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Clinical and radiological predictors of stone-free status after ureteroscopy and shock wave lithotripsy in ureteral stone: A retrospective study

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ABSTRACT

Aim: To identify clinical and non-contrast computed tomography (NCCT)-based radiological predictors of stone-free (SF) status following shock wave lithotripsy (SWL) and ureteroscopy (URS) in patients with solitary ureteral stones.

Methods: This retrospective study included 297 patients treated with SWL (n=147) or URS (n=150) between May 2022 and June 2025. Demographic, clinical, and NCCT-based parameters—stone volume, Hounsfield unit (HU), proximal ureteral diameter (PUD), skin-to-stone distance (SSD), and ureteral wall thickness (UWT)—were recorded. SF status was assessed via imaging four weeks post-treatment. Separate univariate and multivariate logistic regression analyses were performed for each group.

Results: The overall SF rates were 69% in the SWL group and 78% in the URS group. In SWL patients, lower BMI, waist circumference, stone volume, HU, PUD, and low-grade hydronephrosis were significantly associated with SF- status in univariate analysis, but none remained significant in multivariate analysis. In the URS group, younger age, smaller WC, lower stone location, and smaller stone volume were associated with higher SF rates; however, only stone volume remained significant in multivariate analysis.

Conclusion: Stone volume was identified as a consistent and independent predictor of SF status in both treatment modalities. While body composition metrics and NCCT-derived parameters such as HU and PUD showed significant associations—particularly in the SWL group—their predictive value diminished after adjustment, likely due to inter-variable interactions. These results emphasize the importance of integrating radiological and clinical factors to plan treatment decisions for patients with ureteral stones.

Keywords: Ureteral calculi, ureteroscopy, shock wave lithotripsy, treatment outcome.

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1. Introduction

Ureteral calculi are common urological entities and may represent a significant source of morbidity in affected patients. They often require active intervention depending on their size, location, composition, and symptom severity. Shock wave lithotripsy (SWL) and ureteroscopy (URS) are the primary treatment modalities for ureteral calculi, each differing in their mechanism of action, clinical efficacy, and complication profile [1].

SWL is a non-invasive treatment modality using focused acoustic shock waves, and is favored for its outpatient applicability and lower perioperative burden. Its efficacy, however, declines with increased body mass index (BMI), greater skin-to-stone distance (SSD), or high stone density, due to impaired energy transmission [2]. On the other hand, URS enables direct endoscopic visualization and mechanical or laser lithotripsy under general anesthesia. While URS generally provides higher immediate stone-free rates (SFRs), it is associated with the need for hospitalization, increased procedural invasiveness, longer recovery time, and a higher rate of postoperative complications [3].

While both modalities are well-established, treatment outcomes vary widely depending on various patient- and stone- related characteristics. Several radiological parameters measurable on non-contrast computed tomography (NCCT)—such as stone volume, Hounsfield unit (HU), SSD, ureteral wall thickness (UWT), and proximal ureteral diameter (PUD)—have been proposed as potential predictors of SFR, particularly in the context of SWL [4]. In contrast, data regarding their predictive value in URS outcomes remain less comprehensive compared to SWL [5,6].

Despite increasing interest in predictive factors, few studies have assessed clinical and radiologic determinants of SF rates in both SWL and URS. Most available data focus on one modality alone, limiting broader understanding of how patient- and stone-related characteristics influence treatment success. This study aimed to evaluate clinical and NCCT-based radiologic predictors of SF status in patients treated with SWL or URS for solitary ureteral stones, using separate analyses for each modality.

2. Materials and methods

Following the approval of our institution's ethics committee (Sancaktepe Şehit Prof. Dr. İlhan Varank Research and Training Hospital Ethical committee, July 2025, no.259) data from patients treated with SWL or ureteroscopy for solitary ureteral stone from April 2022 to May 2025 in our center were retrospectively evaluated. Exclusion criteria were: patients <18 or >65 years old, pregnancy, patients with multiple stones, indwelling ureteral catheter, solitary kidney and inflammatory and / or malignant diseases. Demographic characteristics such as age, gender, BMI, waist circumference (WC), comorbidity, anticoagulant use, were recorded for each subject. Stone-related characteristics (stone side, level, volume, hardness, skin to stone distance) were derived by NCCT of the patients. Stone volume was calculated by using this formula: (stone's long axis * short axis * depth * 0.52). UWT was measured at the stone site and PUD was the diameter of ureteral lumen above the stone located in the ureter. All measurements were in millimeters.

