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UROLOGY – REVIEW

Comparative analysis of STONE, TOHO, and ITO stone scoring systems for predicting stone-free status following flexible ureteroscopy in patients with renal stones: a prospective study

Kareem Noah[1,2] · Hussien Shaher[2] · Mariam Hamdy[3] · Tamer Diab[2] · Mahmoud Farag[2]

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Abstract

Objective This study aimed to compare the predictive capabilities of three stone scoring systems (STONE, TOHO, and ITO stone score) in determining outcomes, stone-free status, and complications following flexible ureteroscopy (fURS) in patients with renal stones.

Patients and methods This prospective study included 300 patients with renal stones treated at the Urology Department of Benha University Hospital from January 2023 to June 2024, all managed with flexible ureteroscopy (fURS). Eligible participants had renal calculi measuring up to 2.5 cm. For each patient, the three evaluated stone scores were calculated by the same surgeon and an expert radiologist.

Results This study revealed significant negative correlations between stone-free rates (SFR) and the STONE and TOHO scores ($P < 0.05$), while there were significantly positive correlations between SFR and ITO scores (P value < 0.05). The SFR at 1 month was 87%. In terms of postoperative complications, colic was reported in 57 patients (19%), fever in 66 patients (22%), and hematuria in 30 patients (10%). According to the study findings, the three scoring systems effectively predicted the outcomes of flexible ureteroscopy, with area under the curve (AUC) values of 0.805 for STONE, 0.903 for TOHO, and 0.856 for ITOscore.

Conclusion The three studied scoring systems are valid tools for predicting stone-free rates following flexible ureteroscopy in patients with renal stones. The significant correlations observed between these scores and the stone-free rates (87% at 1 month) highlight their effectiveness in assessing surgical outcomes.

Keywords Urolithiasis · Stone scores · fURS · SFR

Introduction

Urolithiasis has become one of the most common health issues, with its incidence steadily rising [1]. Over the years, various treatment options have been developed and utilized for managing renal stones. These include open surgery, percutaneous nephrolithotomy (PNL), retrograde intrarenal surgery (RIRS), and shock wave lithotripsy (SWL). Each method has its own indications, advantages, and limitations, making it crucial for clinicians to choose the most appropriate approach based on individual patient needs and stone characteristics [2].

Recent advancements in high-resolution cameras and auxiliary instruments have positioned flexible ureterorenoscopy (fURS) as a promising treatment option for renal stones. Its effectiveness and versatility have led to increased popularity among urologists, making it a significant choice in the management of urolithiasis. fURS allows for access to stones in various locations within the renal system, often resulting in improved outcomes and reduced recovery times compared to traditional methods [3–5].

Retrograde intrarenal surgery (RIRS) has been recommended for treating renal stones smaller than 2 cm. However, with accumulated experience among surgeons and improved preoperative assessments, urologists have increasingly utilized RIRS for larger stones. This shift has been

✉ Kareem Noah
kareem.noah@uhcw.nhs.uk

1 Urology Department, University Hospital Coventry and Warwickshire, Coventry, England

2 Urology Department, Banha University, Banha, Egypt

3 Radiology Department, Banha University, Banha, Egypt

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facilitated by enhanced surgical techniques, leading to surprisingly positive outcomes. As a result, RIRS is now recognized as a viable option for a broader range of stone sizes, expanding its role in the management of urolithiasis and potentially offering patients effective treatment with fewer complications [6].

To predict postoperative outcomes, success rates, and the likelihood of complications following various treatment options for urinary system stones, several scoring systems have been developed. These systems take into account factors such as stone size, location, patient demographics, and comorbidities. By providing a structured approach to risk assessment, these scoring systems help clinicians make informed decisions about the most appropriate treatment modality [7–10].

Many scoring systems like the Resorlu-Unsal [11], STONE [12], S-ReSC [13], and RIRS [14] were specifically tailored to assess the likelihood of success in flexible ureterorenoscopy (fURS). These tools evaluate factors such as stone characteristics and patient-specific variables, helping clinicians choose the most appropriate treatment options.

