Renal pelvis urine density as a predictor of infectious complications after semi-rigid ureterorenoscopy for ureteral stone treatment

Oguzhan Yildiz, Ufuk Caglar, Huseyin Burak Yazili, Muhammed Rasit Tutal, Arda Meric, Omer Sarilar, Faruk Ozgor
Department of Urology, Haseki Training and Research Hospital, Istanbul, Turkey

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Corresponding author: Dr. Oguzhan Yildiz, Department of Urology, Haseki Training and Research Hospital, Istanbul, Turkey; oguzhanyildiz93@gmail.com

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ABSTRACT

Introduction: This study aimed to investigate whether renal pelvis urine density (RPUD) serves as a reliable predictor of postoperative infectious complications in patients undergoing semi-rigid ureterorenoscopy (URS) for ureteral stone treatment.
Methods: We retrospectively reviewed 1104 patients who underwent semi-rigid URS for ureteral stones. Patients were divided into two groups based on whether they developed postoperative infections within one month (n=64) or not (n=1040). Demographic variables (age, sex, body mass index), comorbidities, stone characteristics (location, size, density), and operative parameters (operation time, stent/catheter placement) were recorded. Renal pelvis urine density was measured in Hounsfield units on preoperative imaging.
Results: Of the 1104 patients, 64 (5.8%) developed postoperative infections. The median RPUD was significantly higher in the infectious group (10 [5–17] HU) compared to the non-infectious group (4 [2–6] HU; p=0.001). On multivariate analysis, sex (odds ratio [OR] 4.001, 95% confidence interval [CI] 2.231–7.174, p=0.001), body mass index (OR 0.920, 95% CI 0.860–0.984, p=0.015), operation time (OR 0.963, 95% CI 0.932–0.996, p=0.028), and RPUD (OR 0.809, 95% CI 0.771–0.849, p=0.001) were independent predictors of postoperative infection. The area under the curve was 0.784 (p<0.001, 95% CI 0.711–0.857), demonstrating good discriminative ability. When a cutoff value of 6.35 was applied, the sensitivity and specificity were 71.9% and 76.9%, respectively, for predicting postoperative infections.
Conclusions: Higher RPUD is significantly associated with an increased risk of infectious complications following semi-rigid URS for ureteral stones. Incorporating RPUD into preoperative assessments may help identify high-risk patients and optimize perioperative management to reduce infection-related morbidity.

INTRODUCTION

Ureterorenoscopy (URS) has become a cornerstone in the management of ureteral stones, offering a minimally invasive approach with high success rates and low morbidity. As a widely utilized procedure in urology, URS is a key component of the treatment in obstructive uropathy resulting from ureteral calculi, ensuring the preservation of renal function and alleviating patient symptoms. Despite its advantages, URS is not without risks, with infectious complications among the most significant concerns [1, 2]. These complications can range from mild febrile episodes to severe conditions such as sepsis, which has been reported in approximately 1–7% of cases in various studies, underscoring the importance of identifying predictive factors to mitigate such risks [3, 4].

In the context of obstructive uropathy caused by ureteral stones, accurately assessing the risk of postoperative infectious complications is crucial[5]. Traditional preoperative evaluations often rely on midstream urine (MSU) culture and sensitivity tests to detect urinary tract infections. However, studies have demonstrated that MSU cultures may not reliably represent infection within the renal pelvis or the obstructing stone itself. Mariappan and Loong (2004) found that MSU culture and sensitivity tests are poor predictors of infected urine proximal to the obstruction and infected stones[6]. This discrepancy suggests that relying solely on MSU cultures could lead to the underestimation of infection risk in patients undergoing semi-rigid URS.

Predicting the presence of infection in the renal pelvis of the obstructed system requires the identification of new preoperative predictors. Yuruk et al. (2017) demonstrated that computer tomography (CT) attenuation values, which quantify the renal pelvic urine density (RPUD) in Hounsfield units (HU), can reliably differentiate hydronephrosis from pyonephrosis, indicating that higher HU measurements may reflect an underlying infection[7]. Additionally, studies by Boeri et al., Erdogan et al., and Lu et al. also supported the diagnostic utility of RPUD using nephrostomy-based urine sampling[8–10], these studies did not evaluate postoperative infectious outcomes. [8–10]. Based on these insights, our study aims to evaluate whether preoperative RPUD, measured in HU on CT imaging, can predict postoperative infectious complications following semi-rigid URS for ureteral stone treatment. By doing so, we seek to enhance risk stratification and improve perioperative management.

