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External validation of the T.O.HO. score and derivation of the modified T.O.HO. score for predicting stone-free status after flexible ureteroscopy in ureteral and renal stones

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Abstract

Objective: The T.O.HO. scoring system was developed to predict stone-free status after flexible ureterenoscopy (fURS) lithotripsy applied for ureter and renal stones. This study aimed to perform the external validation of the T.O.HO. score in the Turkish population and propose a modification for this system.

Material methods: Patients who underwent fURS for kidney and ureteral stones between January 2017 and January 2020 were retrospectively analysed. The patient and stone characteristics and perioperative findings were noted. The T.O.HO. score was externally validated and compared with the STONE score. Stone-free parameters were evaluated with the multivariate analysis. Based on the results of this analysis, the T.O.HO. score was modified and internally validated.

Results: A total of 621 patients were included in the study. The stone-free rate was determined as 79.8% (496/621) after fURS. The regression analysis showed that stone area had better predictive power than stone diameter ($P = .025$). Lower pole (reference), middle pole [odds ratio (OR) = 0.492 $P = .016$] and middle ureteral (OR = 0.227, $P = .024$) localisations, stone density (OR = 1.001, $P < .001$), and stone volume (OR = 1.008, $P < .001$) were determined as independent predictive markers for stone-free status. Based on the effect size of the stone surface area in the nomogram, stone volume was divided into five categories, at 1-point intervals. The AUC values of the T.O.HO., STONE, and modified T.O.HO. score in predicting stone-free status were calculated as 0.758, 0.634, and 0.821, respectively. The modified T.O.HO. created by adding stone volume was statistically significantly superior to the original version (ROC curve comparison, $P < .001$).

Conclusion: The T.O.HO. score effectively predicted stone-free status after fURS. However, modified T.O.HO. SS showed the best predictive performance compared with original T.O.HO. SS.

1 | INTRODUCTION

Urinary system stone treatment management varies according to the characteristics of the stone and patient preference and physician experience. Treatment options include medical therapy, extracorporeal shock wave treatment (ESWL), percutaneous nephrolithotomy (PCNL), and ureterorenoscopy (URS).[1] In addition to PCNL being recommended for stones of >2 cm in size, with the recent developments in the device and laser technologies and increase in surgeon experience, flexible URS (fURS) is also reported to result in satisfactory stone-free rates (SFRs) in these stones.[2,3] Xu et al reported that effective treatment could be applied even in stones with a cumulative burden of >4 cm.[4] The usage area and popularity of fURS is increasing day by day.[5] With the widespread use of fURS in large renal stones, the choice of treatment will become more and more difficult.

Many scoring systems have been developed to predict the success of ESWL, URS, and PCNL in urinary system stones.[6-9] It has been proven that stone-free status (SFS) and development of complications can be effectively predicted with scoring systems, especially in PCNL.[10] In the literature, several scoring systems, including Resorlu-Unsal,[11] STONE,[12] S-ReSC,[13] and RIRS[14] and one nomogram[15] have been defined to predict the success of fURS. Among these scoring systems, only STONE score is used for kidney and ureter stones. The STONE scoring system consists of the parameters of (S)ize, (T)opography (stone localisation), (O)bstruction, (N)umber of stones, and (E)valuation of stone density (Hounsfield unit, HU). Although the developing authors reported high predictive values for this system, their patient data belong to 2006-2012.[12] Considering that the STONE scoring system would not preserve its predictive value in the face of developing technology, Hori et al developed a practical scoring system comprising the (T)allness, (O)ccupied lesion, (HO)unsfield unit components and named it T.O.HO.[16] In the current study, we aimed to evaluate factors associated with SFS in patients treated with fURS for ureteral and kidney stones and perform the external validation of the T.O.HO. and STONE score. We also aimed to derive a modified version of the T.O.HO. score and perform the internal validation of this version.

In this study, we aimed to re-evaluate possible factors associated with SFS in patients treated with RIRS for ureteral and kidney stones and to perform external validation of TOHO and STONE score. We also aimed to derive a modified version of the TOHO score and perform internal validation of this version.

What's known

- Scoring systems are used to predict stone-free status after endoscopic stone treatment.
- Resorlu-Unsal, STONE, S-ReSC, and RIRS and Ito's nomogram are the most well-known scoring systems developed only for renal stones.
- However, f-URS is also used in the treatment of ureteral stones.
- The T.O.HO scoring system that can be used in both ureteral and renal stones was developed from a data set that includes patients with new devices.