The primary goal of developing and adopting various scoring systems is to effectively select the most appropriate surgical method during preoperative consultations. These systems provide a predictive framework for understanding potential success rates and the likelihood of complications, enabling clinicians to make informed decisions and set realistic expectations for patients [15, 16].

In this study, we aim to evaluate the predictive value of three different scoring systems—STONE, TOHO, and ITO—for stone-free rate (SFR) outcomes following retrograde intrarenal surgery (RIRS). By comparing these scoring systems, we seek to identify which may provide the most accurate predictions of success in managing upper tract urinary stones.

Patients and methods

This prospective study involved 300 patients with renal stones treated at the Urology Department of Benha University Hospital between January 2023 to June 2024, all managed with flexible ureteroscopy (fURS). Eligible participants had renal calculi up to 2.5 cm. Exclusions included patients with advanced medullary calcinosis (complicating stone-free rate assessment), those who underwent secondary fURS during percutaneous nephrolithotomy (PCNL), individuals with stones in calyceal diverticula requiring alternative treatments (like PCNL), and patients with sepsis or significant coagulopathy.

Demographic data of the enrolled patients were collected, including age, sex, and BMI. Stone characteristics assessed included size, location, composition, number, infundibulopelvic angle, and degree of hydronephrosis. Laboratory investigations were conducted to evaluate renal and liver functions, complete blood count, fasting blood sugar, bleeding profile, and urine analysis and culture. Radiological studies included multi-slice spiral CT to measure stone size (using the longest axis) and plain abdominal radiographs of the kidneys, ureters, and bladder (KUB).

Score analysis

All patients were assessed with non-contrast computed tomography (NCCT) study before the procedure and NCCT were revised preoperatively and classified each case using the different three scores (Tables 1, 2, 3).

In contrast to the other three scores, a high total score is predictive of a successful fURS outcome.

Operative technique

All retrograde intrarenal surgeries (RIRS) were conducted under spinal anesthesia with the patient in a lithotomy position. The procedure commenced with ureteral dilation to 12–14 Fr, after which an 11/13 Fr ureteral access sheath (Cook Medical, Bloomington, IN, USA) was inserted over

Table 1 STONE score settings

Parameter	1	2	3
Size	< 5 mm	5–10 mm	More than 10 mm
Topography	Distal ureter	Proximal ureter Renal (except lower calyx)	Lower calyx
Obstruction	No obstruction or preoperative Stenting	Minimal or moderate obstruction	Major obstruction
Number	One	Two	Three or more
Density	< 750 HU	750–1000 HU	More than 1000 HU

Scores range from 5 to 15 points

Table 2 TOHO score sittings

Parameters	1	2	3
Renal stone density (HU)	≤ 1000	> 1000	
Inferior pole stone	Non-inferior	Inferior with RIPA > 30°	Inferior with RIPA ≤ 30°
RIL (mm)	≤ 25	> 25	
Stone burden (mm)	≤ 10	> 10 and ≤ 20	> 20

Scores range from 4 to 10 points

Table 3 ITO score settings

Stone volume	< 5 mm (13 pts)	5 mm to 1 cm (8 pts)	1–2 cm (5 pts)	More than 2 cm (0 pts)
No lower pole stones	Yes (5 pts)			
Operator experience more than 50 cases	Yes (3 pts)			
Absence of hydronephrosis	Yes (2 pts)			
Number of stones	Solitary (2 pts)			

Scores range from 0 to 25

a guidewire using fluoroscopy. Whenever feasible, a safety guidewire was left outside the access sheath. The flexible ureteroscope utilized in this study was the LithoVue™ System (Boston Scientific, 9.5 Fr). Stones were dusted using a holmium: YAG laser set to 0.5 J energy, 15–20 Hz frequency, and a long pulse duration of 800 ms. Any larger fragments were retrieved with a zero tip nitinol basket catheter. At the conclusion of the procedure, a JJ stent was placed. The operative time was defined as the duration from the introduction of instruments through the urethra to the insertion of the JJ stent.

