

Does the use of a small-diameter 22Fr resectoscope sheath reduce urethral stricture after transurethral resection of the prostate?

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Summary Purpose: Urethral stricture represents a significant late complication of transurethral resection of the prostate (TURP), leading to deterioration in urinary function and quality of life. This study aimed to compare the impact of 22Fr and 26Fr continuous-flow resectoscope sheaths on postoperative urethral stricture formation and perioperative outcomes.

Methods: Patients who underwent bipolar TURP between 2021 and 2025 were retrospectively evaluated. Patients were divided according to sheath size into 22Fr (n = 135) and 26Fr (n = 145) groups. The primary endpoint was postoperative urethral stricture. A multivariable Cox proportional hazards model with Firth's penalized likelihood correction was used to identify independent predictors of stricture. Stricture-free survival was analyzed using Kaplan-Meier curves and compared with the log-rank test.

Results: Urethral stricture occurred in 5 patients (3.7%) in the 22Fr group and 22 patients (15.2%) in the 26Fr group (p = 0.0011). Operation time was shorter in the 26Fr group, while functional outcomes were comparable between groups. In multivariable Firth's penalized Cox regression analysis, use of a 26Fr sheath was the only independent predictor of urethral stricture (adjusted HR 4.08; 95% CI 1.16–14.37; p = 0.029). Kaplan-Meier analysis demonstrated a significantly higher cumulative incidence of urethral stricture in the 26Fr group (log-rank p = 0.003).

Conclusions: Use of a 22Fr resectoscope sheath is associated with a significantly lower hazard of postoperative urethral stricture without compromising functional outcomes. Sheath diameter represents a clinically relevant and modifiable technical factor that may significantly influence long-term urethral morbidity after TURP.

KEY WORDS: Benign prostatic hyperplasia; Surgical instruments; Transurethral resection of the prostate; Urethral stricture.

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INTRODUCTION

Transurethral resection of the prostate (TURP) remains the reference surgical treatment for men with benign prostatic hyperplasia (BPH) who fail medical therapy (1). While most perioperative complications are transient, late adverse events may have lasting clinical consequences. Among

these, urethral stricture represents a clinically significant complication, as it can impair urinary flow, necessitate repeat instrumentation, and convert a single procedure into chronic management (2-4). Reported incidence rates range between 2% and 10% (5), but real-world rates may be higher depending on surveillance intensity.

The pathogenesis of post-TURP urethral stricture is multifactorial. Mechanical stretch and compression of the urethral mucosa during resectoscope insertion, particularly at the penoscrotal junction, may compromise microvascular perfusion (4). When radial pressure exceeds capillary perfusion pressure, ischemia may progress to fibrosis and scar formation. Operative duration and instrument diameter are therefore plausible contributors to urethral injury (6).

Resectoscope sheath diameter may serve as a modifiable procedural factor reflecting differing degrees of urethral stretch and instrumentation burden. Standard practice favors 26-28Fr continuous-flow systems for improved irrigation and visualization. However, the urethra is often the limiting structure, and several studies have reported higher stricture rates with larger instruments (7-9). Direct comparative data evaluating a 22Fr continuous-flow TURP system remain scarce, largely because these instruments are not routinely available. Miniaturized laser enucleation techniques (MiLEP) have adopted 22Fr access to reduce meatal and urethral trauma (10, 11), yet whether this rationale translates to conventional TURP remains uncertain.

Using individual patient data from our unit, we compared postoperative urethral stricture rates following TURP performed with 22Fr versus 26Fr continuous-flow sheaths. We hypothesized that reducing sheath diameter would decrease mechanical stress on the urethral mucosa and subsequently lower stricture incidence. We additionally evaluated stricture location, perioperative performance, and functional outcomes (Q_{max} , IPSS, and PVR), while acknowledging the inherent limitations of retrospective inference.

MATERIALS AND METHODS

Study design and patient selection

The present study protocol was reviewed and approved by the Institutional Review Board of Karamanoğlu Mehmetbey

University Faculty of Medicine (approval number: 307651). The study was conducted in accordance with the ethical principles of the 1964 Declaration of Helsinki and its later amendments. The requirement for informed consent was waived owing to the retrospective nature of the study. Medical records of patients who underwent TURP for BPH at *Karaman Training and Research Hospital* between January 2021 and December 2025 were retrospectively reviewed.