METHODS

This retrospective study was conducted from 2019 to 2024 in the Urology Department of our tertiary-level medical center. The investigation adhered to the principles of the Declaration of Helsinki and received approval from our institutional ethics committee.

Individuals who underwent URS for ureteral stones were enrolled in the analysis. Eligibility was restricted to those aged 18 years or older who had preoperative CT imaging for HU assessment and radiologically confirmed hydronephrosis graded from 1 to 4. Only patients with negative preoperative midstream urine culture results were included in the study, while those with positive cultures were excluded to minimize confounding due to active urinary tract infection. Other exclusion criteria comprised multiple calculi in a single kidney or both kidneys, presence of a JJ stent or percutaneous nephrostomy before the intervention, solitary kidney status, inadequate kidney function, ongoing hemofiltration or hemodialysis, suspected or confirmed malignancies of the urinary tract, and absence of a preoperative CT scan performed within one week prior to the surgery. In our institution, preoperative non-contrast CT scans for ureteral stones are routinely obtained within one week of surgery. Patients were subsequently divided into two groups based on whether they developed infectious complications within one month of the procedure.

Infectious complications were defined as either the presence of postoperative fever with a positive urine culture or the occurrence of systemic inflammatory response syndrome (SIRS), sepsis, or septic shock. SIRS was determined based on the criteria set forth by the American College of Chest Physicians and the Society of Critical Care Medicine, which include a body temperature above 38°C or below 36°C, a heart rate over 90 beats per minute, a respiratory rate exceeding 20 breaths per minute or a $PaCO_2$ under 32 mm Hg, and a white blood cell count over 12,000/µL or below 4,000/µL (or more than 10% immature neutrophils). Sepsis was described as SIRS in the presence of a confirmed infection, and septic shock was identified when sepsis was accompanied by ongoing hypotension despite sufficient fluid resuscitation, necessitating administration of vasopressor therapy to maintain a mean arterial pressure of at least 65 mm Hg, together with signs of end-organ hypoperfusion.

The following demographic and clinical data were collected: sex, age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, and comorbidities (for example, diabetes mellitus, hypertension, and coronary artery disease). Additionally, information regarding previous stone surgeries and any extracorporeal shock wave lithotripsy (ESWL) history was recorded.

Stone-related characteristics were obtained from preoperative imaging, including the following: stone localization, hydronephrosis grade, stone burden, stone density, and RPUD. The stone size was determined by measuring the two largest diameters (length and width) on CT, and we estimated the stone's elliptical cross-sectional area by multiplying its length and width and then applying a factor of 0.785 (i.e., $0.25 \times \pi$). Stone density was calculated by selecting a region of interest (ROI) on the stone in the CT images and determining the mean attenuation value in HU. Stone localization was defined as proximal, mid, or distal based on its position in the ureter relative to the sacroiliac joint. Specifically, stones located above the sacroiliac joint were considered proximal, those at the level of the sacroiliac joint were defined as mid, and those below the sacroiliac joint were regarded as distal. For the RPUD measurement, an ellipse that encompassed as much of the treated side's renal pelvis as possible was drawn, and the average HU value within this ellipse was recorded. Each measurement was performed independently by two experienced urologists, and in cases of discrepancy, the average value was used. The consistency between observers was evaluated through the intraclass correlation coefficient (ICC).

The URS procedure was uniformly performed under general anesthesia while the patient was positioned in lithotomy. A guidewire was first inserted into the ureter; subsequently, a semi-rigid ureteroscope was advanced to localize the ureteral stone. Laser lithotripsy was employed to fragment the stone, and an extraction basket was used to remove any residual fragments. Irrigation during URS was performed using gravity-assisted saline infusion, with the fluid bag positioned approximately 60–80 cm above the patient. No pressurized irrigation systems were employed, and intra-renal pressure was not directly measured. Depending on the intraoperative findings and at the surgeon's discretion, either a JJ stent or a ureteral catheter was inserted at the conclusion of the procedure. Operative parameters were documented, including the following: stent or ureteral catheter placement, operation time, and hospitalization duration.