Table 4 Patient characteristics of the studied patients

	N = 300
Age (years)	
Mean ± SD	40.7 ± 14.87
Range	17–72
Sex	
Male	183 (61%)
Female	117 (39%)
BMI (kg/m^2)	
Mean ± SD	27 ± 3.85
Range	20–34

Postoperative follow-up

The urethral catheter was removed, and patients were discharged on the same day postoperatively whenever possible, provided there were no complications requiring extended admission. Patients were given oral antibiotics (co-amoxiclav 625 mg, TDS for 7 days) upon discharge. A non-contrast CT scan was performed 1 month later, prior to the removal of the JJ stent, to assess the complete stone-free rate (SFR).

Statistical analysis

Data obtained were collected and tabulated in an excel spreadsheet. Data were analyzed using Statistical Package of Social Science for Windows (SPSS, Chicago, IL) version 20. Descriptive data were presented in terms of number, percentages, medians, and average.

Categorical variables were compared using Fisher's exact test to compare the incidence of complications among both groups, while continuous variables were compared by Mann–Whitney *U*-test and Kruskal–Wallis test or student (*t*) test and ANOVA test, whenever appropriate, with significance detected at two tailed *P* value < 0.05. Multivariate logistic regression was used for correction of possible confounders.

Results

This study included 300 patients with upper tract stones. The age of the participants ranged from 17 to 72 years, with a mean age of 40.7 (± 14.87) years. Among the patients, 183 (61%) were male and 117 (39%) were female. The body mass index (BMI) varied from 20 to 34 kg/m^2, with a mean value of 27 (± 3.85) kg/m^2 (Table 4).

Regarding the presentations of the enrolled patients and the characteristics of their stones, loin pain duration ranged from 0.05 to 72 months, with a mean of 5.33

Table 5 Loin pain and stone characteristics of the studied patients

	N = 300
Loin pain (months)	
Mean ± SD	5.3 ± 10.43
Range	0.05–72
Stones size (mm)	
Mean ± SD	14.4 ± 5.1
Range	8–25
Stone density (H.U)	
Mean ± SD	1200.6 ± 430.42
Range	333–1899
Stone number	
One	264 (88%)
Two	30 (10%)
Three	6 (2%)

Table 6 STONE, TOHO, and ITO scores of the studied groups

	N = 300
STONE score	
Median	9
IQR	8–10
TOHO score	
Median	7
IQR	6–8
ITO score	
Median	12
IQR	11–14

TOHO Tallness, Occupied lesion, Hounsfield unit evaluation

(± 10.43) months. Stone size varied from 8 to 25 mm, with a mean size of 14.4 (± 5.1) mm. Stone density ranged from 333 to 1899 H.U., with a mean density of 1200.57 (± 430.42) H.U. In terms of stone number, 264 (88%) patients had one stone, 30 (10%) had two stones, and 6 (2%) had three stones (Table 5).

As regard studied stone scores in this study, the median (IQR) of STONE score was 9 (8–10). The median (IQR) of TOHO score was 7 (6–8). The median (IQR) of ITO score was 12 (11–14) (Table 6).

SFR after 1 month was free in 261 (87%) patients. Colic occurred in 57 (19%) patients. Fever occurred in 66 (22%) patients. Hematuria occurred in 30 (10%) patients (Tables 7, 8).

There were significantly negative correlations between SFR and (STONE and TOHO) (*P* value < 0.05). There were significantly positive correlations between SFR and ITO score (*P* value <0.05) (Table 8) (Figs.1, 2, 3).

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Table 7 SFR after 1 M, post-fURS complications of the studied patients

	n = 300
SFR after 1 M	
Free	261 (87%)
No	39 (13%)
Post-fURS complications	
No	147 (49%)
Colic	57 (19%)
Fever	66 (22%)
Hematuria	30 (10%)

SFR stone-free rate

Table 8 Correlation between SFR after 1 month (STONE, TOHO, and ITO scores) of the studied groups

	SFR
STONE score	
r	− 0.359
P value	**< 0.001***
TOHO score	
r	− 0.479
P value	**< 0.001***
ITO score	
r	0.298
P value	**< 0.001***

SFR stone-free rate

*Significant as *P* value ≤ 0.05

STONE score can significantly predict stone-free rate (*P* < 0.001 and AUC = 0.805) at cut-off > 9 with 79.49% sensitivity, 67.05% specificity, 26.5% PPV, and 95.6% NPV (Fig. 4; Table 9).