Patients aged over 45 years with a prostate volume < 80 mL, refractory to medical therapy, who underwent primary TURP and had a minimum follow-up of 12 months were included. Patients with a history of urethral stricture, prior transurethral surgery, prostate cancer, active

urinary tract infection, neurogenic bladder, bladder stones, intraoperative catheter traction, or the presence of an indwelling catheter were excluded. To minimize technical variability, all procedures were performed by a single experienced surgeon using a bipolar energy source and a continuous-flow resectoscope system.

A total of 280 patients were included and divided into two groups according to resectoscope sheath diameter:

- Group 1: 22Fr (n = 135)
- Group 2: 26Fr (n = 145)

Patient selection and flow are illustrated in Figure 1.

Group allocation was not randomized. The 26Fr sheath was the institutional standard during the initial study period; following the procurement and introduction of

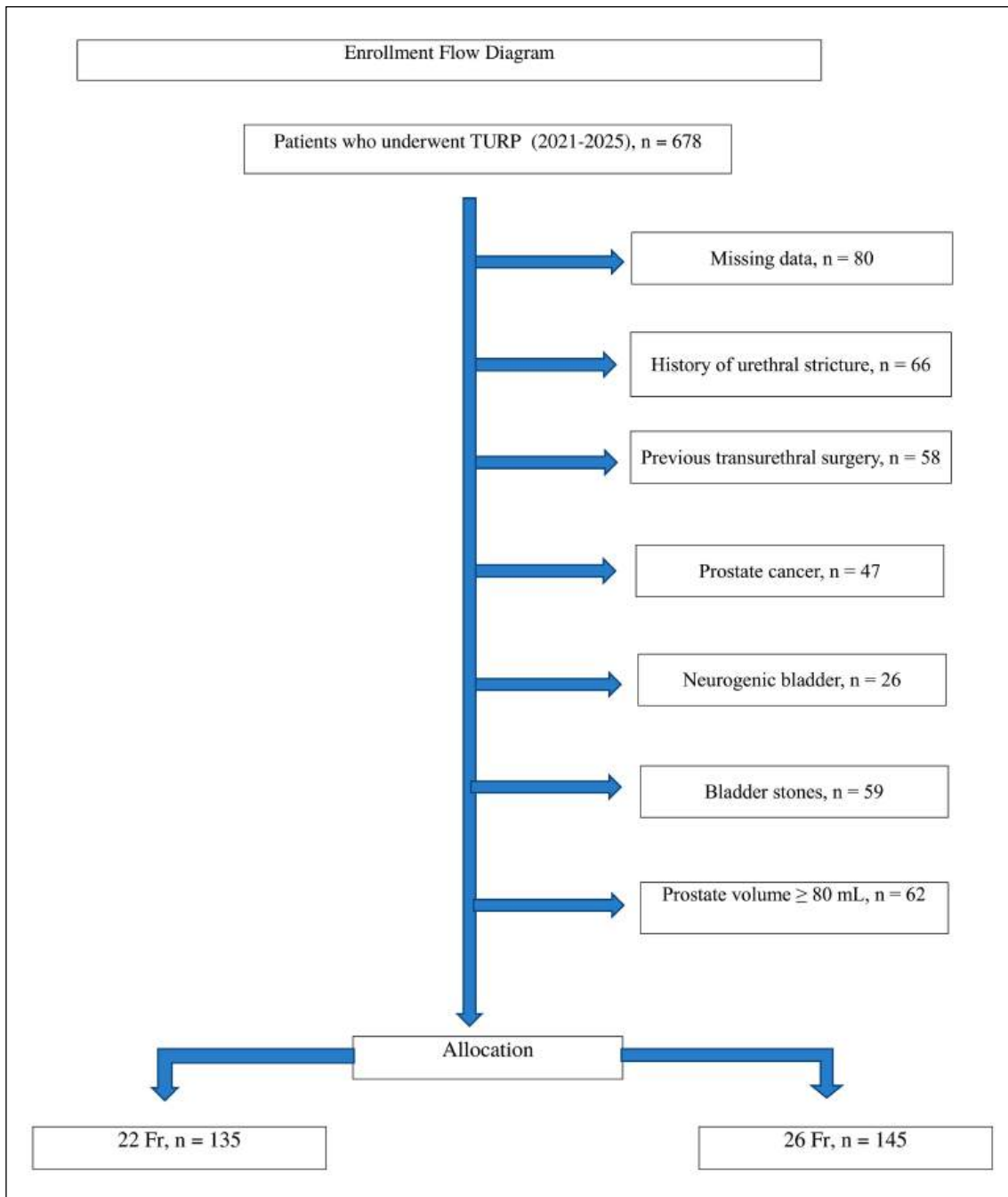


Figure 1. Flow diagram of patient selection and group allocation.

the 22Fr continuous-flow resectoscope system, all eligible patients were operated with the smaller-caliber instrument, resulting in a sequential before-after cohort design.

Preoperative evaluation

All patients underwent preoperative assessment, including physical examination, complete urinalysis, urine culture, serum *prostate-specific antigen* (PSA), transabdominal prostate volume measurement, maximum urinary flow rate (Q_{max}), *International Prostate Symptom Score* (IPSS), and *post-void residual urine volume* (PVR).

Surgical protocol

All procedures were performed by the same urologist experienced in TURP, following a standardized surgical protocol. Resections were carried out using the Plasma EDGE-Bipolar Plasma Resection System with true bipolar (TruBipolar™) electrodes (*Lamidey Noury Medical, Verrieres Le Buisson, France*) and either a 22Fr or 26Fr continuous-flow resectoscope sheath.

Irrigation was performed using 0.9% isotonic saline. Electrocautery settings were standardized at 140 W for cutting and 100 W for coagulation. Meatal dilatation was performed when deemed necessary. Resection time and the weight of resected prostate tissue were recorded.