Statistical analyses

Statistical analyses were conducted using SPSS version 27 (IBM Corp., Armonk, NY, USA). Data that followed a normal distribution are represented as mean ± standard deviation, whereas non-normally distributed data are summarized using the median and interquartile range (IQR). Categorical variables are displayed as absolute frequencies and percentages. For comparisons between groups, the Student's t-test was applied to normally distributed continuous variables, whereas the Mann–Whitney U test was utilized for non-normally distributed data. Categorical data were analyzed using either the chi-square test or Fisher's exact test, depending on the nature of the dataset. To identify independent predictors of postoperative infectious complications, a multivariate logistic regression analysis was performed, with outcomes presented as odds ratios (OR) and corresponding 95% confidence intervals (CI). A p-value of less than 0.05 was regarded as statistically significant. To evaluate the performance of RPUD in terms of predicting postoperative infectious complications, a receiver operating characteristic (ROC) analysis was applied.

RESULTS

In total, 1,104 patients underwent URS for ureteral stone treatment, with 1,040 patients not developing postoperative infectious complications and 64 patients experiencing such complications. Age distribution did not differ significantly between the infectious and non-infectious groups (44.8 ± 12.7 years vs. 46.7 ± 13.6 years, $p = 0.243$). However, the infectious group had a significantly greater percentage of female patients (56.3% vs. 22.2%, $p = 0.001$) and a notably higher mean BMI (28.3 ± 4.5 kg/m² vs. 26.7 ± 3.6 kg/m², $p = 0.007$) than the non-infectious group. There was no significant difference between the two groups concerning ASA score, diabetes mellitus, hypertension, coronary artery disease, previous stone surgery, and history of ESWL (all $p > 0.05$) (Table 1).

Stone-related characteristics were generally similar across the groups, displaying no statistically significant variations in stone localization, hydronephrosis grade, stone burden, or stone density ($p = 0.317$, $p = 0.991$, $p = 0.738$, and $p = 0.380$, respectively). Notably, the RPUD was significantly higher in the infectious group than the non-infectious group (median 10 [IQR 5–17] HU vs. 4 [IQR 2–6] HU, $p = 0.001$) (Table 2). Two seasoned urologists conducted RPUD measurements, yielding an ICC of 0.924 (95% CI: 0.915–0.933) that reflects excellent agreement between observers.

Regarding operative data, patients in the infectious group had a longer mean operation time (46.8 ± 9.2 minutes vs. 44.0 ± 7.6 minutes, $p = 0.021$) and a markedly prolonged hospitalization period (median 144 [IQR 120–168] hours vs. 24 [IQR 24–24] hours, p =

0.001). There was no significant difference in the type of postoperative stent or ureteral catheter placement between the groups (p = 0.996) (Table 2).

Multivariate logistic regression analysis identified four independent predictors of postoperative infectious complications. Being female was associated with a fourfold increase in the likelihood of infection (OR = 4.001, 95% CI: 2.231–7.174, p = 0.001). Additionally, BMI (OR = 0.920, 95% CI: 0.860–0.984, p = 0.015), operation time (OR = 0.963, 95% CI: 0.932–0.996, p = 0.028), and RPUD (OR = 0.809, 95% CI: 0.771–0.849, p = 0.001) emerged as significant predictors (Table 3). These findings underscore the potential role of preoperative RPUD, along with specific demographic and operative factors, in predicting postoperative infectious complications following URS. A ROC curve was generated to assess the performance of RPUD (Figure 2). The area under the curve (AUC) was 0.784 (p < 0.001, 95% CI: 0.711–0.857), demonstrating good discriminative ability. When a cutoff value of 6.35 was applied, the sensitivity and specificity were 71.9% and 76.9% for predicting postoperative infections.

