokhter et al. [13], who identified that a larger prostate size was independently associated with a higher risk of urethral stricture after TURP (aOR: 1.038, 95% CI: 1.014–1.062). Elsaqa et al. [16], in their two-center study, showed similar results in their multivariate analysis (HR: 1.222, 95% CI: 1.057–1.411). Similarly, Grechenkov et al. [17] also identified this variable as an independent factor (aOR: 1.035, 95% CI: 1.009–1.061), although in these series the outcome included both US and BNS. It is known that urine extravasation into the subepithelial area following epithelial damage is part of the pathogenesis of stricture formation, as this

results in inflammation, activation of fibrotic processes in the sinusoids of the corpus spongiosum, and subsequent eschar formation. Myofibroblasts are likely responsible for stricture formation, while giant cells are responsible for collagen synthesis. Type 1 collagen is responsible for the formation of the post-traumatic scar by TURP, unlike other stenoses, in which type 3 collagen is responsible [4, 18]. Thus, a large prostate implies a longer operating time, therefore, a greater exposure to urethral trauma.

Additionally, a history of urinary catheterization in the last year was observed in 25.5% of cases. This incidence is relevant, as it is one of the variables most strongly associated with US, as evidenced in a study conducted in Malaysia, where a history of catheterization had an aOR of 5.413 ($p = 0.002$); furthermore, they included this variable in their predictive nomogram for post-TURP US [13]. In our country, Segovia-Quintanilla [12], found that this variable had an OR of 2.97, consistent with our results, making it a significant risk factor.

Urethral exposure to catheters can cause areas of ischemia by forcefully compressing the urethral epithelium, especially when the appropriate diameter is not used, which could be involved in the development of the disease [19]. Likewise, the American Urology Association (AUA) [20] and the European Association of Urology (EUA) [21] indicate that any form of urethral instrumentation, including prior catheterization, has significant clinical relevance. This variable has been proposed as one of the strongest predictors and has been included in the AUA and EUA guidelines as one of the main risk factors to consider.

Regarding the energy used, in our study, the use of monopolar energy was an independent risk factor for the development of post-TURP US, with a risk more than four times higher than that of B-TURP. Pirola et al. [22] refer to possible thermal damage from urethral exposure to electric current. This could be justified by the fact that monopolar current covers a larger area of heat, increasing urethral trauma. In M-TURP, current travels from the current generator to the cutting loop, and then to the electrode on the skin. Furthermore, the heat wave produced is close to 300 watts (W), and the generated temperature reaches up to 400 degrees Celsius (°C), distributed over a large area of tissue. In contrast, in B-TURP, the current starts and ends at the cutting loop. This results in a shorter circuit and lower energy intensity (170 W). Consequently, temperatures are significantly lower (40–70°C) and distributed over a smaller amount of tissue [10]. While previous studies have shown conflicting results regarding the impact of energy type on post-TURP US, most are based on unadjusted analyses. For example, a meta-analysis determined that the incidence of US was higher after TURP, particularly with monopolar energy; however, this comparison was mainly made against enucleation and ablation techniques, and not through a direct, adjusted comparison between monopolar and bipolar TURP [22]. In contrast, Komura et al. [23] found in their randomized controlled trial (RCT) that B-TURP was associated with a higher incidence of US in their unadjusted model; however, the energy type was not included in the multivariate analysis, as it was limited to identifying factors within the bipolar TURP group. Our findings provide further evidence when evaluating this factor using a multivariate model. This is the first study, to our knowledge, to identify M-TURP as an independent predictor of US.

On the other hand, our study identified a postoperative UTI rate of 21%, which is considerably higher in the case group compared to the control group (54% vs. 10%, respectively). Like our results, a Nigerian study reported a 19.1% rate of symptomatic UTI post-TURP [15]. This variable was the most significant in our study, coinciding with the study by Tao et al. [8], who concluded that postoperative UTI was strongly associated with the development of post-TURP US ($p < 0.028$).

Previous studies have demonstrated an association between postoperative catheter duration and the development of UTI [2, 10]; however, these studies did not include this variable in their adjusted models. Our study expands upon these results by maintaining its significance in the multivariate analysis, coinciding with Wan Mokhter et al. [13], who obtained an aOR of 2.147 ($p < 0.001$) and included it in their predictive nomogram. Urethral manipulation, such as catheter use, is known to be directly related to the development of UTIs. This is demonstrated by the study by Yu et al. [24], where postoperative catheter duration was significantly related to the presence of postoperative UTIs ($p = 0.003$). Similarly, Osman et al. [25] also found an association between both variables ($p = 0.007$).