TOHO score can significantly predict stone-free rate (*P* < 0.001 and AUC = 0.903) at cut-off > 7 with 92.31% sensitivity, 74.71% specificity, 35.3% PPV, and 98.5% NPV (Fig. 5; Table 10).

ITO score can significantly predict SFR after fURS (*P* < 0.001 and AUC = 0.856) at cut-off > 10 with 91.19% sensitivity, 71.79% specificity, 95.6% PPV, and 54.9% NPV (Fig. 6; Table 11).

In this multivariate analysis, the TOHO score**,** ITO score**,** and STONE score all emerged as significant independent predictors of stone-free rate (SFR) following fURS. A TOHO score > 7 significantly reduced the odds of SFR by 65% (OR = 0.35, *P* < 0.001), underscoring the negative impact of unfavorable ureteral anatomy on outcomes. Conversely, an ITO score > 10 nearly tripled the likelihood of SFR (OR = 2.80, *P* < 0.001), highlighting the importance of favorable infundibulopelvic anatomy. While the STONE score (> 9) remained significant (OR = 0.42, *P* = 0.001), its effect weakened when adjusted for TOHO and ITO scores,

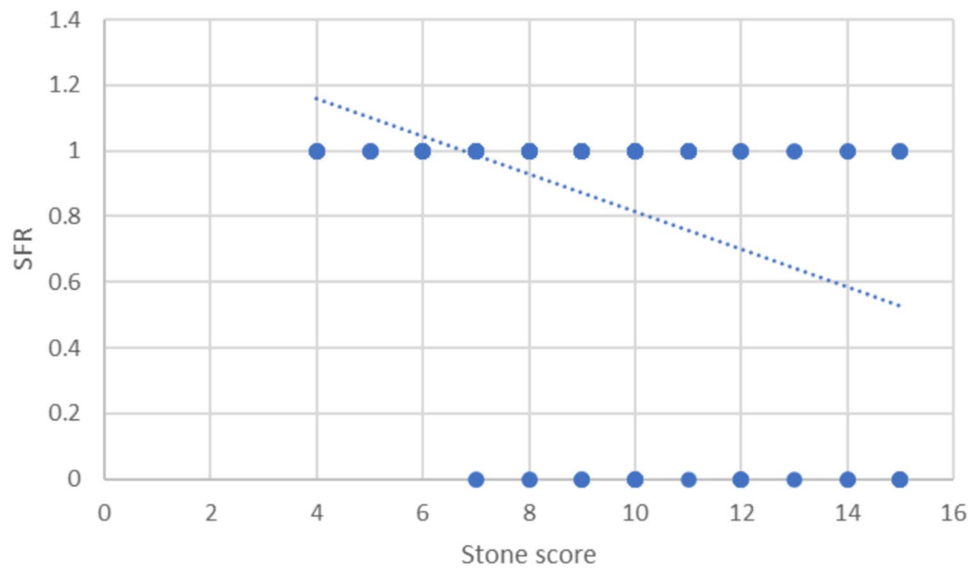

Fig. 1 Correlation between SFR after 1 M and STONE score of the studied groups

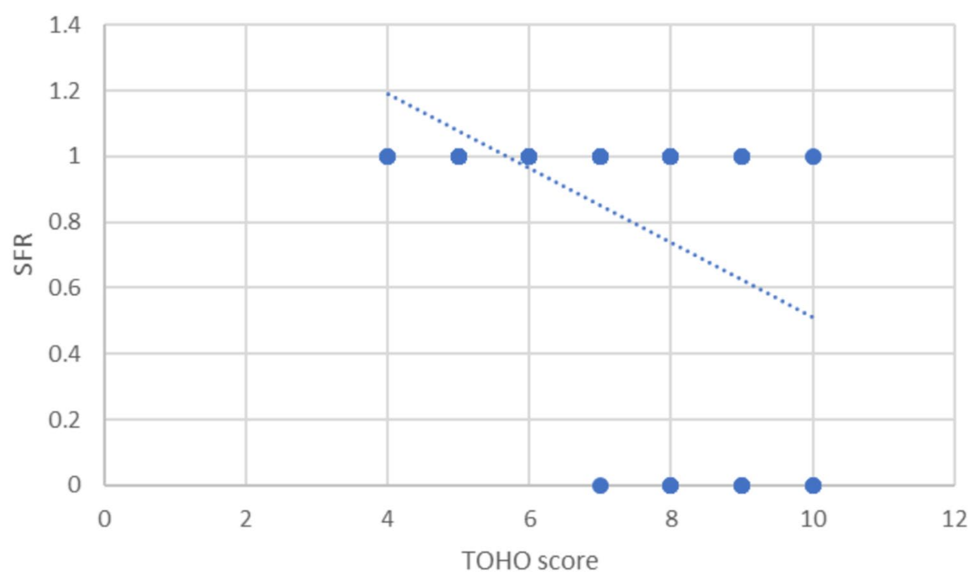

Fig. 2 Correlation between SFR after 1 M and TOHO score of the studied groups

suggesting it partially overlaps with these anatomic factors. Other variables stone size, density, multiplicity, BMI, and loin pain duration did not independently predict SFR, likely because their influence is mediated through the scoring systems or they lack direct clinical relevance. These findings support the combined use of STONE score, TOHO score, and ITO score for optimal preoperative risk stratification (Table 12).