At the end of the procedure, all patients received a standard 20 Fr 3-way silicone-coated latex Foley catheter, which was removed within 2-5 days. No catheter traction was applied.

Follow-up and outcome assessment

Postoperative follow-up was conducted at 3, 6, and 12 months and annually thereafter. Each visit included clinical assessment, IPSS, and uroflowmetry.

Patients with a peak urinary flow rate (Q_{max}) below 10 mL/s underwent *retrograde urethrography* (RUG). If RUG findings were suggestive of stricture, the diagnosis was confirmed by office cystoscopy. Time-to-event was

defined as the interval between surgery and confirmed stricture diagnosis.

Statistical analysis

Statistical analyses were performed using SPSS (*IBM Corp., Armonk, NY, USA*) and R software (*R Foundation for Statistical Computing, Vienna, Austria*). Continuous variables were expressed as mean \pm standard deviation (95% confidence interval) or median (interquartile range), and categorical variables as frequencies and percentages. Group comparisons were performed using the Independent Samples t-test, Mann-Whitney U test, Chi-square test, or Fisher's exact test, as appropriate. Stricture-free survival was estimated using the Kaplan-Meier method and compared between groups using the log-rank test.

To identify independent predictors of urethral stricture, a multivariable Cox proportional hazards regression model was constructed. Given the relatively low number of events ($n = 27$) compared to the number of covariates, Firth's penalized likelihood correction was applied to mitigate small-sample bias and produce more reliable *hazard ratio* (HR) estimates.

Variable selection followed a pre-specified, clinically driven approach to avoid model overfitting given the limited number of stricture events. The covariates included age, prostate volume, resected tissue weight, operation time, and sheath size (22Fr vs. 26Fr). Adjusted HR with 95% *confidence intervals* (CI) were reported. A two-sided p -value < 0.05 was considered statistically significant. The proportional hazards assumption was assessed using Schoenfeld residuals and was confirmed to be satisfied for all covariates included in the model.