Successful outcome was defined as being completely SF on NCCT four weeks after the treatment. A maximum of three sessions was applied in patients treated with SWL. If no residual stones were observed after the first or second session, the patient was labelled as SF. Success rates were evaluated in comparative manner. Patients with residual fragments < 4mm were also considered as SF. A total of 297 patients were included into this study.

The SWL treatment was done by the electromagnetic lithotripter, Modulith SLX-F2- FD21 (Storz Medical AG, Tägerwilen /

Switzerland) under fluoroscopy in all patients. The standard pulse frequency was 60 shockwaves per minute with a maximum of 3000 shocks applied at each session. A minimum interval of one week was applied between consecutive SWL sessions. The ureteroscopies were performed with 6.5/8.5 semirigid ureteroscope (Richard Wolf, Germany). Holmium:YAG laser was used for stone fragmentation. Fragmentation was performed with laser settings of 0.8–1.2 Joules and 10–12 Hz in most cases, with minor adjustments according to stone size, location, and hardness. Patients who needed flexible-ureteroscopy for upper ureteral stone were not included into this study.

2.1. Statistical analysis

Statistical analyses were conducted using Jamovi software (version 2.6.0, Mac OS). The normality of continuous variables was assessed using the Kolmogorov–Smirnov test. Depending on the distribution, comparisons between groups were made using the Mann–Whitney U test for continuous variables and the Chi-square test for categorical variables. To identify factors associated with SF-status, univariate and multivariate analyses were performed. A p-value of less than 0.05 was considered statistically significant.

3. Results

A total of 297 patients diagnosed with solitary ureteral stones were retrospectively evaluated; 147 underwent SWL, while 150 were treated with URS. The overall SFRs were 69% in SWL, 78% in URS cohort. Complication rates were 8.8% in the SWL cohort and 22.0% in the URS cohort, with all complications being minor or moderate; no major complications were reported.

In the SWL cohort, SF group had significantly lower BMI (26.06 ± 3.3 vs. 27.4 ± 4.01, p=0.02) and WC (92.9 ± 9.3 mm vs. 96.6 ± 10.3 mm, p=0.04) compared to non-SF group. In terms of stone-related parameters, SF patients had significantly smaller stones (138.9 ± 86.3 mm³, vs 181.9 ± 103.9 mm³ p=0.006), lower HU (677.9 ± 270.7 vs. 773.8 ± 265.6, p=0.02), and lower PUD (8.25 ± 2.82 mm vs. 9.75 ± 2.98 mm, p=0.006) values to non-SF group. Higher grade hydronephrosis was also associated with lower SFRs (p=0.01). No significant differences were observed regarding age, sex, SSD, or stone location (Table 1).

In the URS cohort, SF patients were younger compared non-SF patients (40.9 ± 11.7 vs. 45.8 ± 12.4 years, p=0.03). Mean BMI and WC values were lower in SF patients compared to non-SF patients, but this difference did not reach statistically significance. Stone volume was significantly smaller in the SF group (207.4 ± 232.7 mm³ vs. 324.5 ± 184.5 mm³, p<0.001), and lower stone location was associated with higher SFRs (p=0.03). No significant differences were noted regarding sex, hydronephrosis grade, UWT, SSD, or HU values (Table 2).

In SWL cohort, univariate logistic regression identified BMI (p=0.036), WC (p=0.038), stone volume (p=0.014), hydronephrosis (p=0.005), and PUD (p=0.006) as significant predictors of SF-status in SWL cohort. However, in multivariate analysis, none of these parameters retained statistical significance (all p>0.05) (Table 3). ROC curve analysis of the multivariate model demonstrated an AUC of 0.70, indicating a fair discriminative ability for predicting stone-free status (Figure 1).

In URS cohort, univariate logistic regression, age (p=0.04), WC (p=0.04), lower stone location (p=0.01) and stone volume (p=0.03) were found to be associated with SF-status. Among these, only stone volume

Table 1. Comparison of clinical and radiological factor between Stone-free and Non-stone-free patients in the SWL group.