Discussion

Retrograde intrarenal surgery (RIRS) has emerged as one of the most widely used techniques for treating renal and upper ureteric stones, due to its highly favorable outcomes [17, 18]. Additionally, RIRS minimizes the significant complications often associated with alternative procedures. It can be safely performed on a broader spectrum of patients, including those on anticoagulant therapy. In contrast, other methods such as percutaneous nephrolithotomy (PCNL) and extracorporeal shock wave lithotripsy (ESWL) frequently encounter substantial limitations in these patients [17–19].

Stone scores were developed to predict both outcomes and complications following surgical procedures. These scoring systems, which have been in use for years, have proven effective in the preoperative assessment of patients and in forecasting stone-free rates (SFR) after surgery [20].

Various scoring systems have been implemented to predict outcomes after retrograde intrarenal surgery (RIRS),

Fig. 3 Correlation between SFR after 1 M and ITO score of the studied groups

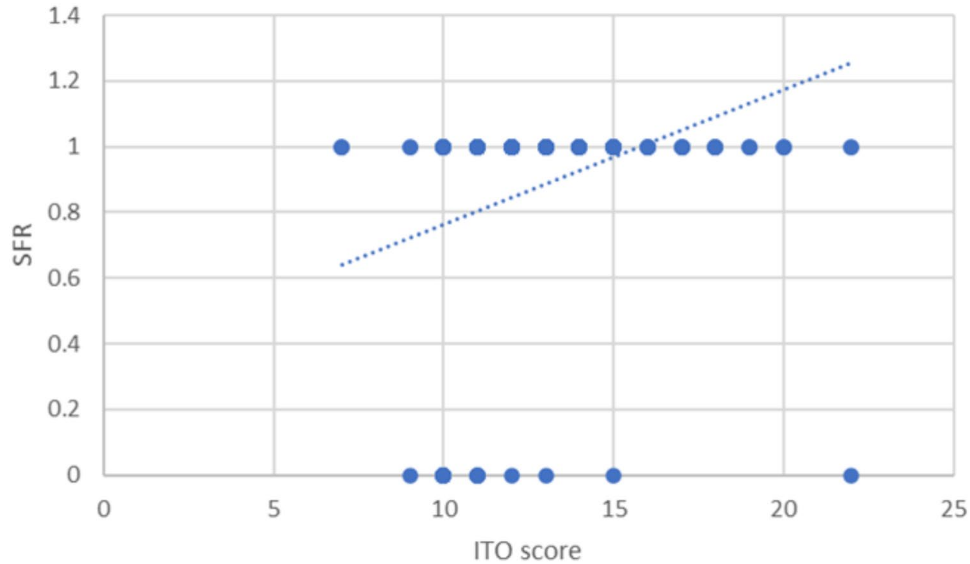

Table 9 Role of STONE score in prediction of stone-free rate

Cut-off	Sensitivity	Specificity	PPV	NPV	AUC	*P* value
> 9	79.49%	67.05%	26.5%	95.6%	0.805	< **0.001***