RESULTS

Demographic and preoperative characteristics are summarized in Table 1. No significant differences were

Variable	22Fr Group (n = 135)	26Fr Group (n = 145)	P-value
Age, years (Mean \pm SD) (95% CI)	67.48 \pm 6.02 (66.45-68.50)	68.07 \pm 7.76 (66.80-69.35)	0.475
BMI, kg/m ² (Mean \pm SD) (95% CI)	27.00 \pm 3.54 (26.40-27.60)	26.96 \pm 3.52 (26.38-27.53)	0.917
CCI Score (Median [IQR])	1.0 [0.0-2.0]	1.0 [0.0-2.0]	0.128
Diabetes mellitus, n (%)	31 (23.0%)	44 (30.3%)	0.208
Anticoagulant/Antiplatelet use, n (%)	33 (24.4%)	39 (26.9%)	0.740
Prostate volume, cc (Mean \pm SD) (95% CI)	50.00 \pm 9.55 (48.38-51.63)	50.03 \pm 9.28 (48.51-51.56)	0.979
PSA, ng/mL (Mean \pm SD) (95% CI)	2.85 \pm 1.31 (2.63-3.07)	2.79 \pm 1.28 (2.58-3.00)	0.695
Baseline IPSS (Mean \pm SD) (95% CI)	21.77 \pm 5.69 (20.80-22.74)	22.14 \pm 6.25 (21.11-23.16)	0.608
Baseline Q_{max} , mL/s (Mean \pm SD) (95% CI)	9.85 \pm 3.50 (9.26-10.45)	9.75 \pm 3.27 (9.21-10.29)	0.803
Baseline PVR, mL (Mean \pm SD) (95% CI)	121.68 \pm 79.24 (108.19-135.17)	132.16 \pm 80.16 (119.00-145.31)	0.273
Urinary retention	34 (25.2%)	31 (21.4%)	0.540
Indwelling catheter	24 (17.8%)	24 (16.6%)	0.910
Positive urine culture	12 (8.9%)	10 (6.9%)	0.691

Continuous variables are presented as mean \pm standard deviation (95% confidence interval). CCI score is presented as median (interquartile range). Categorical variables are presented as frequency (percentage). Independent samples t-test was used for comparison of continuous variables, Mann-Whitney U test for scores, and Chi-square test or Fisher's exact test for categorical variables. A p-value < 0.05 was considered statistically significant.

BMI: Body Mass Index; CCI: Charlson Comorbidity Index; CI: Confidence Interval; IPSS: International Prostate Symptom Score; PSA: Prostate-Specific Antigen; PVR: Post-void Residual; Q_{max} : Peak Urinary Flow Rate; SD: Standard Deviation.

Table 1.
Demographic and preoperative characteristics.

Variable	22Fr Group (n = 135)	26Fr Group (n = 145)	P-value
Meatal dilation, n (%)	20 (14.8%)	87 (60.0%)	< 0.0001
Urethral dilation, n (%)	11 (8.1%)	19 (13.1%)	0.2517
Resected tissue, g (Mean ± SD) (95% CI)	23.79 ± 8.43 (22.35 - 25.22)	23.79 ± 8.17 (22.45 - 25.13)	0.9999
Operation time, min (Mean ± SD) (95% CI)	60.00 ± 11.72 (58.00 - 61.99)	50.00 ± 10.49 (48.28 - 51.72)	< 0.0001

Continuous variables are presented as mean ± standard deviation (95% confidence interval). Categorical variables are presented as frequency (percentage). Comparison was performed using Independent Samples t-test for continuous variables and Chi-square test for categorical variables. Exact p-values are provided; values < 0.0001 are reported as < 0.0001.

Table 2.
Intraoperative outcomes.

Variable	22Fr Group (n = 135)	26Fr Group (n = 145)	P-value
Catheterization days (Mean ± SD) (95% CI)	3.13 ± 1.40 (2.83-3.32)	2.83 ± 1.40 (2.57-3.03)	0.0756
Recatheterization, n (%)	5 (3.7%)	3 (2.1%)	0.4074
Follow-up time, days (Mean ± SD) (95% CI)	448.7 ± 154.7(422.4-475.0)	475.6 ± 157.6(449.7-501.5)	0.1509
Clavien-dindo Grade 0	111 (82.2%)	119 (82.1%)	0.9977
Clavien-Dindo Grade 1	3 (2.2%)	3 (2.1%)	
Clavien-Dindo Grade 2	16 (11.9%)	17 (11.7%)	
Clavien-Dindo Grade 3	5 (3.7%)	6 (4.1%)	
Urethral stricture Event, n (%)	5 (3.7%)	22 (15.2%)	0.0011
IPSS change (Mean ± SD) (95% CI)	-13.62 ± 3.54(-14.22- -13.02)	-13.65 ± 3.42(-14.21- -13.09)	0.8367
Q _{max} change, mL/s (Mean ± SD) (95% CI)	10.12 ± 1.85(9.81-10.44)	9.75 ± 1.81(9.45-10.05)	0.1777
Postoperative PSA, ng/mL (Mean ± SD) (95% CI)	1.14 ± 0.65(1.03-1.25)	1.17 ± 0.68(1.06-1.28)	0.4226
Incidental prostate cancer, n (%)	7 (5.2%)	8 (5.5%)	1.0000