What's new

- The T.O.HO. score has been validated on a dataset including patients with large renal stones.
- It has been shown that stone length is not a optimal parameter for evaluating stone burden.
- Modified T.O.HO, in which stone area was used instead of stone length, was more effectively in predict the stone-free status.

2 | MATERIALS AND METHODS

After receiving the ethics board approval of Amasya University (decision no. 2/25/2021), patients that underwent fURS for the treatment of renal and ureteral stones between January 2017 and January 2020 were retrospectively evaluated. Patients that completed ureteral stone treatment with semi-rigid URS, those with ureteral or renal anomalies or calyceal diverticula, and those with unavailable data were excluded from the study.

All operations were started by entering the ureter through a guide wire (0.035 inch, Microvasive; Boston Scientific Corp., Natick, MA) with semi-rigid URS. Active dilatation was applied with URS. Ureterorenoscopic lithotripsy was performed using fURS (7.5F; Karl Storz Flex-X2, Tutlingen, Germany and Olympus P-5TM, Olympus, Tokyo, Japan) and 270-350 μm Holmium laser (AMS; Sureflex). Ureteral access sheath (12/14 or 14/16 F, Cook Medical, Bloomington, IN or 11/13 or 13/15 F, Boston Scientific, Natick, MA, USA) was utilised to facilitate the removal of stones and reduce intrarenal pressure in both renal and ureteral stones. All operations were performed by experienced surgeons. In all patients, 1.5 F-2.2 F tipless nitinol baskets were used for removal of residual stones. Preoperative D-J placement was applied in patients with treatment-resistant renal colic, pyelonephritis, and a narrow ureter that could prevent access to stone. A postoperative D-J stent or ureteral catheter was placed according to the surgeon's preference and clinical necessity. If no clinically significant stones were shown by KUB, uretral catheter was removed at POD 1. D-J stent was removed 2 weeks after the procedure.

The presence of residual stones was investigated using non-contrast computed tomography at the first postoperative month (POM1). SFS was defined as no evidence of stone.

As a result of the retrospective examination, the clinical characteristics of the patients [age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) score, stone side, ESWL history, preoperative stent requirement, and degree of hydronephrosis], stone characteristics (localisation, number, density, and size), and perioperative findings (operation time, length of hospital stay, SFS, and development of complications) were noted.

Complications were graded according to the Clavien-Dindo classification. The degree of hydronephrosis was measured according to the Society For Fetal Urology Hydronephrosis Grading System. Stone length was measured as the longest diameter and stone width as the shortest diameter in the reconstructed coronal section.[17] Stone area was calculated using the formula, length × width × π × 0.25, where π is a mathematical constant equal to 3.14.[18] The mean HU measurement was performed in the longest diameter of the stone with bone window and large magnification. The burden and HU value of multiple stones were calculated as described in the original T.O.HO. study.[16] The T.O.HO. scoring system does not specify how to grade multi-calyceal stones. Therefore, the stone localisation with the highest score was used in the presence of multi-calyceal stones at different localisations.

2.1 | Statistical analysis

Categorical data were presented with number and percentage of rows. Only ESWL, preoperative stent requirement, and complication rates were presented as percentages of column for the convenience of comparison for the reader. Continuous data were evaluated using the Kolmogorov-Smirnov test to verify the normality of distribution of variables. Normally distributed data were expressed with mean + standard deviation (SD), and non-normally distributed data with median and percentile (25-75th) values. The independent-samples *t*-test was used to compare two independent normally distributed data, while the Mann-Whitney *U*-test was conducted for the comparison of data without normal distribution. In the comparison of categorical variables, Pearson's or Yate's chi-square test was used as appropriate. The relationship of stone size and stone surface area with SFS was evaluated with the multivariate logistic regression analysis, and stone surface area was determined as an independent predictive factor [odds ratio (OR) = 1.004, P = .025] (Table 1). Therefore, the measurement of surface area, which is used in both computed tomography and kidney, ureter, bladder radiography in clinical practice, was undertaken to predict stone volume. Possible predictive variables associated with SFS were evaluated with the multivariate logistic regression analysis, and the Backward elimination (Wald) method was used to construct a model. The exclusion criterion for the model was set at $P < .1$. A new nomogram including stone surface area was created using the regression coefficients of independent predictive variables. The predictive ability of the nomogram was evaluated with the receiver operating characteristic (ROC) analysis. Then, the T.O.HO., STONE and modified T.O.HO. scores were calculated for each patient. The ability of the scores to predict SFS was analysed using the ROC analysis, and sensitivity and specificity values were calculated by determining the cut-off value for each scoring. A P value of .05 was considered statistically significant. SPSS software (version 23.0; IBM Corporation, Armonk, NY, USA) was used for statistical analyses and the R-project statistical software and “rms” package for the construction of the nomogram.