DISCUSSION

With rapid advancements in endourology, the management of urinary stones has dramatically improved, leading to higher success rates and a marked reduction in overall complication rates. Nevertheless, postoperative infections remain among the most significant complications associated with URS, with outcomes ranging from mild febrile episodes to severe sepsis. The incidence of infectious complications following URS varies across studies and is reported as between 1% and 7% in the literature[2, 11]. This variability may stem from differences in patient populations, including sociocultural and racial factors influencing infection susceptibility, as well as disparities in preoperative management protocols. For instance, variations in the duration between initial diagnosis and definitive surgical intervention—due to attempts at spontaneous passage or medical expulsive therapy—may prolong urinary stasis, creating opportunities for bacterial colonization and subsequent infection[12, 13]. In our study, the observed infection rate of 5.8% aligns with the upper range of published data, which we hypothesize may reflect extended waiting times prior to surgery in our patient population.

Recent evidence underscores the limitations of relying solely on MSU cultures for the detection of upper urinary tract infections. Mirzazadeh et al. found that MSU cultures often did not match renal pelvis cultures, with 31% of patients harboring pathogens detected only in the renal pelvis [14]. Additionally, renal pelvis cultures demonstrated a higher concordance with blood cultures (95% vs. 50%), underscoring their superior diagnostic value. In light of the suboptimal performance of MSU cultures in obstructed systems, quantifying RPUD via non-contrast CT emerges as a promising diagnostic modality for predicting pyelonephrosis, offering enhanced microbial detection and a more accurate reflection of the underlying infectious burden.

Yuruk et al. reported that the mean RPUD was significantly higher in the pyonephrosis group than the hydronephrosis group (13.51 ± 13.29 vs. 4.67 ± 5.37, p = 0.0001) [7]. Conflicting data exist regarding the diagnostic value of RPUD in infection. Basmaci et al. reported that lower RPUD values were linked to infection. In their urinary tract infection study, culture-positive patients had a median RPUD of –6 HU (range: –17.8 to +11) compared to 12 HU (range: 0 to +32) in culture-negative patients ($p < 0.001$; n = 58)[15]. Similarly, in pyelonephrosis, infected cases showed a median RPUD of –8.5 (range: –29 to –1) versus 10 (range: –4 to +17) in non-infected cases ($p < 0.001$; n = 51)[16]. In contrast, subsequent studies by Lu (n = 240), Erdogan (n = 159), and Boeri (n = 122) consistently demonstrated that higher HU values are associated with pyonephrosis[8–10]. Our study, along with that of Yuruk et al. and these later findings, indicates that high HU is indicative of infection. The discrepancies in Basmaci et al.'s results may be attributable to their relatively small sample sizes (n = 58 and n = 51).

High HU values in renal pelvis urine are not only indicative of pyelonephrosis but also strongly associated with increased postoperative infectious complications, a finding that holds considerable importance for preoperative patient management in stone treatment. For instance, in a multicenter prospective ESWL study of 1,436 patients, those in the highest RPUD quartile had an odds ratio of 32.36 (95% CI: 13.32–78.60) for severe infections compared to the lowest quartile, with an ROC AUC of 0.895 and a cut-off of 12.0 HU (sensitivity: 78.59%, specificity: 85.94%)[17]. Similarly, Caglar et al. reported a median RPUD of 15 HU in the infective group versus 8 HU in the non-infective group for RIRS patients; each unit increase in RPUD raised the infection risk by 1.107-fold, with an ROC-derived cut-off of 14 HU (sensitivity: 61%, specificity: 78%) [18]. These findings underscore that integrating preoperative non-contrast CT-based RPUD measurements into clinical decision-making could help identify high-risk patients and guide tailored prophylactic and interventional strategies to reduce postoperative complications.

In addition to RPUD, our analysis revealed that female sex, elevated BMI, and longer operative time were significant predictors of postoperative infectious complications. Female patients demonstrated a higher risk of infection, potentially due to anatomical factors, such as a shorter urethra and variations in urinary microbiota. In addition, patients with a higher BMI likely exhibit a pro-inflammatory state that further predisposes them to infection. Furthermore, longer operative times, which may reflect greater surgical complexity and increased intrarenal pressures that facilitate bacterial translocation, are associated with an additional elevation in infection risk. These observations are consistent with findings from Southern et al. (2018), who, in a large retrospective study of 3,298 ureteroscopies for stone disease, demonstrated that BMI, female sex, and prolonged operative time independently predicted postoperative fever and SIRS. This evidence confirms that these preoperative and intraoperative parameters are robust predictors that could guide more tailored prophylactic and perioperative management strategies[11].