Continuous variables are presented as mean ± standard deviation (95% confidence interval). Categorical variables are presented as frequency (percentage). Comparison was performed using Independent Samples t-test for continuous variables and Chi-square test or Fisher's exact test for categorical variables. A p-value < 0.05 was considered statistically significant. Exact p-values are reported. Median follow-up time (IQR) is reported in the main text for survival analysis.

Table 3.
Postoperative outcomes, complications, and functional results.

observed between groups regarding age, BMI, Charlson Comorbidity Index (CCI), prostate volume, PSA level, or medical therapy for BPH (all $p > 0.05$), indicating comparable baseline characteristics.

Intraoperative data are presented in Table 2. Operation time was significantly longer in the 22Fr group (60.0 ± 11.7 min) compared with the 26Fr group (50.0 ± 10.5 min; $p < 0.001$). Meatal dilation was required significantly more frequently in the 26Fr group (60.0% vs 14.8%; $p < 0.001$). There was no significant difference in resected tissue weight between the groups ($p = 0.999$).

Postoperative functional outcomes, complications, and urethral stricture incidences are summarized in Table 3. During follow-up, urethral stricture developed in 27 patients (9.6%). The incidence was 3.7% ($n = 5$) in the 22Fr group and 15.2% ($n = 22$) in the 26Fr group, representing a statistically significant difference ($p = 0.0011$). Median follow-up duration was 462 days (IQR 354-580), with no significant difference between groups.

Most strictures in both groups were located in the bulbar urethra, followed by the meatal-fossa navicularis region and the penile urethra. Among patients without urethral stricture, no significant differences were observed between groups in changes in Q_{max} , IPSS, or PVR (all $p > 0.05$).

Postoperative complication rates were comparable between groups, with no significant differences in fever, hematuria, or recatheterization rates. No patient required a blood transfusion or reoperation.

In multivariable Firth's penalized Cox regression analysis, sheath size was the only independent predictor of urethral stricture. Use of a 26Fr sheath was associated with a 4.08-fold increased hazard of stricture development (adjusted HR 4.08; 95% CI 1.16-14.37; $p = 0.029$). The forest plot summarizing the multivariable Cox model is presented in Figure 2.

Kaplan-Meier survival analysis (Figure 3) demonstrated sustained divergence of stricture-free survival curves without early clustering of events, indicating that the impact of sheath diameter extended beyond the early postoperative period.

DISCUSSION

Benign prostatic hyperplasia is one of the most prevalent conditions affecting aging men, and despite ongoing technological advances, TURP remains the reference standard surgical treatment (12). Nevertheless, postoperative urethral stricture continues to represent a major late complication, significantly impairing quality of life and imposing a substantial burden on healthcare systems (13).

Multiple factors have been implicated in urethral stricture development after TURP, including resectoscope sheath diameter, urethral caliber, postoperative catheter traction, prostate size, patient age, operative time, and potential current leakage due to inadequate insulation of the resectoscope sheath (14). At the tissue level, stricture formation results from multifactorial processes, with mechani-