Parameters	SWL patients			*p* value
	All patients	**Stone-free group**	**Non- stone-free group**	
Number	147	102	45	
Age	40.8 ± 10.9	39.8 ± 10.4	43.1 ± 11.9	*0.07*[a]
Sex				*0.4*[b]
Male	107	76	31	
Female	40	26	14	
Body mass index	26.4 ± 3.5	26.06 ± 3.3	27.4 ± 4.01	***0.02***[a]
Waist circumference (mm)	94.09 ± 9.8	92.9 ± 9.3	96.6 ± 10.3	***0.04***[a]
Comorbidity				***0.03***[b]
None	110	80	30	
Diabetes mellitus	20	9	11	
Coronary artery disease	17	13	4	
Anticoagulant use				*0.3*[b]
Yes	135	95	40	
No	12	7	5	
Stone side				*0.5*[b]
Right	61	44	17	
Left	86	58	28	
Stone location				*0.1*[b]
Upper	77	48	29	
Middle	38	28	10	
Lower	32	26	6	
Stone volume (mm^3)	152.1 ± 93.8	138.9 ± 86.3	181.9 ± 103.9	***0.006***[a]
Hounsfield unit	707.2 ± 271.9	677.9 ± 270.7	773.8 ± 265.6	***0.02***[a]
SSD (Skin-to-stone distance) (mm)	121.8 ± 20.3	120.2 ± 19.8	125.3 ± 21.1	*0.09*[a]
Hydronephrosis				***0.01***[b]
None	0	0	0	
Mild	100	74	26	
Severe	45	28	19	
UWT (Ureteral Wall thickness) (mm)	2.8 ± 1.03	2.8 ± 1.05	2.98 ± 0.97	*0.1*[a]
PUD (Proximal ureteral diameter) (mm)	8.7 ± 2.9	8.25 ± 2.82	9.75 ± 2.98	***0.006***[a]
Complication rate (%)				***<0.001***[b]
None	134	100	34	
Minor	13	2	11	
Major	0	0	0	

[a]*Mann- Whitney U*, [b]*Chi- Square test*

Table 2. Comparison of clinical and radiological factors between Stone-free and Non-stone-free patients in the URS group.

Parameters	URS patients			*p* value
	All patients	**Stone-free group**	**Non- stone-free group**	
Number	150	117	33	
Age	42.03 ± 12.02	40.9 ± 11.7	45.8 ± 12.4	*0.03*[a]
Sex				*0.5*[b]
Male	103	79	24	
Female	47	38	9	
Body mass index	26.1 ± 3.7	25.9 ± 3.4	27.1 ± 4.6	*0.08*[a]
Waist circumference (mm)	89.5 ± 10.3	88.6 ± 9.6	92.7 ± 12.1	*0.07*[a]
Comorbidity				
None	117	92	25	
Diabetes mellitus	14	11	3	*0.8*[b]
Coronary artery disease	19	14	5	
Anticoagulant use				
Yes	18	12	6	*0.4*[b]
No	132	105	27	
Stone side				
Right	66	51	15	*0.8*[b]
Left	84	66	18	
Stone location				
Upper	33	21	12	
Middle	41	31	10	***0.03***[b]
Lower	76	65	11	
Stone volume (mm^3)	228.3 ± 227.3	207.4 ± 232.7	324.5 ± 184.5	***<0.001***[a]
Hounsfield unit	827.4 ± 325.7	803.7 ± 325.9	911.3 ± 315.9	*0.06*[a]
SSD (Skin-to-stone distance) (mm)	109.7 ± 23.5	108.4 ± 23.4	114.7 ± 23.7	*0.2*[a]
Hydronephrosis			1	
None	12	11	16	
Mild	84	68	16	*0.1*[b]
Severe	54	38		
UWT (Ureteral Wall thickness) (mm)	2.5 ± 0.9	2.5 ± 0.97	2.7 ± 0.8	*0.06*[a]
PUD (Proximal ureteral diameter) (mm)	9.1 ± 2.7	8.9 ± 2.8	9.6 ± 2.1	*0.1*[a]
Complication rate (%)				
None	129	117	12	
Minor	20	0	20	***<0.01***[b]
Major	1	0	1	

[a]*Mann- Whitney U*, [b]*Chi- Square test*

Table 3. Univariate and Multivariate logistic regression analyses of factors associated with Stone-free status in the SWL group.

