Original Article

DOI: 10.14235/bas.galenos.2026.04378
Bezmialem Science

The Relationship Between Hounsfield Unit and Flexible URS Clinical Outcomes: A Single-center Experience

Hounsfield Ünitesi ile Esnek URS Klinik Sonuçları Arasındaki İlişki: Tek Merkezli Bir Deneyim

İbrahim EROL, Serdar GEYİK, Muammer BABAYİĞİT

Aksaray University Education and Research Hospital, Department of Urology, Aksaray, Türkiye

ABSTRACT

Objective: This study aimed to evaluate the relationship between Hounsfield unit (HU) and clinical outcomes after flexible ureteroscopy (fURS), including stone-free rate (SFR), operative time, and postoperative complications.

Methods: A total of 300 adult patients who underwent fURS for unilateral renal stones <20 mm between January 2020 and May 2025 were retrospectively analyzed. Demographic characteristics, stone parameters, and perioperative data were recorded. The primary outcome was SFR assessed at 4-6 weeks; residual fragments <4 mm were considered clinically insignificant. Continuous variables were compared using independent-samples t-test or Mann-Whitney U test as appropriate, and categorical variables using chi-square or Fisher's exact test. Multivariable logistic regression identified predictors of SFR and postoperative complications. Receiver operating characteristic analysis was performed to evaluate the predictive value of HU for prolonged operative time, defined as durations exceeding the median operative time.

Results: Mean HU was 948±290, mean stone size was 11.8±4.9 mm, and overall SFR was 80.7%. Larger stone size significantly reduced the likelihood of achieving SFR, while stone multiplicity showed borderline significance. Age, sex, body mass index, and hydronephrosis were not significant predictors. Postoperative complications occurred in 14.8% of patients, and ureteral access sheath use significantly reduced complication risk. HU demonstrated moderate discriminatory ability for predicting prolonged operative duration.

ÖZ

Amaç: Bu çalışmada Hounsfield ünitesi (HU) ile fleksibl üreteroskopi (fURS) sonrası klinik sonuçlar arasındaki ilişkinin; taşsızlık oranı (SFR), operasyon süresi ve postoperatif komplikasyonlar açısından değerlendirilmesi amaçlandı.

Yöntemler: Ocak 2020-Mayıs 2025 tarihleri arasında tek taraflı ve <20 mm renal taş nedeniyle fURS uygulanan 300 erişkin hasta retrospektif olarak analiz edildi. Demografik özellikler, taş parametreleri ve perioperatif veriler kaydedildi. Primer sonuç ameliyat sonrası 4-6. haftada değerlendirilen SFR idi; 4 mm'den küçük artık fragmanlar klinik olarak önemsiz kabul edildi. Sürekli değişkenler uygun olduğunda bağımsız örneklem t-testi veya Mann-Whitney U testi ile, kategorik değişkenler ise ki-kare veya Fisher'in kesin testi ile karşılaştırıldı. Taşsızlık ve komplikasyonların prediktörleri çok değişkenli lojistik regresyon ile değerlendirildi. HU'nun uzamış operasyon süresini öngörme gücü alıcı işletim karakteristiği analizi ile incelendi.

Bulgular: Ortalama HU değeri 948±290, taş boyutu 11,8±4,9 mm olup genel SFR %80,7 idi. Daha büyük taş boyutu taşsızlık olasılığını anlamlı şekilde azaltırken taş çokluğu sınırda anlamlılık gösterdi. Yaş, cinsiyet, vücut kitle indeksi ve hidronefroz anlamlı prediktörler değildi. Postoperatif komplikasyon oranı %14,8 olup üreteral erişim kılıfı kullanımı komplikasyon riskini anlamlı şekilde azalttı. HU'nun uzamış operasyon süresini öngörme gücü orta düzeyde bulundu.

