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Preoperative prediction of infectious-inflammatory complications after endoscopic ureterolithotripsy in adults: development and internal validation of a discriminant model



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Abstract. Infectious-inflammatory complications (IIC) remain among the most clinically significant adverse events after endoscopic treatment of ureteral stones and, in their severe forms, may progress to urosepsis; reliable preoperative risk stratification could allow prophylaxis and monitoring to be individualized. This study aimed to identify independent predictors of IIC in adults after endoscopic ureterolithotripsy and to develop and internally validate a discriminant prognostic model. We analyzed 385 adult patients who underwent endoscopic treatment of ureteral stones at a



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single tertiary urology center; demographic, laboratory, stone-related, and operative variables were compared between patients with and without IIC using univariate tests, independent predictors were selected by stepwise discriminant analysis, and the resulting canonical discriminant function was internally validated on an independent prospectively assembled sample of 43 patients. IIC occurred in 76 of 385 patients (19.7%) and were predominantly mild: postoperative fever without an infectious focus (50.0%) and urinary tract infection (28.9%) prevailed, whereas acute pyelonephritis (18.4%) and urosepsis (2.6%) were uncommon; female sex ($p = 0.031$), preoperative bacteriuria and pyuria, combined bacteriuria plus pyuria, preoperative upper-tract drainage, longer operative time, and greater blood loss were significantly associated with IIC, whereas age, body-mass index, and stone location, size, and density were not. The final four-variable model — pyuria, peripheral-blood leukocyte count, bacteriuria, and emergency upper-tract drainage — showed strong discrimination (eigenvalue 0.754; canonical correlation 0.656; Wilks' $\lambda = 0.570$; $\chi^2 = 214.1$; $p < 0.000001$), with sensitivity 76.3%, specificity 81.5%, and overall accuracy 80.4%; on internal validation, overall accuracy was 81.4%, sensitivity 81.8%, and specificity 81.3%. A simple four-predictor discriminant model built from routinely available preoperative parameters thus reliably stratifies adults by the risk of IIC after endoscopic ureterolithotripsy, and its high negative predictive value identifies low-risk patients and supports individualized antimicrobial prophylaxis and postoperative monitoring.

Keywords: ureteral calculi; ureteroscopy; postoperative complications; urinary tract infection; urosepsis; risk assessment; discriminant analysis.

Relevance of the topic. Urolithiasis is one of the most common urological conditions worldwide [1], and the widespread adoption of minimally invasive endoscopic techniques has made endoscopic ureterolithotripsy the standard of care for most ureteral stones [2]. These procedures achieve high stone-free rates with low overall morbidity; nevertheless, infectious-inflammatory complications (IIC) continue to represent one of the most clinically important groups of adverse events [3, 4].

The clinical spectrum of IIC ranges from transient postoperative fever and uncomplicated urinary tract infection to acute pyelonephritis and urosepsis. Although severe forms are uncommon, they carry a disproportionate clinical burden, may require intensive care, and remain a recognized cause of stone-related mortality [5, 6, 7, 8]. Systematic reviews and cohort studies have identified a range of factors associated with post-ureteroscopy infection — including preoperative bacteriuria, pyuria, indwelling drainage, and operative complexity — but their relative contribution and combined predictive value remain incompletely defined [4, 9, 10, 11].

In routine practice, decisions about the intensity of antimicrobial prophylaxis and postoperative surveillance are still made largely empirically [12]. A validated, quantitative tool that translates readily available preoperative parameters into an individual risk estimate could support rational, patient-specific prophylaxis and reduce both undertreatment of high-risk patients and unnecessary antibiotic exposure in low-risk patients [13, 25]. To date, most predictive tools in endourology have been developed for percutaneous nephrolithotomy, using nomograms or



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machine-learning models to forecast postoperative sepsis [18, 19], whereas validated instruments specific to ureteroscopic stone treatment remain comparatively scarce [16, 17].

Aim of the study. The aim of the present study was to identify the independent clinical and laboratory predictors of IIC in adults undergoing endoscopic treatment of ureteral stones and, on this basis, to develop and internally validate a discriminant prognostic model suitable for preoperative risk stratification.

Materials and methods. We performed an analytical study of 385 adult patients (≥ 18 years) who underwent endoscopic treatment of ureteral stones at a single tertiary specialized urology center. Each patient was counted once, irrespective of the number of clinical episodes or treatment stages. The adult cohort was analyzed separately from a parallel pediatric cohort to avoid methodological bias arising from anatomical and physiological differences between age groups. Patients were eligible if they had radiologically confirmed ureteral calculi treated endoscopically and had complete perioperative clinical and laboratory documentation; patients with incomplete infection-related laboratory data or with primary treatment by non-endoscopic modalities were excluded.