The use of a urinary catheter promotes the upward colonization of bacteria, primarily from perianal or hospital-acquired flora. Consequently, bacteria form biofilms on the catheter surface, making them resistant to antibiotics and potentially affecting the renal parenchyma or causing life-threatening sepsis, especially considering that most patients are elderly. [26] Urinary catheterization, particularly if prolonged, can cause microlesions, ischemia, and local inflammation that strengthen the fibrotic process leading to UTI. Sustained inflammation of the lower urinary tract promotes prolonged urothelial damage. [25]

In this study, the discriminative capacity of significant variables was evaluated using ROC curves. The duration of postoperative catheterization proved to have the best discriminative capacity for patients at risk of post-TURP US (AUC: 0.724), with acceptable discriminative performance. The AUC values allow for estimating the discriminative performance of each variable as an individual test. These finding positions prolonged catheterization time as a useful clinical marker for identifying patients with a higher probability of developing the complication. With a cutoff point of ≥ 8.5 days, it does not detect all cases (sensitivity 56%), but it predicts risk well (specificity 78%). This variable is useful for confirming risk rather than ruling it out. Cerda-Guerrero et al. [10] determined that for a catheterization duration of 2 days, the risk was 0.7%, for 5 days it was 3%, and for 12 days it was 46%; results that can be indirectly compared with our cutoff point. An Egyptian RCT determined that removing the catheter before 24 postoperative hours is a safe and effective strategy. Since it shortens hospital stay, reduces pain and discomfort, without increasing complications [27]. However, another study concluded that very early removal of a urinary catheter can lead to re-catheterization, especially when removed on the same day [28]. This is why it is very important to determine an appropriate cutoff point to prevent the risk of complications, considering the modifiable nature of this variable.

Overall, the results support the idea that the duration of postoperative catheterization is not only an independent risk factor, but also the parameter with a clinically useful practical utility for stratifying the

risk of urethral stricture after TURP. In contrast, age and prostate volume, although independently associated with the outcome, showed limited discriminatory capacity, reflecting their lower clinical utility as isolated predictors. It is important to highlight that the objective of the ROC analysis was to evaluate the individual performance of each variable and not to construct a predictive model. Therefore, AUC values should be interpreted as complementary tools to multivariate analysis and not as definitive diagnostic tests.

Among the limitations found in our study, we emphasize the retrospective, single-center design, which implies dependence on pre-existing medical records, with an inherent risk of selection bias, as well as a limitation on extrapolating this study to other hospital settings. Furthermore, other variables such as resectoscope caliber, catheter diameter, type of lubricant, and resection speed were not considered, which we suggest be included in future studies. Postoperative UTI was the strongest variable in our study; however, the associated pathogen was not determined in each case. Finally, the ROC curve analysis was performed on individual variables, without developing a combined predictive model, as this was not the objective of this study. However, it is important to highlight that this study represents one of the few case-contol studies conducted in Peru and in Latin America evaluating clinical and surgical factors associated with the development of post-TURP US. These findings provide relevant local evidence and suggest that optimizing potentially modifiable factors, such as catheterization duration and preventing postoperative urinary tract infections, could contribute to reducing the incidence of urethral stricture after TURP. Prospective and multicenter studies are needed.

Conclusions

In this study, demographic (age), preoperative (prostate volume and prior catheterization), perioperative (energy type used), and postoperative (UTI and catheter duration) factors were identified as significantly associated with a higher risk of urethral stricture after TURP for BPH. Among the variables, the duration of postoperative catheterization stands out, both as an independent risk factor and as the parameter with the greatest discriminatory capacity for identifying patients more likely to develop urethral stricture, giving it particular clinical relevance.

Abbreviations

AUA
American Urological Association
AUC
Area Under the Curve
BNS
Bladder Neck Stenosis
BPH
Benign Prostatic Hyperplasia
B-TURP

Bipolar Transurethral Resection of the Prostate
CI
Confidence Interval
COPD
Chronic Obstructive Pulmonary Disease
DM
Diabetes Mellitus
EAU
European Association of Urology
HT
Hypertension
IQR
Interquartile Range
M-TURP
Monopolar Transurethral Resection of the Prostate
NLR
Neutrophil-to-Lymphocyte Ratio
NSAIDs
Nonsteroidal Anti-inflammatory Drugs
OR
Odds Ratio
PLR
Platelet-to-Lymphocyte Ratio
PSA
Prostate-Specific Antigen
PV
Prostate Volume
RCT
Randomized Controlled Trial
ROC
Receiver Operating Characteristic
SD
Standard Deviation
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
TURP
Transurethral Resection of the Prostate
US
Urethral Stricture
UTI

Urinary Tract Infection
W
Watts
°C
Degrees Celsius

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of the Hospital Central de la Fuerza Aérea del Perú (approval number: NC-50-HCCE-Nº001). The requirement for informed consent was waived by the Institutional Review Board due to the retrospective nature of the study.