Parameters	Univariate analysis			Multivariate analysis
Predictor	***p* value**	**Odds Ratio**	**95% CI**	***p* value**
Body mass index	**0.036**	0.90	0.20 to 0.01	0.568
Waist-circumference	**0.038**	0.96	-0.08 to 0.00	0.271
Stone volume	**0.014**	1.00	-0.01 to 0.00	0.251
Hounsfield unit	0.053	1.00	-0.00 to 0.00	
Hydronephrosis	**0.005**	0.54	-1.05 to -0.19	0.217
PUD (Proximal ureteral diameter)	**0.006**	0.84	-0.30 to -0.05	0.415

Note: Estimates represent the log odds of "stone free = yes" vs. "stone free = no".

Table 4. Univariate and Multivariate logistic regression analyses of factors associated with Stone-free status in the URS group.

Predictor	Univariate analysis			Multivariate analysis
	***p* value**	**Odds Ratio**	**95% CI**	***p* value**
Age	**0.04**	0.97	-0.06 to 0.00	0.307
Body mass index	0.09	0.92	-0.18 to 0.02	
Waist -circumference	**0.04**	0.96	-0.07 to 0.00	0.200
Stone volume	**0.03**	1.00	-0.00 to 0.00	**0.04**
Stone location (Upper – Middle)	0.265	1.77	1.58 to 0.43	0.495
Stone location (Upper – Lower)	**0.01**	3.38	2.17 to 0.26	0.06
Hounsfield unit	0.09	1.00	-0.00 to 0.00	
UWT (Ureteral Wall thickness)	0.14	0.74	-0.69 to 0.10	
PUD (Proximal ureteral diameter)	0.18	0.91	-0.25 to -0.05	

Note: Estimates represent the log odds of "stone free = yes" vs. "stone free = no".

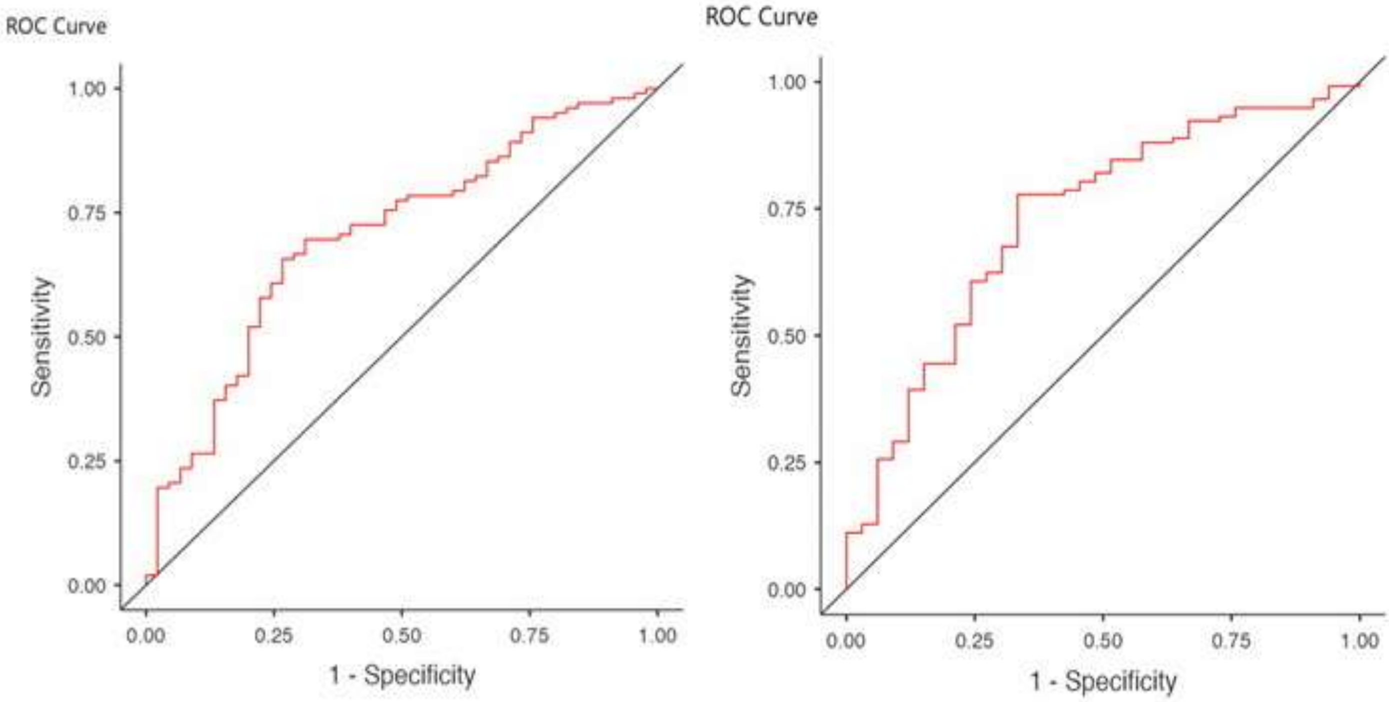

Figure 1. A) ROC curve of the multivariate model for SWL (AUC = 0.70). **B)** ROC curve of the multivariate model for URS (AUC = 0.73).