The primary endpoint was the occurrence of an infectious-inflammatory complication in the postoperative period, defined by standard clinical and laboratory criteria and graded as: postoperative fever without an identifiable infectious focus; urinary tract infection; acute pyelonephritis; and urosepsis (a systemic inflammatory response of infectious origin) [12]. Patients were classified as IIC-positive if any of these events occurred and as IIC-negative otherwise. Recorded variables included demographic and anthropometric data (sex, age, body-mass index); preoperative infection markers (bacteriuria; pyuria quantified as leukocyturia by the Nechiporenko method; peripheral-blood leukocyte count); stone characteristics on computed tomography (location, maximum diameter, density in Hounsfield units); and tactical and intraoperative factors (preoperative upper-tract drainage, type of endoscopic intervention, operative time, and estimated blood loss).

Continuous variables are presented as mean $\pm$ standard deviation or median with interquartile range, and categorical variables as counts and percentages. Between-group comparisons used the χ^2 test or Fisher's exact test for categorical variables and the Student t-test or Mann-Whitney U test for continuous variables, as appropriate; $p < 0.05$ was considered significant. Independent predictors were selected by stepwise discriminant analysis with forward inclusion, with the contribution of each variable assessed by Wilks' λ . A canonical discriminant function was derived, and its classification performance (sensitivity, specificity, and overall accuracy) was evaluated at the optimal threshold. The model was then applied to an independent validation sample of 43 patients, for whom the discriminant score was computed and used to assign each patient to a low- or high-risk group; predicted and observed outcomes were cross-tabulated.

Results. Among the 385 adults, IIC developed in 76 patients (19.7%), while 309 (80.3%) had an uncomplicated postoperative course. The complication profile was dominated by mild forms: postoperative fever without an infectious focus accounted for half of all events, and urinary tract



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infection for a further quarter. Severe complications — acute pyelonephritis and urosepsis — were comparatively rare but clinically decisive (Table 1).

Table 1. Frequency and structure of infectious-inflammatory complications in adults (n = 76)

Type of complication	n	%
Postoperative fever without infectious focus	38	50.0
Urinary tract infection	22	28.9
Acute pyelonephritis	14	18.4
Urosepsis	2	2.6
Total patients with IIC	76	100.0

Preoperative infectious status showed the strongest association with IIC. Bacteriuria, pyuria (leukocyturia), and — most markedly — their combination were significantly more frequent in patients who developed complications. Among tactical and intraoperative factors, preoperative upper-tract drainage, longer operative time, greater blood loss, and the type of intervention were all significantly associated with IIC. Female sex was also associated with higher risk, whereas age, body-mass index, and the anatomical characteristics of the stone (location, diameter, and density) showed no significant association (Table 2).

Table 2. Univariate analysis of factors associated with IIC in adults (n = 385)

Factor	IIC (n = 76)	No IIC (n = 309)	p
Female sex, n (%)	32 (42.1)	111 (35.9)	0.031
Age, years (M ± SD)	46.1 ± 15.2	45.0 ± 15.6	0.48
Body-mass index, kg/m ² (M ± SD)	29.1 ± 5.3	28.6 ± 5.0	0.44
Bacteriuria, n (%)	41 (53.9)	70 (22.7)	<0.001
Pyuria (leukocyturia), n (%)	48 (63.2)	96 (31.1)	<0.001
Bacteriuria + pyuria, n (%)	36 (47.4)	54 (17.5)	<0.001



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Factor	IIC (n = 76)	No IIC (n = 309)	p
Stone location (upper/mid/lower)	—	—	0.21
Stone size	—	—	0.74
Stone density (HU)	—	—	0.63
Preoperative drainage, n (%)	39 (51.3)	67 (21.7)	<0.001
Operative time, min (M ± SD)	72.4 ± 18.6	58.9 ± 15.3	<0.001
Blood loss, mL (M ± SD)	148 ± 52	96 ± 41	<0.001
Type of intervention	—	—	0.003

Note. HU — Hounsfield units. Data on stone location, size, and density were available for subsets of patients; dashes indicate factors compared across ordered categories, none of which reached statistical significance.

Variables significant on univariate analysis were entered into stepwise discriminant analysis. Four independent predictors provided the best separation of patients with and without IIC: pyuria (Nechiporenko leukocyturia > 4000/mL), peripheral-blood leukocyte count, bacteriuria, and emergency upper-tract drainage performed for infectious indications. The resulting canonical discriminant function was highly significant (eigenvalue 0.754; canonical correlation 0.656; Wilks' $\lambda = 0.570$; $\chi^2 = 214.1$; $df = 4$; $p < 0.000001$) (Table 3).

Table 3. Unstandardized coefficients of the canonical discriminant function

Predictor	Coefficient
A — pyuria (Nechiporenko leukocyturia > 4000/mL; 0/1)	0.203
B — peripheral-blood leukocytes ($\times 10^9/L$)	0.204
C — bacteriuria (0/1)	3.664
D — emergency upper-tract drainage (0/1)	8.405
Constant	-6.656

Discriminant function. $Z = 0.203 \cdot A + 0.204 \cdot B + 3.664 \cdot C + 8.405 \cdot D - 6.656$, where A, C, and D are binary (0 = absent, 1 = present) and B is the peripheral-blood leukocyte count ($\times 10^9/L$). A



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threshold of $Z = -0.649$ corresponds to a 50% predicted probability of IIC; higher Z values indicate progressively higher risk.