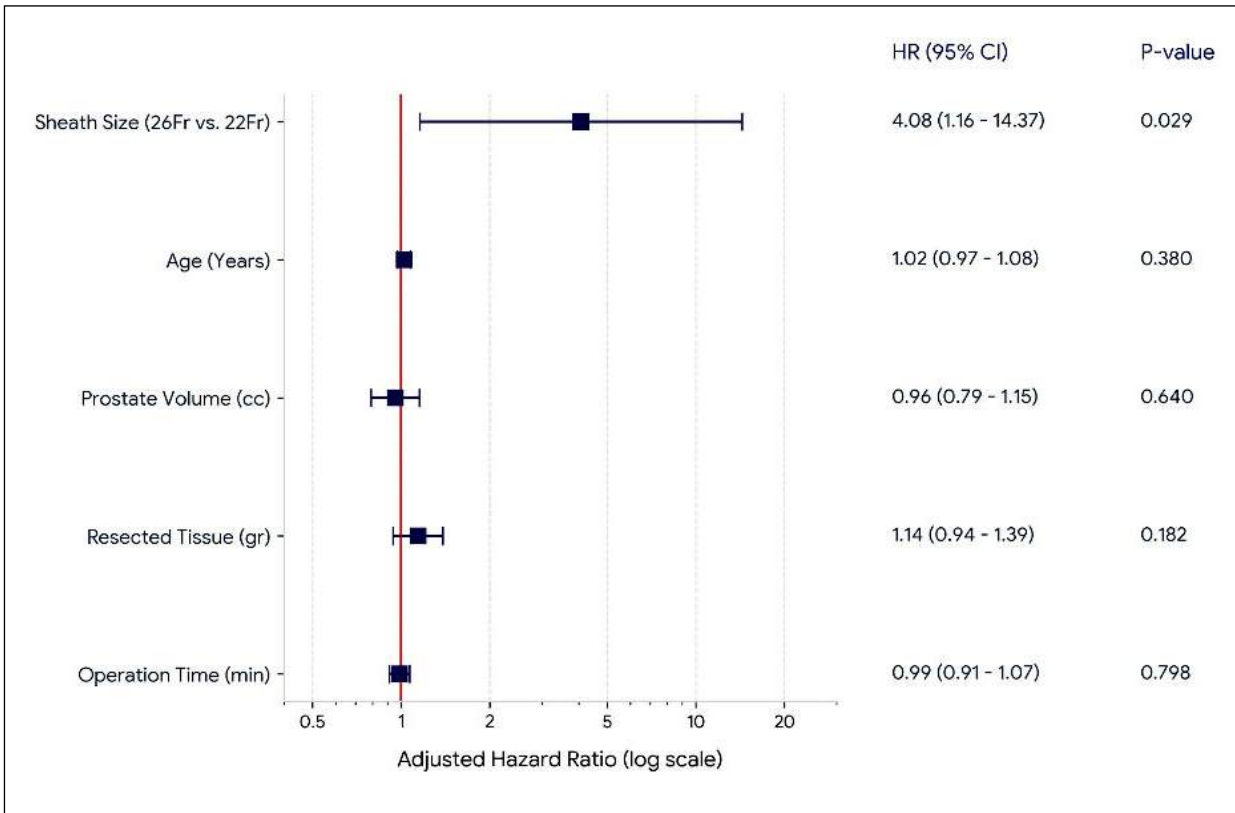


Figure 2. Multivariable Firth's penalized Cox regression analysis for predictors of urethral stricture. Use of a 26Fr sheath was independently associated with increased risk of stricture (adjusted HR 4.08; 95% CI 1.16-14.37).