Sonuç: HU, fURS sonrası operasyon zorluğunu öngörmede klinik açıdan anlamlı bir parametredir. Taş boyutu ve anatomik

Address for Correspondence: İbrahim Erol MD, Aksaray University Education and Research Hospital, Department of Urology, Aksaray, Türkiye
E-mail: irbam07@hotmail.com
ORCID IDs of the authors: İ.E.: 0000-0003-3626-0309, S.G.: 0000-0002-8712-7682, M.B.: 0000-0002-9619-684X

Cite this article as: Erol İ, Geyik S, Babayiğit M. The relationship between hounsfield unit and flexible URS clinical outcomes: a single-center experience. Bezmialem Science. [Epub Ahead of Print]

Received: 23.11.2025
Accepted: 05.03.2026
Epub: 01.07.2026

ABSTRACT

Conclusion: HU is a clinically meaningful indicator of procedural complexity following fURS. Incorporating HU together with stone size and anatomical factors may improve preoperative planning, surgical decision-making, and patient counseling.

Keywords: Hounsfield unit, flexible ureteroscopy, stone-free rate, operative time, renal calculi

ÖZ

faktörlerle birlikte değerlendirilmesi, preoperatif planlama ve hasta bilgilendirmesini iyileştirebilir.

Anahtar Kelimeler: Hounsfield ünitesi, fleksibl üreteroskopi, taşsızlık oranı, operasyon süresi, renal taş

Introduction

Hounsfield unit (HU), a quantitative parameter derived from non-contrast computed tomography (CT), reflects tissue density and provides valuable information regarding stone hardness and crystalline composition (1,2). The well-established association between HU and stone structure has positioned this metric as an essential component of preoperative decision-making in contemporary endourological practice (3-5).

Flexible ureteroscopy (fURS) has become a widely adopted treatment modality for small and moderate renal stones, offering high stone-free rates (SFR) with low morbidity. However, procedural difficulty and treatment efficacy vary considerably across patients. Higher HU values and certain anatomical factors—particularly lower pole configuration—have consistently been associated with increased procedural complexity, prolonged operative duration, and reduced SFRs (6-9). These observations suggest that stone density may play a more critical role in determining surgical difficulty and postoperative outcomes than traditionally assumed.

Given the increasing emphasis on individualized surgical planning and outcome optimization, understanding the predictive value of HU in fURS is of significant clinical importance. Therefore, this study aimed to investigate the relationship between HU and key clinical outcomes—including stone-free status, operative duration, and postoperative morbidity—in a single-center retrospective cohort of patients undergoing fURS.

Methods

A retrospective review was conducted on 300 consecutive adult patients who underwent fURS at our institution between January 2020 and May 2025. Patients younger than 18 years, those with bilateral renal stones, stones larger than 20 mm, congenital or acquired renal anatomical anomalies (such as horseshoe kidney, pelvic kidney, or duplicated collecting system), concurrent surgical procedures during the same session, incomplete radiological or clinical data, or postoperative follow-up shorter than 4 weeks were excluded.

Collected variables included demographic characteristics [age, sex, and body mass index (BMI)]; stone characteristics (stone size, mean HU, and anatomical location categorized as lower pole, mid pole, renal pelvis, or upper pole); stone multiplicity; presence of hydronephrosis; and pre-stenting status.

All procedures were performed using a 7.5F fURS (HugeMed) and the same holmium: YAG laser platform, with standardized laser settings of 1.2 J energy and 15 Hz frequency. A 273-μm disposable laser fiber was used in all patients to ensure uniformity of laser fragmentation technique. Dusting or fragmentation strategies were selected according to intraoperative visibility and stone response. The use of a ureteral access sheath (UAS) was left to the discretion of the operating surgeon.

Stone density was measured using non-contrast CT performed with a 64-slice scanner. HU measurements were obtained on axial images by placing a 3-5 mm circular region of interest (ROI) over the largest cross-sectional area of the stone while avoiding partial-volume effects. The mean HU value was recorded for analysis.

The primary outcome was the SFR at 4-6 weeks postoperatively. Stone-free status was assessed primarily using non-contrast CT, which represents the standard follow-up imaging modality at our institution. In selected cases, ultrasonography or kidney-ureter-bladder (KUB) radiography was used according to routine clinical follow-up protocols when CT was not considered clinically necessary. Residual fragments smaller than 4 mm were considered clinically insignificant. Secondary outcomes included postoperative complications classified according to the Clavien-Dindo system.

Ethics Approval

This study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Aksaray University Health Sciences Scientific Research Ethics Committee (decision no: 2025/200, protocol no: SAGETİK 2025-129, date: 09.10.2025). Because the study was retrospective and based on anonymized data, the requirement for written informed consent was waived by the committee.