Our study extends these findings by specifically investigating the predictive value of RPUD for postoperative infectious complications following semi-rigid URS. In doing so, we not only corroborate the association between high HU values and an infected state in the renal pelvis but also highlight the potential of RPUD as a novel prognostic biomarker for risk stratification and tailored perioperative management in ureteral stone treatment.

This study has several important limitations that should be acknowledged. First, the retrospective design may introduce potential biases inherent to such studies. Second, being conducted at a single center limits the generalizability of our findings. Third, the relatively small number of infectious complications (n=64) may affect the precision of our conclusions and limit the power for more detailed subgroup analyses. These methodological constraints suggest that while our findings are statistically significant, they should be interpreted with appropriate caution. Future multicenter prospective studies with larger sample sizes would be valuable to confirm and extend our observations.

CONCLUSIONS

Our findings indicate that an increased RPUD on non-contrast CT is a strong predictor of postoperative infectious complications following ureteroscopic stone treatment. In our study, factors such as female sex, higher BMI, and longer surgical duration were also independently associated with an elevated risk of infection. These results underscore the value of a detailed preoperative evaluation to identify patients at higher risk, thereby allowing clinicians to implement personalized prophylactic measures such as early drainage and targeted antibiotic administration. Future prospective research is needed to further validate these observations and refine strategies to reduce infectious complications in this patient population.

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FIGURES AND TABLES

Figure 1. Non-contrast computed tomography images illustrating renal pelvis urine density (RPUD) measurements. (A) Patient without postoperative infectious complications showing low RPUD. (B) Patient with postoperative infectious complications demonstrating high RPUD.

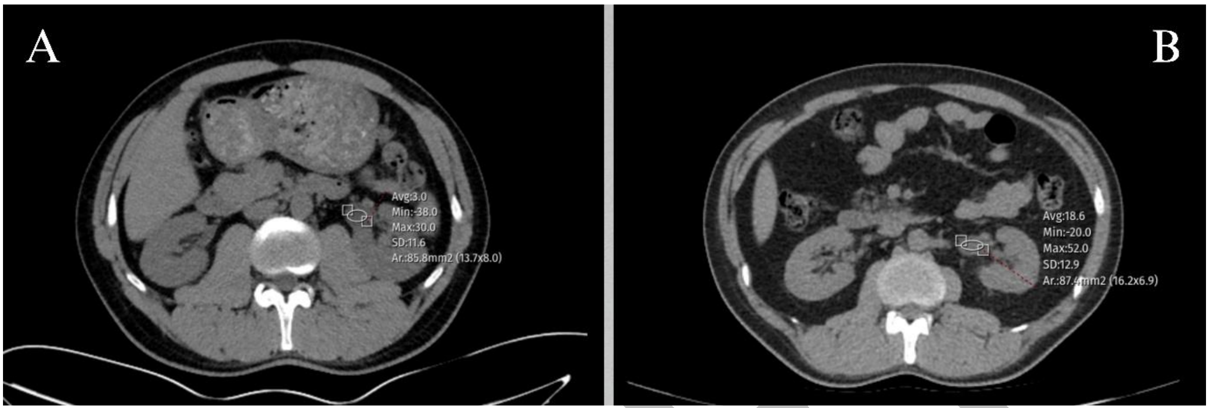

Figure 2. Receiver operating curve (ROC) illustrating the predictive value of renal pelvis urine density (RPUD) for postoperative infectious complications following semi-rigid ureterorenoscopy. (area under the curve 0.784, 95% confidence interval 0.711–0.857, p< 0.001).