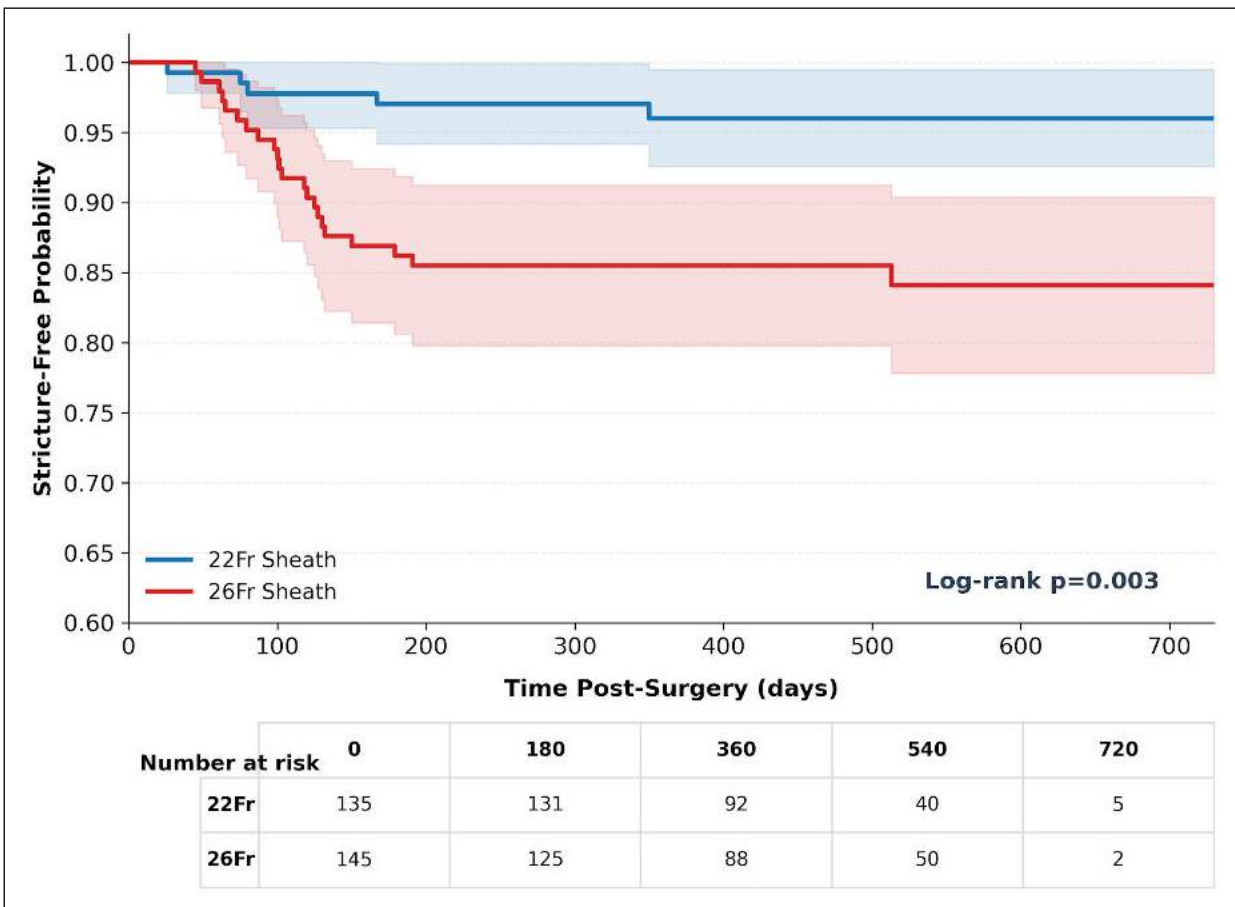


Figure 3. Kaplan-Meier curves of stricture-free survival according to resectoscope sheath diameter (log-rank $p = 0.003$).

cal trauma and ischemia representing the predominant mechanisms. Forced passage of a large-diameter sheath through a narrow urethra may disrupt mucosal integrity, particularly at the penoscrotal junction, which is exposed to the highest pressure as a result of the lever effect during instrument manipulation. When radial pressure exceeds capillary perfusion pressure within the corpus spongiosum, ischemia ensues and may progress to fibrosis and scar formation with prolonged operative duration (15). Although bipolar energy systems have reduced the risk of thermal injury associated with current leakages in monopolar systems, urethral stricture formation following TURP remains a clinically relevant problem (16).

The reported incidence of urethral stricture after TURP ranges from 2.2% to 9.8% (17). In the present study, the incidence was significantly higher in the 26Fr group (15.2%) compared with the 22Fr group (3.7%). This finding supports previous reports suggesting that increased friction and radial pressure associated with larger resectoscope sheaths may exceed the ischemic tolerance of the urethral mucosa, particularly in the bulbar urethra (7), whereas smaller-diameter systems may remain below this threshold and preserve microcirculation. The relatively higher incidence observed in the 26Fr group warrants further consideration and may also be influenced by our increased use of diagnostic cystoscopy prompted by postoperative flow deterioration. Similarly, Sekar et al. reported a urethral stricture rate of 14.3% with a 26 Fr sheath, which decreased to 7.2% when a 24 Fr sheath was used (13).