PPV positive predictive value, *NPV* negative predictive value, *AUC* area under the curve

*Significant as *P* value ≤ 0.05

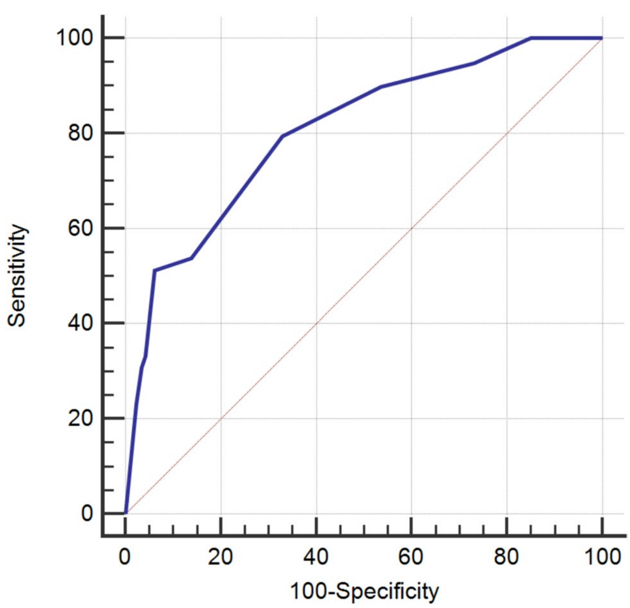

Fig. 4 ROC curve of STONE score in prediction of stone-free rate

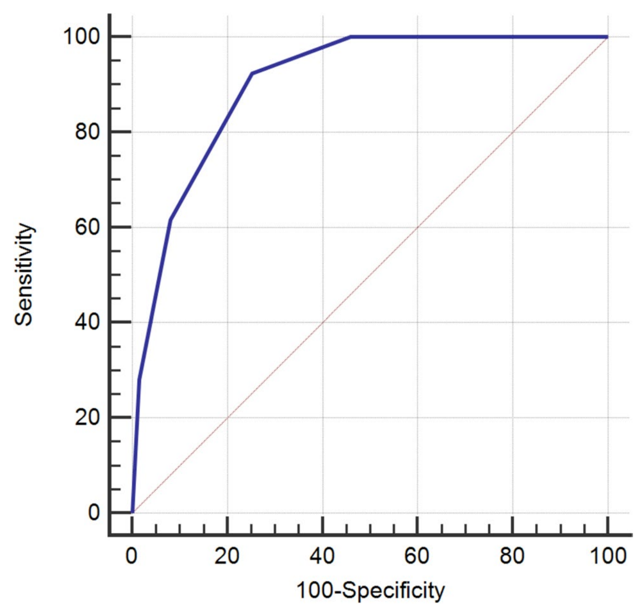

Fig. 5 ROC curve of TOHO score in prediction of stone-free rate

including the STONE score [11], S-ReSC [12], RIRS score [13], and a specific nomogram [14].

While many previous studies have compared various stone scores for renal or ureteric stones, to our knowledge, no prior research has specifically compared the three scores examined in this study for upper tract stones.