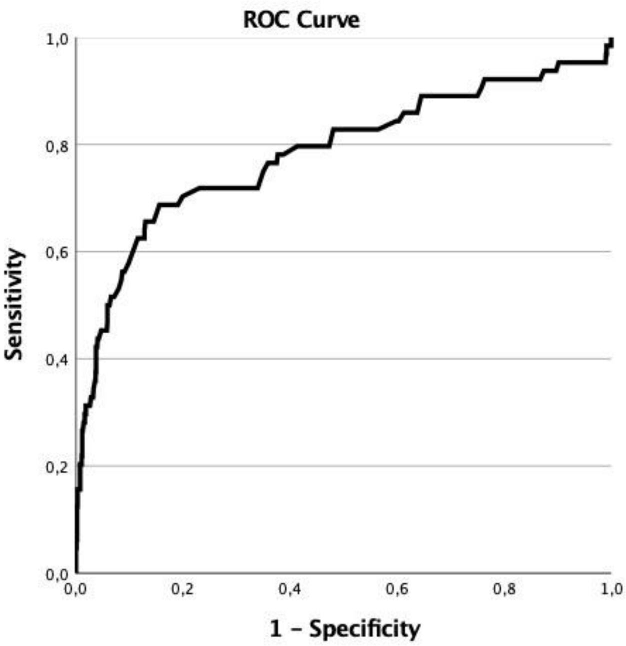

Table 1. Comparison of patients' demographic data and medical characteristics			
	Non-infectious (n=1040)	**Infectious (n=64)**	**p**
Age (years)	44.8 ± 12.7	46.7 ± 13.6	0.243
Sex, n (%)			**0.001**
Male	809 (77.8%)	28 (43.8%)	
Female	231 (22.2%)	36 (56.3%)	
BMI* (kg/m²)	26.7±3.6	28.3±4.5	**0.007**
ASA score*	1.52±0.7	1.53±0.7	0.907
Hypertension, n (%)	160 (15.4%)	14 (21.9%)	0.167
Diabetes mellitus, n (%)	112 (10.8%)	10 (15.6%)	0.229
Coronary artery disease, n (%)	38 (3.7%)	5 (7.8%)	0.098
Previous stone surgery, n (%)	219 (21.1%)	24 (26.6%)	0.297
Previous ESWL history, n (%)	230 (22.1%)	12 (18.8%)	0.528

*Mean ± standard deviation. ASA: American Society of Anesthesiologists; BMI: body mass index; ESWL: extracorporeal shockwave lithotripsy.

Table 2. Comparison of patients' stone-related characteristics, operative data, and postoperative outcomes			
	Non-infectious (n=1040)	**Infectious (n=64)**	**p**
Side			0.084
Right	518 (49.8%)	39 (60.9%)	
Left	522 (50.2%)	25 (39.1%)	
Stone localization, n (%)			0.317
Proximal ureter	188 (18.1%)	15 (23.4%)	
Mid ureter	250 (24%)	18 (28.1%)	
Distal	602 (57.9%)	31 (48.4%)	
Hydronephrosis, n (%)			0.991
Grade 1–2	568 (54.6%)	35 (54.7%)	
Grade 3–4	472 (45.4%)	29 (45.3%)	
Stone burden (mm²)**	50 (36–79)	53 (33–78)	0.738
Stone density (HU)	991.6±216.9	882.1±261.0	0.380
Renal pelvis density (HU)**	4 (2-6)	10 (5-17)	**0.001**
Stent/catheter placement, n (%)			0.996
Double-J stent	894 (86%)	55 (85.9%)	
Ureteral catheter	146 (14%)	9 (14.1%)	
Operation time (min)*	44.0±7.6	46.8±9.2	**0.021**
Hospitalization time (hours)**	24 (24–24)	144 (120–168)	**0.001**

*Mean ± standard deviation. **Median (interquartile range). HU: Hounsfield units.

Table 3. Multivariate analysis of factors related to the development of postoperative infection

	Odds ratio	95% CI	p
Sex	4.001	2.231–7.174	**0.001**
BMI (kg/m²)	0.920	0.860–0.984	**0.015**
Operation time (min)	0.963	0.932–0.996	**0.028**
Renal pelvis density (HU)	0.809	0.771–0.849	**0.001**

BMI: body mass index; CI: confidence interval; HU: Hounsfield units.