Multivariable Firth's penalized Cox regression analysis confirmed that the use of a 26Fr resectoscope remained independently associated with increased hazard of urethral stricture, even after adjustment for age, prostate volume, resected tissue weight, and operation time. This magnitude of effect (HR 4.08) suggests a clinically meaningful increase rather than a marginal statistical association. Importantly, this association persisted across survival analysis, suggesting a durable effect over time rather than an early postoperative artifact.

Meatal-fossa navicularis strictures, the second most common stricture location after the bulbar urethra, were also observed more frequently in the 26Fr group. This finding is consistent with the significantly higher rate of meatal dilatation in this group and likely reflects greater urethral caliber mismatch associated with larger instruments (8, 12). When a 26Fr instrument is introduced into a urethra of smaller native caliber, the radial tension exerted by the sheath may compress the microvasculature of the corpus spongiosum. If this compression exceeds diastolic perfusion pressure over the duration of resection, it may result in ischemia, inflammation, and subsequent collagen deposition (18). In contrast, 22Fr systems may remain below the natural elastic threshold of the male urethra, thereby preserving microcirculation.

Although operative time was shorter in the 26Fr group, there was no significant difference in resected tissue weight or functional improvement between the groups. This suggests that the smaller 22Fr sheath does not compromise surgical efficacy despite a clinically acceptable increase in operative duration.

Previous studies comparing standard TURP and HoLEP

with conventional large-diameter sheaths found no significant difference in urethral stricture incidence (19, 20). However, publications evaluating miniaturized systems such as MiLEP, in which both enucleation and morcellation are performed with a 22Fr sheath, report reduced need for meatal dilation and emphasize adapting the instrument to the urethra rather than the urethra to the instrument (10, 11). These studies also indicate that overall operative time and enucleation duration are comparable between MiLEP and standard HoLEP, and that miniaturization does not compromise surgical efficiency.

Although smaller-diameter systems might be expected to impair visualization or complicate bleeding control, potentially prolonging surgery, our findings did not support this concern, as no bleeding-related extension of operative time, transfusion, or reoperation was observed. The use of a standardized 20Fr postoperative catheter in both groups also eliminated any catheter-related confounding effect on urethral stricture risk. Similarly, no significant difference was observed between groups in bladder neck contracture, consistent with previous reports indicating that this complication is more closely related to prostate size than to resectoscope sheath diameter (20-22).

To our knowledge, this study represents the first direct comparison of 22Fr and 26Fr continuous-flow resectoscope systems in TURP. This provides important and novel clinical evidence regarding the impact of sheath diameter on urethral morbidity.

The main limitations include the retrospective design and the single-surgeon nature of the cohort, which may limit external validity. In addition, residual confounding cannot be entirely excluded despite multivariable adjustment. Furthermore, preoperative urethral caliber was not objectively assessed, which may have influenced individual susceptibility to stricture formation.

DECLARATIONS

Ethical approval and consent to participate: The study was approved by the Ethics Committee of Karamanoglu Mehmetbey University (Protocol no. 307651). The requirement for informed consent was waived due to the retrospective nature of the study.

Consent for publication: Not applicable.

Availability of data and material: The datasets generated and/or analyzed during the current study are not publicly available due to patient confidentiality but are available from the corresponding author upon reasonable request.

Competing interests: The authors declare that they have no competing interests.

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The absence of randomization and potential selection bias inherent to retrospective analyses should also be acknowledged.

More specifically, group assignment followed a sequential institutional cohort design: patients operated before the introduction of the 22Fr system comprised the 26Fr cohort, and those treated thereafter constituted the 22Fr cohort. Although baseline characteristics were comparable between groups (Table 1), the possibility of unmeasured confounding cannot be entirely excluded. Ideally, a prospective randomized design would be needed to eliminate these biases and provide a higher level of evidence.

CONCLUSIONS

Transurethral resection of the prostate remains the standard surgical treatment for BPH. This study demonstrates that use of a 22Fr sheath is associated with significantly lower hazard of urethral stricture development over time, without compromising perioperative or functional outcomes. Resectoscope sheath diameter remained the only independent predictor of urethral stricture.

These findings suggest that the use of smaller-diameter instruments in endoscopic surgery may offer a meaningful advantage in preserving urethral integrity. Although miniaturization may modestly prolong operative time, it does not adversely affect resection volume or functional outcomes. Prospective, multicenter studies are warranted to validate these results across different ethnicities and prostate sizes.

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