Consent for publication

Not applicable

Clinical Trial Number

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

GVP, MGM, and RV contributed to the conceptualization and methodology of the study. GVP and RV were responsible for data acquisition. GVP and JMVR performed the statistical analysis and contributed to data analysis and interpretation. All authors contributed to drafting the manuscript. MGM and JMVR critically revised the manuscript for important intellectual content. JMVR obtained funding. RV provided administrative, technical, and material support. GVP, RV, and JMVR supervised the study. All authors approved the final manuscript.

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Not applicable

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Figures

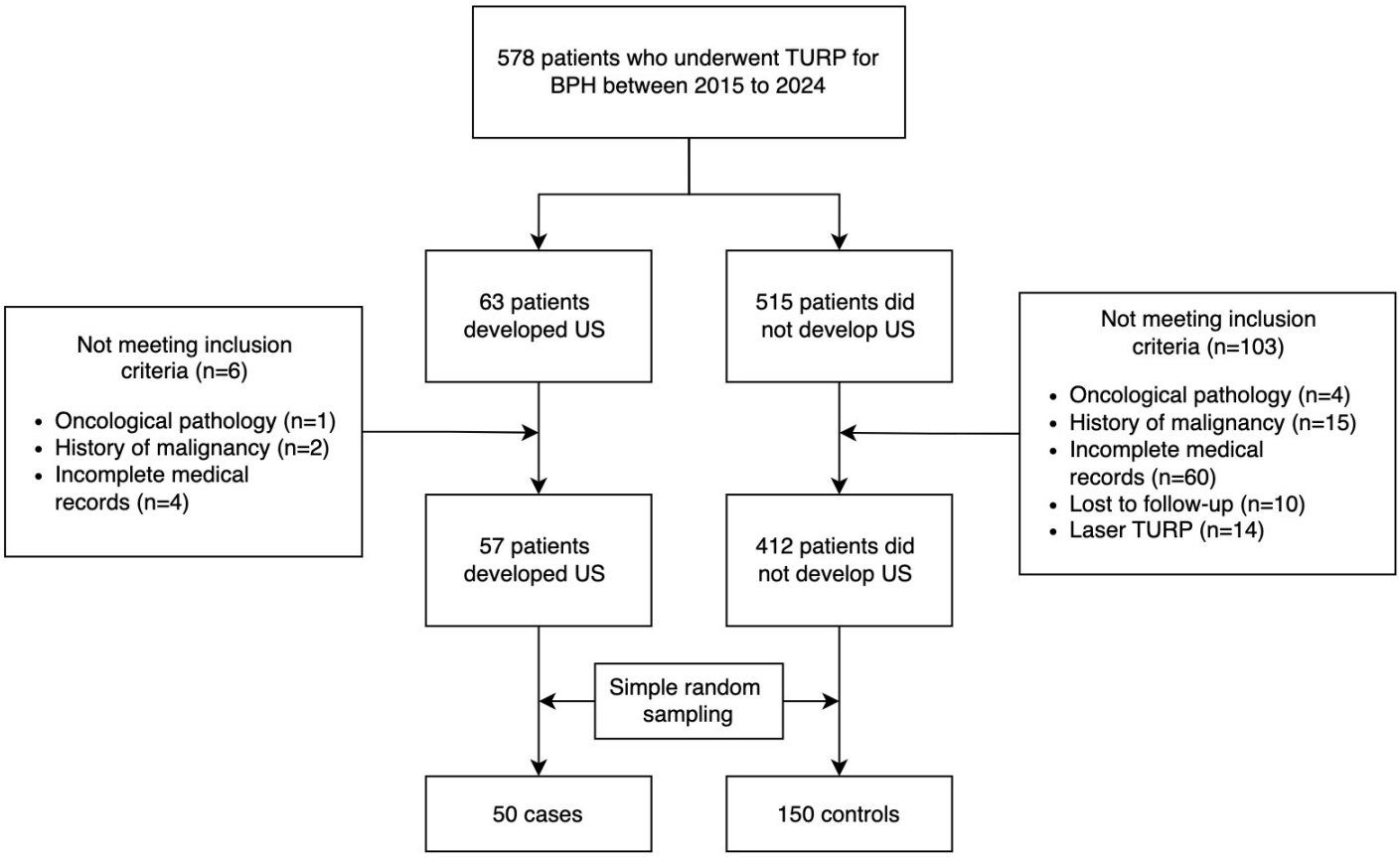


Figure 1

Flowchart of the study population. TURP: transurethral resection of the prostate, BPH: benign prostatic hyperplasia, US: urethral stricture

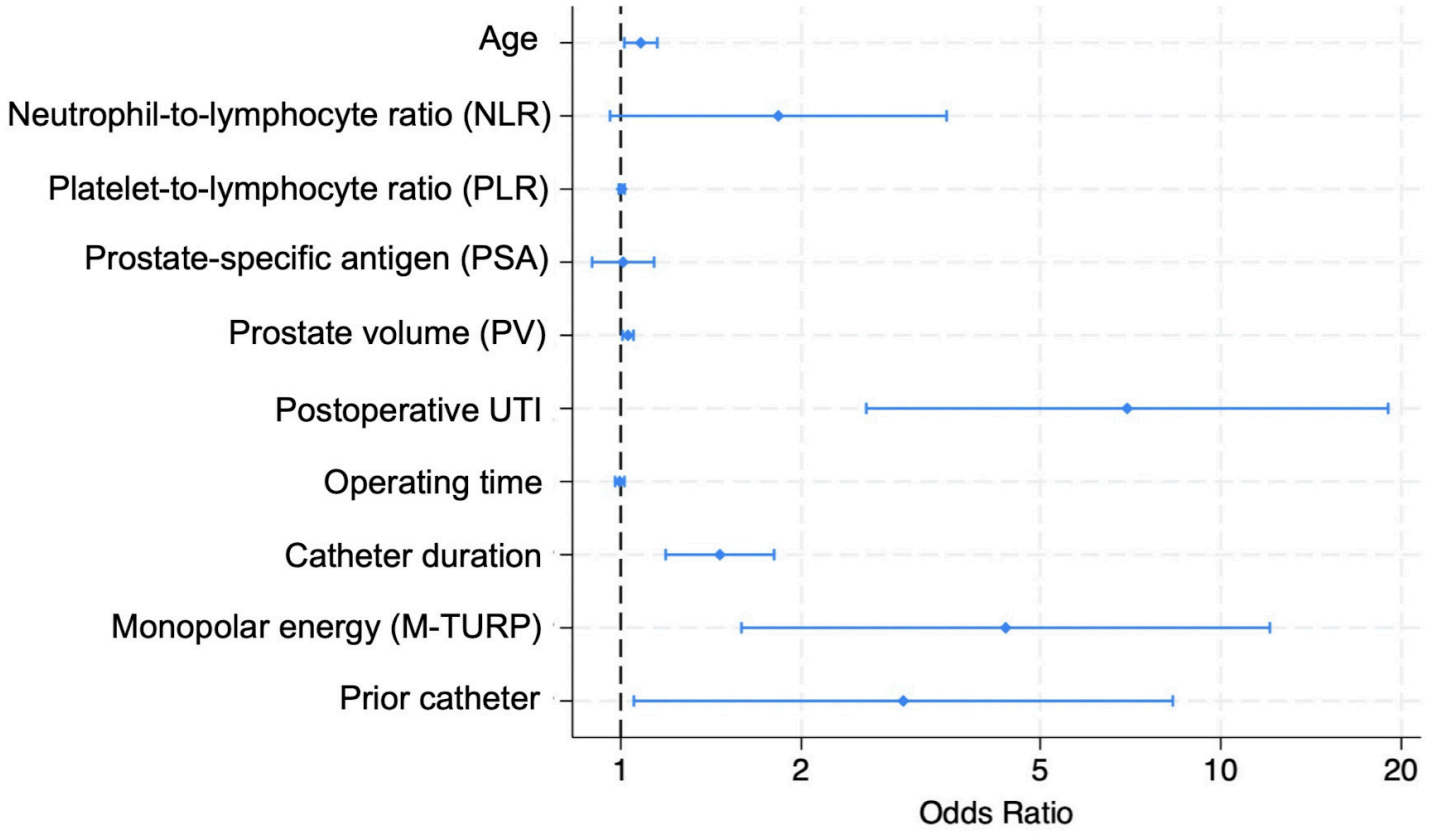


Figure 2

Forest Plot of the multivariate analysis. The statistically significant variables were age, prostate volume, history of catheter use, monopolar TURP, postoperative UTI, and catheter duration.