This study was a prospective study and it concluded 300 patients with upper tract stones, the age of the enrolled patient ranged from 17 to 72 years with a mean value (± SD) of 40.7

Table 10 Role of TOHO score in prediction of stone-free rate

Cut-off	Sensitivity	Specificity	PPV	NPV	AUC	*P* value
> 7	92.31%	74.71%	35.3%	98.5%	0.903	< **0.001***

PPV positive predictive value, *NPV* negative predictive value, *AUC* area under the curve

*Significant as *P* value ≤ 0.05

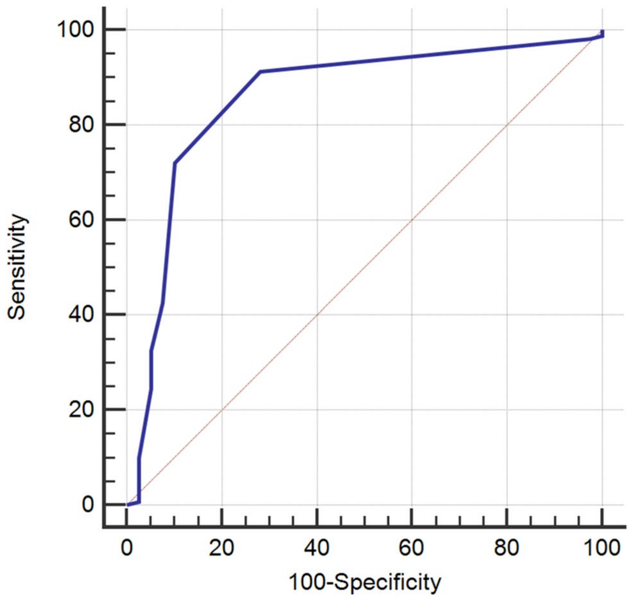

Fig. 6 ROC curve of ITO score in prediction of stone-free rate

Table 12 Multivariate logistic regression for SFR (1 month post-fURS)

Variable	Odds ratio (OR)	95% CI	*P*-value
STONE score (> 9 vs. ≤ 9)	0.42	0.25–0.70	0.001
TOHO score (> 7 vs. ≤ 7)	0.35	0.20–0.61	< 0.001
ITO score (> 10 vs. ≤ 10)	2.80	1.65–4.75	< 0.001
Stone size (per 1 mm)	0.97	0.91–1.03	0.32
Stone density (per 100 HU)	0.98	0.94–1.03	0.45
Multiple stones (vs. single)	0.90	0.50–1.65	0.74
BMI (per 1 kg/m^2)	1.02	0.95–1.10	0.55
Loin pain duration (per month)	1.01	0.98–1.04	0.50

(± 14.87) years. The stone size ranged from 8 to 25 mm with a mean value (± SD) of 14.4 (± 5.1) mm. The stone density ranged from 333 to 1899 H.U with a mean value (± SD) of 1200.57 (± 430.42) H.U, while stone number was one in 264 (88%) patients, two in 30 (10%) patients, and three in 6 (2%) patients.

This study results revealed significant negative correlations between SFR and (S T O N E, TOHO scores) (*P* value < 0.05); however, there were significantly positive correlations between SFR and ITO scores (*P* value < 0.05). SFR after 1 month was (87%). In terms of postoperative complications colic occurred in 57 (19%) patients, fever occurred in 66 (22%) patients, and hematuria occurred in 30 (10%) patients.

According to the study results, the three studied scores could effectively predict the outcomes of flexible ureteroscopy with AUC of STONE, TOHO, and Ito score were 0.805, 0.903, and 0.856, respectively.

The results of this study are consistent with those of a 2021 study by Salih Polat et al., which assessed and compared the TOHO and STONE scores while also modifying the TOHO score to include stone volume as a variable. This study included 621 patients who underwent flexible ureteroscopy (fURS) for renal or ureteric stones between 2017 and 2020, reporting a stone-free rate (SFR) of 79.8%. The area under the curve (AUC) values were 0.758 for the TOHO score, 0.634 for the STONE score, and 0.821 for the modified TOHO score. These findings suggest that the evaluated stone scores effectively predict outcomes after RIRS and that incorporating stone volume into the TOHO score enhances its predictive accuracy [21].