Statistical Analysis

Statistical analyses were performed using SPSS version 25.0. Data normality was assessed with the Shapiro-Wilk test. Continuous variables were compared using the independent-samples t-test or Mann-Whitney U test, and categorical variables using the chi-square or Fisher's exact test as appropriate. Multivariable logistic regression analysis was used to identify predictors of stone-free status and postoperative complications. Receiver operating characteristic (ROC) analysis evaluated the predictive value of HU for prolonged operative time. A p-value <0.05 was considered statistically significant.

Results

A total of 300 patients who underwent fURS were included in the analysis. The mean age was 46.8±13.5 years, and 57% of the cohort were male. The mean BMI was 27.4±3.9 kg/m², the mean stone size was 11.8±4.9 mm, and the mean stone density was 948±290 HU (Figure 1). Lower pole stones accounted for 50% of all cases, while 21% of patients had multiple stones, and 18% underwent pre-stenting prior to the procedure. The mean operative time was 71.9±22 minutes, and the overall SFR at 4-6 weeks was 80.7%. Baseline demographic and stone characteristics are presented (Table 1).

Multivariable logistic regression analysis demonstrated that larger stones were associated with reduced SFR [odds ratio (OR)=0.90; 95% confidence interval: 0.8-1.0; p=0.01]. Stone multiplicity showed a borderline association with lower SFR (OR=0.57; p=0.07), while hydronephrosis, age, sex, and BMI were not significant predictors. In the location analysis, stones in the mid pole (OR=3.58; p<0.001), renal pelvis (OR=3.22; p=0.01), and upper pole (OR=2.70; p=0.02) demonstrated higher odds of achieving SFR compared with lower pole stones, which were used as the reference category in the model. Full regression results are summarized (Table 2).

None of the other evaluated variables—including, stone size, multiplicity, hydronephrosis, sex, BMI, age, or operative time—were significantly associated with postoperative complications, and stone location likewise did not demonstrate a significant effect (Table 3).

To further explore the influence of stone density on procedural difficulty, a ROC analysis was performed to evaluate the ability of HU to predict prolonged operative time, defined as a duration above the median. The relationship between HU and operative time is illustrated (Figure 2), and HU demonstrated moderate discriminative ability for identifying longer procedures (Figure 3).

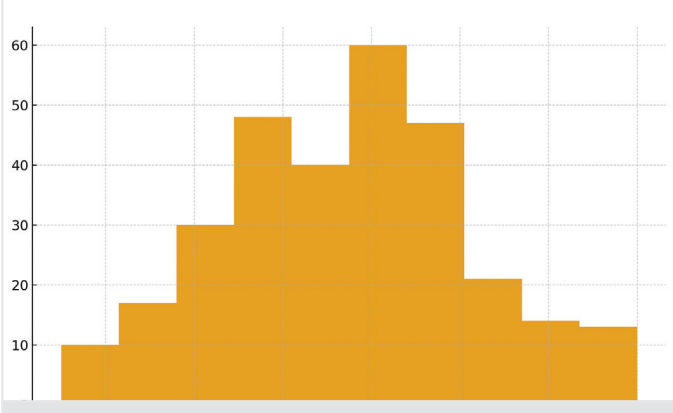

Figure 1. Distribution of stone density (HU)

Histogram showing the distribution of HU values measured on non-contrast CT in the study population

HU: Hounsfield unit, CT: Computed tomography

Table 1. Baseline demographic, stone, and operative characteristics

Variable	Value
Age (years, mean ± SD)	46.8±13.5
Sex (male/female)	57%/43%
BMI (kg/m²)	27.4±3.9
Stone size (mm)	11.8±4.9
Stone density (HU)	948±290
Lower pole stones (%)	50%
Multiple stones (%)	21%
Pre-stented (%)	18%
Operative time (min, mean ± SD)	71.9±22
Stone-free rate (%)	80.7%

Note: Values are presented as mean ± standard deviation or percentage
SD: Standard deviation, BMI: Body mass index, HU: Hounsfield unit