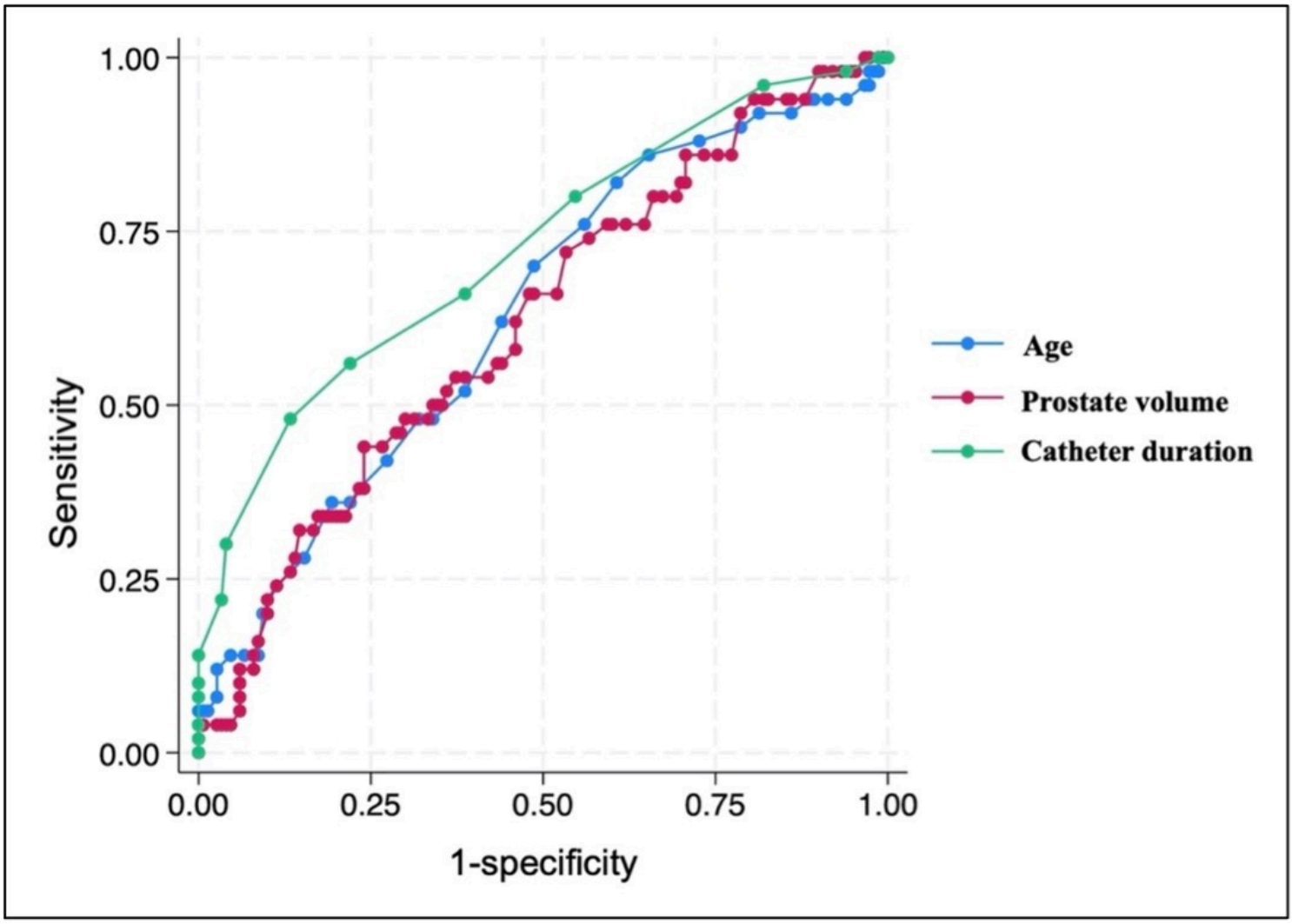


Figure 3

ROC curves of quantitative variables associated with post-TURP urethral stricture. Age (blue): AUC = 0.631, Prostate volume (red): AUC = 0.619; Catheter duration (green): AUC = 0.724.