3 | RESULTS

A total of 621 patients were included in the study. The patient characteristics are presented in Table 1. The median age of the patients was 46 (36-56) years, and their median BMI was 26.0 (24.0-28.6) kg/m^2. Of the patients, 30.8% had a history of ESWL and 21.7% required preoperative stents. Stones were located in the pelvis in 35.9% of the patients, lower calyx in 17.9%, and multi-calyceal in 13.0%. In addition, 68 (11.0%) patients had proximal stones and 38 (6.1%) patients had stones in the middle ureter. According to the localisation classification of the T.O.HO. scoring system, 46.2% of the stones were located in the middle pole and 31.2% in the lower pole, while 17.6% of the patients had multiple stones. The median stone size was 16 (12-22.5) mm, and the median stone area was 126 (77-204) mm^2. Total SFR was 79.9%. Complications rate was 10.6% and the majority of complications were grade I-II (n = 58, 9.3%).

Table 1 presents the comparison of patient and stone characteristics according to SFS. SFR was higher in patients with higher BMI (P = .018). There was statistically significant difference in SFS according to stone localisation ($P < .001$). In the post-hoc analysis, the multi-calyceal stones had significantly lower SFR compared with the pelvic and proximal ureteral stones, while the lower calyceal stones had significantly lower SFR compared with only proximal ureter stones. According to the localisation classification of T.O.HO., the lower pole stones had lower SFR compared with the stones located in the middle pole and ureter. Multiple stone number, high HU value, high stone size and stone area, and prolonged operation time and length of hospital stay were determined to be associated with fURS failure. The median T.O.HO., STONE and modified T.O.HO. scores were determined as 8, 11 and 8, respectively for the failure group and 7, 10 and 6, respectively, for the patients with SFS ($P < .001$ for all).

Table 2 shows the multivariate logistic regression analysis results of possible predictive factors associated with SFS given in Table 1. According to the results, stone area had better predictive power than stone diameter (P = .025). Lower pole (reference), middle pole (OR = 0.492 P = .016) and middle ureteral (OR = 0.227, P = .024) localisations, stone density (OR = 1.001, $P < .001$), and stone volume (OR = 1.008, $P < .001$) were determined as independent predictive markers for SFS. A nomogram was constructed to predict fURS failure (Figure 1). Based on the effect size of stone surface area in the nomogram, stone volume was divided into five categories, at 1-point intervals, as <120 mm^2, 120-240 mm^2, 240-360 mm^2, 360-480 mm^2 and >480 mm^2. The newly created scoring system was defined as modified T.O.HO. (Figure 1). The nomogram was found to have high predictive power, with an area under the curve (AUC) value of 0.838 (Figure 2).

The T.O.HO., STONE and modified T.O.HO. scores were calculated for each patient included in our dataset. The external validation of the original T.O.HO. and STONE systems and the internal validation of the modified T.O.HO. system were undertaken. The AUC value was calculated as 0.758 for original T.O.HO., 0.634 for STONE, and 0.821 for modified T.O.HO. at the asymptotic significance of

TABLE 1 Comparison of patient characteristics according to post-operative stone-free status