In a 2020 study by Richard et al., various scoring systems were compared to predict stone-free status following flexible ureteroscopy. The scores evaluated included the STONE score, RUSS score, S-ReSC score, and Ito score. This study involved 800 fURS procedures conducted between 2009 and 2016, yielding a stone-free rate (SFR) of 74.1%. The area under the curve (AUC) values were 0.617 for the STONE score, 0.644 for the RUSS score, 0.651 for the S-ReSC score, and 0.735 for the Ito score. The findings aligned with those of the current study, indicating that all assessed scores effectively predict

Table 11 Role of ITO score in prediction of stone-free rate

Cut-off	Sensitivity	Specificity	PPV	NPV	AUC	*P* value
> 10	91.19%	71.79%	95.6%	54.9%	0.856	< **0.001***

PPV positive predictive value, *NPV* negative predictive value, *AUC* area under the curve

*Significant as *P* value ≤ 0.05

SFR after fURS, with the Ito score demonstrating the highest sensitivity among the four [22].

The results of this study align with those of a multicenter study by Ibrahim Halil Bozkurt et al. published in 2020. This study included 949 patients with renal stones recruited between 2015 and 2020, who were evaluated preoperatively using four different stone scores—RUSS, modified S-ReSC, ITO, and RIRS—to predict outcomes and complications after RIRS. The findings indicated that all the scoring systems successfully predicted stone-free status, with area under the curve (AUC) values of 0.689 for RUSS, 0.657 for modified S-ReSC, 0.303 for Ito, and 0.690 for RIRS [23].

In a trial conducted by Jasser et al. to assess the STONE score's ability to predict outcomes following flexible ureteroscopy, 92 patients with renal stones were evaluated preoperatively using this score, which considers five parameters: size, topography, obstruction, number, and density of the stones. The results of their study were comparable to those of the current research, demonstrating that the STONE score effectively predicts outcomes after flexible ureteroscopy, with an area under the curve (AUC) of 0.731 and a stone-free rate (SFR) of 81% [24].

Although the RIRS stone score is not included in the current study, its reliability has been evaluated in several research efforts. This score primarily assesses renal anatomy, focusing on factors such as the renal infundibulopelvic angle, infundibular length, presence of lower pole stones, kidney stone density, and overall stone burden. In a study by Cong Wang et al. published in 2021, 147 patients were enrolled between 2018 and 2019 and evaluated using the RIRS stone score prior to their flexible ureteroscopy procedures. The study found that stone-free status was achieved in 105 patients (71.43%), with an area under the curve (AUC) of 0.737 [6].

This study has several limitations that should be acknowledged. First, it was conducted at a single tertiary referral center, which may limit the generalizability of the findings due to institutional variations in surgical practice and patient demographics. While this allowed for consistency in surgical technique and data collection, a multicenter study would enhance external validity. Second, the follow-up period was limited to 1 month postoperatively, which, although useful for assessing early clinical success, may not fully capture the risk of residual fragments or stone recurrence. Longer-term follow-up of 6–12 months would provide a more robust evaluation of treatment durability. Third, although efforts were made to standardize the surgical technique such as the type of ureteroscopy, use of access sheath, laser dusting settings, and postoperative stenting minor variations inherent to real-world clinical practice may still influence outcomes. Fourth, stone composition, a known factor affecting fragmentation and clearance, was not routinely analyzed due to logistical challenges and limited sample retrieval in cases of spontaneous passage or fine dusting. This limits our ability to assess the impact of stone type on surgical outcomes. Finally, although three validated scoring systems (STONE, TOHO, and ITO) were used to predict stone-free status, the RIRS score was not included. This was to avoid redundancy with overlapping parameters and because some components of the RIRS score require advanced imaging and may be subject to interobserver variability. However, its potential value is recognized, and future multicenter studies will consider including it for broader comparison and validation.

Conclusion

This study demonstrated that the STONE, TOHO, and Ito scoring systems are effective tools for predicting stone-free rates after flexible ureteroscopy in patients with renal stones. The significant correlations found between these scores and the stone-free rates (87% at 1 month) demonstrate their utility in evaluating surgical outcomes. The predictive accuracy of the scoring systems with AUC values is 0.805 for STONE, 0.903 for TOHO, and 0.856 for ITO stone score. These results indicate that these scoring systems can be valuable in guiding patient management and surgical decision-making.

Author contributions K.N, M.H, M.F collected data, prepared tables and wrote the manuscript H.S, T.D shared in operative aspects all authors revised the manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

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