Table 2. Multivariable logistic regression analysis predicting stone-free status

Predictor	OR	95% CI	p-value
Intercept	28.74	2.1-392.2	0.01
Mid pole vs. lower pole (reference)	3.58	1.6-8.0	0.001
Renal pelvis vs. lower pole	3.22	1.4-7.3	0.01
Upper pole vs. lower pole	2.70	1.2-6.2	0.02
Male sex	0.74	0.4-1.3	0.33
Stone size (mm)	0.90	0.8-1.0	0.01
Multiple stones	0.57	0.3-1.0	0.07
Pre-stented	1.32	0.7-2.4	0.37
Hydronephrosis	0.82	0.4-1.5	0.51
BMI	1.04	1.0-1.1	0.26
Age	0.99	1.0-1.0	0.45

Note: Lower pole location used as reference category
OR: Odds ratio, CI: Confidence interval, BMI: Body mass index

Table 3. Multivariable logistic regression analysis predicting postoperative complications (Clavien >0)

Predictor	OR	95% CI	p-value
Intercept	0.03	0.0-2.2	0.11
Mid pole vs lower pole (reference)	0.85	0.3-2.8	0.79
Renal pelvis vs lower pole	1.12	0.3-3.8	0.86
Upper pole vs lower pole	0.86	0.2-3.0	0.82
Male sex	0.98	0.4-2.3	0.96
Stone size (mm)	1.07	1.0-1.2	0.22
Multiple stones	0.65	0.3-1.5	0.31
Pre-stented	0.82	0.3-1.9	0.64
Hydronephrosis	0.95	0.4-2.2	0.91
BMI	0.95	0.9-1.0	0.31
Age	1.01	1.0-1.0	0.46
Operative time	1.01	1.0-1.0	0.21
Access sheath used	0.21	0.1-0.5	<0.001

OR: Odds ratio, CI: Confidence interval, BMI: Body mass index

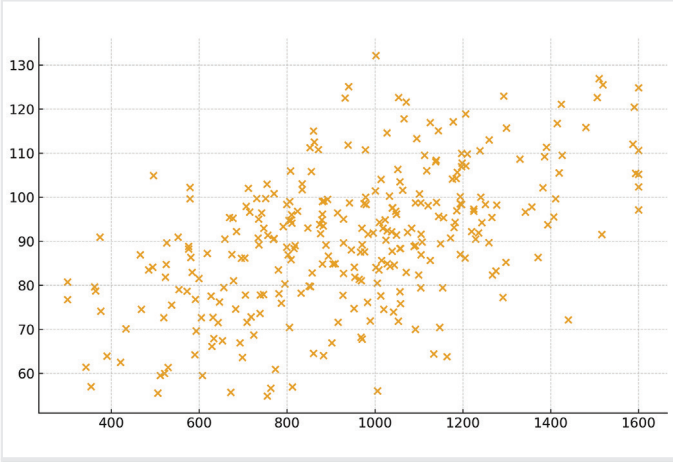

Figure 2. Relationship between HU and operative time

Scatter plot illustrating the association between stone density (HU) and operative duration during flexible ureteroscopy

HU: Hounsfield unit

Discussion

Our findings demonstrated that stone density, quantified by HU on non-contrast CT, is relevant to procedural complexity following fURS. The substantial variation in HU values in our cohort reflects heterogeneous stone composition and reinforces its relevance as a preoperative indicator of fragmentation difficulty and procedural complexity (1-5). In the present study, HU demonstrated moderate discriminatory ability for prolonged operative duration, supporting the role of stone density in preoperative assessment of procedural complexity (6-9).

The overall SFR (80%) observed in our study aligns with previously published rates ranging from 75% to 85% (1-3,8,9). Stone size also negatively influenced stone-free outcomes, while stone multiplicity demonstrated borderline statistical significance. These findings are consistent with previously developed scoring systems such as the Resorlu-Unsal score and the R.I.R.S. scoring system, both of which incorporate stone burden into predictive models of surgical success (10-13).