At the optimal threshold, the model achieved a sensitivity of 76.3%, a specificity of 81.5%, and an overall predictive accuracy of 80.4%. Its high negative predictive value allowed reliable identification of low-risk patients, which is of particular clinical value when deciding on the scope of prophylactic measures.

The model was applied to an independent sample of 43 patients, of whom 11 (25.6%) developed a systemic inflammatory response and 32 (74.4%) did not. Nine of the 11 patients with complications were correctly assigned to the high-risk group, and 26 of the 32 patients without complications to the low-risk group (Table 4). Overall classification accuracy was 81.4%, with a sensitivity of 81.8% and a specificity of 81.3%, confirming good and reproducible predictive performance.

Table 4. Classification of the independent validation sample (n = 43)

Observed outcome	Predicted: IIC	Predicted: no IIC	Total
Infectious-inflammatory complications	9	2	11
No complications	6	26	32
Total	15	28	43

Applied prospectively, the function separates clinically distinct risk profiles. A patient with a normal leukocyte count, minimal leukocyturia, no bacteriuria, and no emergency drainage yields a very low Z value and a predicted IIC probability below 1%, warranting only standard observation. In contrast, a patient with leukocytosis, marked leukocyturia, and confirmed bacteriuria yields a Z value corresponding to a substantially elevated probability, indicating the need for reinforced monitoring, early correction of antimicrobial therapy, and readiness to intervene at the first signs of a systemic inflammatory response.

In this cohort of 385 adults, IIC occurred in nearly one in five patients but were predominantly mild, with fever and uncomplicated urinary tract infection accounting for the majority of events and urosepsis remaining rare. This distribution is consistent with contemporary series and reaffirms the overall safety of endoscopic ureterolithotripsy while underscoring that the small subset of severe infections drives most of the clinical burden [3, 4].

The central finding is that the risk of IIC is governed principally by the patient's baseline infectious status rather than by the anatomical characteristics of the stone. Bacteriuria, pyuria, and their combination were strongly associated with complications, whereas stone location, diameter, and density were not — a pattern that aligns with systematic-review evidence identifying



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preoperative urinary infection as the dominant modifiable risk factor [4, 9, 13]. This accords with growing evidence that even asymptomatic bacteriuria warrants careful evaluation before stone surgery [14, 15]. The significant association with female sex is likewise consistent with the known epidemiology of urinary tract infection.

Tactical and intraoperative factors — preoperative drainage, longer operative time, greater blood loss, and more invasive interventions — were also associated with IIC. These variables plausibly reflect both a more severe baseline clinical state and the greater tissue trauma and bacterial exposure of complex procedures; preoperative drainage in particular may act as both a marker of severity and a route for persistent bacterial colonization [23, 24], and the risk of urosepsis is especially pronounced in patients with preexisting urinary tract infection [22].

Building on these observations, the four-predictor discriminant model integrates the most informative parameters into a single, easily computed index. All four inputs — pyuria, blood leukocyte count, bacteriuria, and emergency drainage — are routinely available before surgery, so the model requires no additional testing. Comparable predictive efforts in endourology have largely targeted percutaneous nephrolithotomy through nomograms and machine-learning models [18, 19, 20, 21], whereas fewer validated tools address ureteroscopic treatment specifically [16, 17]; the present model adds to this smaller body of work. Its high specificity and negative predictive value make it especially useful for confidently identifying low-risk patients who can be spared intensified prophylaxis, thereby supporting antimicrobial stewardship [12, 25], while flagging high-risk patients for tailored prophylaxis and closer surveillance. Internal validation on an independent sample reproduced the development-set performance closely, supporting the model's stability.

This study has several limitations. It was conducted at a single center with a retrospective analytical design, which may limit generalizability. The model underwent internal, but not external, validation, and the validation sample was modest; the presence of false-positive and false-negative classifications indicates that the tool should complement, not replace, clinical judgment. Discriminant analysis assumes multivariate normality and homogeneity of covariance, which may not hold fully for binary predictors. Finally, the endpoint combined a spectrum of infectious events of differing severity, and larger multicenter cohorts will be needed to confirm performance and to refine risk thresholds for specific outcomes such as urosepsis.

Conclusion.

1. In adults, infectious-inflammatory complications after endoscopic treatment of ureteral stones arise chiefly from a combination of an unfavorable preoperative infectious background and factors reflecting surgical complexity, rather than from the anatomical characteristics of the stone.

2. Four independent preoperative predictors were identified — pyuria (Nechiporenko leukocyturia $> 4000/\text{mL}$), peripheral-blood leukocyte count, bacteriuria, and emergency upper-tract drainage — and a discriminant model based on them provided good discrimination (accuracy 80.4%; sensitivity 76.3%; specificity 81.5%).



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3. On internal validation in an independent sample, the model retained its performance (accuracy 81.4%; sensitivity 81.8%; specificity 81.3%), confirming its stability and reproducibility.

4. Because it relies solely on routinely available preoperative data, the model offers a practical means of preoperative risk stratification that can guide individualized antimicrobial prophylaxis and postoperative monitoring, and thereby improve the safety of endoscopic ureterolithotripsy.

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