remained significant in multivariate analysis (*p*=0.04). The odds of achieving SF status decreased with increasing stone burden. Although lower ureteral location showed a trend toward higher SFRs (OR 3.38; *p*=0.06), this did not reach statistical significance in the multivariate model (Table 4). ROC curve analysis of the URS multivariate model showed an AUC of 0.73, indicating a moderate discriminative performance for predicting SF status (Figure 2).

4. Discussion

Optimal treatment selection for ureteral stones depends not only on stone characteristics but also on patient-specific anatomical and clinical variables. As both SWL and URS offer different advantages and limitations, identifying reliable predictors of treatment success has become increasingly important. Recent attention has turned to NCCT-based measurements to guide decision-making, yet their clinical utility remains a subject of ongoing investigation.

Body habitus—particularly BMI—has been shown to significantly affect the success of SWL. Increased adiposity leads to greater SSD, resulting in attenuation of shockwave energy before it reaches the stone, thereby reducing the likelihood of complete fragmentation. In a study by Yang et al., BMI was found to be an independent predictor of SWL failure in upper ureteral stones, whereas buttock circumference (BC), a surrogate for pelvic SSD, was associated with failure in middle and lower ureteral calculi [7]. Similarly, Pareek et al [8]. demonstrated that higher BMI was independently associated with lower SFRs after SWL for upper urinary tract stones, suggesting that increased body habitus not only impairs shockwave transmission but may also hinder targeting and coupling accuracy during treatment. Consistent with previous literature, our study also demonstrated that lower BMI and WC were significantly associated with higher SFRs in SWL.

Stone volume emerged as a significant predictor of SWL success in our study. This finding is in line with previous literature demonstrating that larger stones are more resistant to SWL fragmentation and clearance. Simsekoglu et al. [9] showed that ureteral stones larger than 1 cm^2 were significantly associated with SWL failure in multivariate analysis. Additionally in a different study, it has been shown that while mean stone density and SSD were independent predictors of SWL outcomes, increasing stone size also negatively impacted SFRs, particularly for ureteral calculi [10].

Stone density, measured in Hounsfield units on NCCT, is a key determinant of SWL success. Prior studies have shown that stones with higher HU values, particularly above 900–1000, are associated with significantly lower stone-free rates, in line with our study [11,12]. We also found that greater PUD and higher-grade hydronephrosis were negatively associated with SWL success. Dilated ureters may indicate chronic obstruction or impacted stones, which fragment or pass less effectively. Previous studies have linked moderate to severe ureteral dilatation and high-grade hydronephrosis to reduced SWL efficacy [13,14]. However, in our cohort, neither PUD nor hydronephrosis retained significance in multivariate analysis—possibly due to collinearity with stone size/location.

Interestingly, in the SWL cohort, several parameters that were significant in univariate analysis (BMI, WC, stone volume, HU, PUD, hydronephrosis) lost their significance in the multivariate model. This phenomenon may be explained by several factors. First, the limited sample size might have reduced the statistical power to detect independent associations once multiple variables were included simultaneously. Second, collinearity between variables is likely to have played a role—for example, strong correlations may exist between stone volume and PUD or hydronephrosis, or between BMI and WC—diminishing the apparent independent effect of each factor. Finally, unmeasured confounders, such as SWL energy settings, or surgeon-related factors, may have influenced treatment outcomes and masked the role of clinical or radiological parameters. These findings highlight that SWL success may not be reliably predicted by a single parameter, but rather by an integrated assessment of patient- and stone- related characteristics.

On the other hand, in our URS cohort, advanced age was inversely associated with SF status after URS in univariate analysis. This aligns with the hypothesis that age-related anatomical or inflammatory changes may limit endoscopic access or clearance. However, this association did not persist in multivariate analysis, suggesting confounding by other variables such as stone size or location. Conversely, a recent meta-analysis by Shen et al. [15] reported that patients aged ≥60 or ≥65 years had comparable SF and complication rates to younger individuals undergoing URS, highlighting that advanced age does not independently predict adverse outcomes after URS.