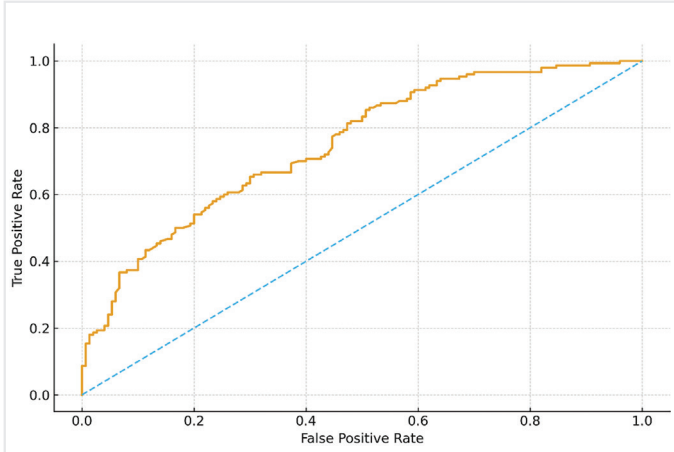

Figure 3. ROC curve for HU predicting prolonged operative time (AUC=0.75)

ROC curve demonstrating the discriminative ability of HU in predicting operative duration exceeding the median operative time

ROC: Receiver operating characteristic, HU: Hounsfield unit, AUC: Area under the curve

Previous literature has highlighted additional CT-based predictors of surgical complexity. Traxer and Thomas (14) emphasized the importance of preoperative ureteral evaluation, while systematic reviews examining UAS use have demonstrated its potential benefits in facilitating ureteroscopy and improving intraoperative conditions (15). Furthermore, HU-based threshold values proposed in earlier studies and reports linking higher stone density with procedural difficulty support the clinical relevance of CT-derived attenuation measures in endourological planning (16-20).

Beyond density alone, CT-derived attenuation parameters and skin-to-stone distance have also been associated with lithotripsy success and procedural difficulty. These findings collectively support the view that HU is not only a marker of stone composition but also an indicator of procedural complexity (21).

Postoperative complication rates in our cohort were low and limited to minor-to-moderate events, consistent with previous fURS series. Notably, UAS use significantly reduced complication rates. This observation likely reflects improved irrigation flow, reduced intrarenal pressure, and enhanced intraoperative visibility, mechanisms previously demonstrated in experimental and clinical studies (22,23). The absence of major complications further supports the

safety profile of fURS even in patients with higher-density stones.

Another important finding of this study was the moderate predictive value of HU for prolonged operative duration. Denser stones often require longer laser fragmentation time and increased intraoperative manipulation. Emerging machine-learning-based predictive models have been explored in urinary stone disease, supporting the broader potential of data-driven approaches in individualized endourological decision-making (24,25).

Taken together, these findings reinforce the clinical value of HU as a preoperative indicator of procedural complexity that may enhance surgical planning, optimize intraoperative strategy, and improve patient counseling.

Study Limitations

This study has several limitations. First, its retrospective single-center design may introduce selection bias and may limit the generalizability of the findings. Second, patients with congenital or acquired renal anatomical anomalies were excluded, which may restrict applicability to more complex anatomical scenarios. Third, long-term postoperative outcomes—such as ureteral stricture formation or delayed complications—were not evaluated. Additionally, although HU measurements were standardized using consistent ROI placement, inter-observer variability may still occur in routine clinical practice.

Another limitation is the use of different imaging modalities for postoperative stone-free assessment. Although non-contrast CT was the primary follow-up method at our institution, ultrasonography or KUB radiography was used in selected cases according to routine clinical practice. This heterogeneity may have influenced the accuracy of SFR evaluation.

Prospective multicenter studies with longer follow-up are needed to further validate the predictive role of HU in fURS.

Conclusion

HU is a clinically relevant indicator of procedural complexity following fURS. HU demonstrated moderate discriminatory ability for prolonged operative duration, indicating increased procedural complexity with denser stones. Stone size remains an important determinant of treatment success, while the use of a UAS appears to reduce postoperative complications. Incorporating HU into preoperative assessment may support surgical planning, improve patient counseling, and optimize case selection. Further prospective multicenter studies integrating HU with anatomical parameters and advanced predictive models are needed to refine clinical decision-making in endourology.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Aksaray University Health Sciences Scientific Research Ethics Committee (decision no: 2025/200, protocol no: SAGETİK 2025-129, date: 09.10.2025).

Informed Consent: As the study was retrospective and based on anonymized data, the requirement for written informed consent was waived by the committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: İ.E., S.G., M.B., Concept: İ.E., Design: İ.E., S.G., Data Collection or Processing: İ.E., M.B., Analysis or Interpretation: İ.E., S.G., Literature Search: İ.E., M.B., Writing: İ.E., M.B.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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