Stone size is a well-established determinant of URS success. In our cohort, stone volume was significantly larger in the non-SF group compared to the SF group, and remained an independent predictor of treatment failure in multivariate analysis. Prior studies have reported that semirigid URS is less effective for stones >10 mm, particularly in the upper ureteral stones. Atis et al. observed a SFR of only 60% for proximal ureteral stones treated with semirigid URS [16]. These findings are consistent with current EAU guidelines, which acknowledge stone size as a key factor influencing the choice and success of endourological interventions [1]. Our results further reinforce the negative association between increasing stone burden and URS efficacy.

WC was identified as a significant predictor of URS outcomes in our cohort, with larger measurements associated with lower SFRs. While obesity has been widely studied in the context of urolithiasis risk and treatment outcomes, most previous research has focused on BMI rather than central adiposity. There are some studies reporting that obesity does not significantly impact URS efficacy or complication rates [17]. However, our findings suggest that WC—reflecting visceral fat distribution—may have a distinct influence on endoscopic stone clearance, potentially due to technical challenges or altered ureteral dynamics in patients with central obesity. Further studies are needed to validate this association.

In our study, stone location was found to be a significant predictor of URS outcomes. Distal ureteral stones had higher SFRs with semirigid URS, likely due to easier access, reduced ureteral mobility, and improved endoscopic visualization. In contrast, proximal ureteral stones were more challenging and associated with lower SFRs. This may be attributed to the increased ureteral angulation, stone migration during lithotripsy, and the limited reach of semirigid instruments in the upper tract. As our study excluded cases managed with flexible ureteroscopy, the reduced success in proximally located stones is not unexpected. These findings align with previous literature reporting significantly lower success rates for proximal stones treated with semirigid URS [18,19].

From a practical standpoint, our findings may offer useful insights for patient selection. SWL appears more suitable for individuals with smaller stones, lower HU values, mild or no hydronephrosis, and favorable body composition (lower BMI and WC). In contrast, URS should be prioritized in patients with larger or proximally located stones, where the likelihood of SWL success decreases, but where endoscopic access enables higher SFRs.

Importantly, stone volume emerged as the most consistent and independent predictor of treatment success across both modalities. This is clinically relevant, as stone size is a routinely available and easily measurable parameter on NCCT. Our results therefore support the use of stone burden as a central factor when counseling patients and planning treatment. At the same time, the fact that several predictors significant in univariate analyses lost their effect in multivariate models underscores the complexity of decision-making. Rather than relying on any single variable, clinicians should integrate radiological parameters with clinical factors such as BMI, WC, and age to tailor treatment strategies. This integrated approach may prevent unsuccessful SWL attempts in patients with unfavorable profiles, thereby avoiding delays in definitive management, repeated procedures, and unnecessary healthcare costs. Furthermore, the novel observation that central obesity (reflected by WC) may reduce URS efficacy adds an additional layer to preoperative counseling.

Taken together, these insights not only align with existing literature but also extend its practical applicability, providing urologists with a guidance to optimize patient selection, support shared decision-making, and reinforce the importance of individualized treatment planning in routine practice.

On the other hand, our study is not without limitations. Its retrospective design may have introduced selection and information bias, as treatment decisions and imaging protocols were not standardized. Additionally, patients who underwent flexible ureteroscopy were excluded, limiting the applicability of our findings, particularly for proximal ureteral stones. In multivariate analysis, several variables failed to retain statistical significance despite being significant in univariate comparisons. This may be due to inter-variable collinearity or unmeasured confounding factors influencing treatment outcomes. Finally, the single-center nature of the study may affect its generalizability.

4.1. Conclusion: This retrospective study identified several clinical and radiological factors associated with treatment success in patients undergoing semirigid URS and SWL for solitary ureteral stones. In the SWL group, lower stone density (HU), smaller stone size, and lower PUD values were significantly associated with achieving a SF status. Additionally, the presence of mild or no hydronephrosis appeared to be favorable for treatment success in SWL. In contrast, within the URS group, reduced stone volume and smaller WC were correlated with higher SFRs. While multivariate analysis revealed limited independent predictors—likely due to confounding interactions—our findings underline the importance of individualized patient assessment in treatment planning. These results may assist clinicians in optimizing modality selection and counseling patients on expected outcomes. Future prospective studies with larger, multicenter cohorts are needed to further validate these findings.

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