Variables	Total (n = 621)	Not stone-free (n = 125)	Stone-free (n = 496)	*P value*
Age, years	46 (36-56)	44 (32.5-56)	46 (36-56)	.174
Gender, n (%)				.229*
Female	215 (34.6)	49(22.8)	166 (77.2)	
Male	406 (65.4)	76 (18.7)	330 (81.3)	
BMI, kg/m^2	26.0 (24.0-28.6)	25.5 (23.5-27.5)	26.3 (24.2-29)	**.018**
Side				.517*
Left	334 (53.8)	64 (19.2)	270 (80.8)	
Right	287 (46.2)	61 (21.3)	226 (78.7)	
ASA category, n (%)				.311*
ASA I	266 (42.8)	46 (17.3)	220 (82.7)	
ASA II	318 (51.2)	71 (22.3)	247 (77.7)	
ASA ≥ III	37 (6.0)	8 (21.6)	29 (78.4)	
Previous history of ESWL, n (%)	191 (30.8)	34 (27.2)	157 (31.7)	.335*
Preoperative stent, n (%)	135 (21.7)	33 (26.4)	102 (20.6)	.102*
Preoperative hydronephrosis, n(%)				.222*
Grade 0	126 (20.3)	27 (21.4)	199 (78.6)	
Grade 1-2	362 (58.3)	65 (18.0)	297 (82.0)	
Grade 3-4	133 (21.4)	33 (24.8)	100 (75.2)	
Stone location, n (%)†				**.001***
Lower pole	111 (17.9)	32 (28.8)[a,b]	79 (71.2)[a,b]	
Middle pole	58 (9.3)	11 (19.0)[a,b,c,d]	47 (81.0)[a,b,c,d]	
Upper pole	20 (3.2)	4 (20.0)[a,b,c,d]	16 (80.0)[a,b,c,d]	
Pelvis	223 (35.9)	27 (12.1)[b,d]	196 (87.9)[b,d]	
Middle ureter	38 (6.1)	4 (10.5)[a,b,c,d]	34 (89.5)[a,b,c,d]	
Proximal ureter	68 (11.0)	6 (8.8)[c,d]	62 (91.2)[c,d]	
Multi-calyceal	81 (13.0)	27 (33.3)[a]	54 (66.7)[a]	
Ureter + kidney	22 (3.5)	6 (27.3)[a,b,c,d]	16 (72.7)[a,b,c,d]	
Stone location by T.O.HO., n (%)†				**<.001***
Lower pole	194 (31.2)	58 (29.9)[a]	136 (70.1)[a]	
Middle pole	287 (46.2)	51 (17.8)[b]	236 (82.2)[b]	
Upper pole	34 (5.5)	6 (17.6)[a,b]	28 (82.4)[a,b]	
Proximal ureter (U1)	68 (11.0)	6 (8.8)[b]	62 (91.2)[b]	
Middle ureter (U2)	38 (6.1)	4 (10.5)[b]	34 (89.5)[b]	
Stone number				**<.001***
Single	512 (82.4)	88 (17.2)	424 (82.8)	
Multiple	109 (17.6)	37 (33.9)	72 (66.1)	
Stone density, HU	897 (592-1230)	1050 (665-1313)	851 (572.5-1200)	**.006**
Stone length, mm	16 (12-22.5)	25 (15.5-32)	15 (12-20)	**<.001**
Stone area, mm^2	126 (77-204)	342 (141-573)	110 (66-175)	**<.001**
Operation time, min	75 (60-99)	100 (80.5-120)	70 (60-90)	**<.001**
Length of hospital stay, days	1 (1-2)	2 (1-3)	1 (1-2)	**<.001**
Complication rates, n(%)	66 (10.6)	21 (16.8)	45 (9.1)	**<.019****
Complication grades, n(%)				**.038***
Grade 1-2	58 (9.3)	19 (15.2)	39 (7.9)	
Grade 3-4	8 (1.3)	2 (1.6)	6 (1.2)	

(Continues)

TABLE 1 (Continued)

Variables	Total (n = 621)	Not stone-free (n = 125)	Stone-free (n = 496)	*P value*
T.O.HO. score	7 (6-8)	8 (7-9.5)	7 (6-8)	**<.001**
STONE score	10 (9-11)	11 (10-12)	10 (9-11)	**<.001**
Modified T.O.HO. score	6 (5-7)	8 (7-9)	6 (5-7)	**<.001**

Abbreviations: BMI, body mass index; ESWL, extracorporeal shock wave lithotripsy.

*Pearson's chi-square test.; **Yate's chi-square test.

†No significant difference between the same superscripts.

Bold font indicates statistical significance *P* < 0.05.

TABLE 2 Multivariate logistic regression analysis of independent predictors of post-operative stone-free status

	Multivariate		Reduced (Backward)	
Variables	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Stone-free status				
Stone length	1.046 (0.979-1.117)	.182		
Stone area	1.004 (1.000-1.007)	**.025**		
Stone-free status				
BMI	0.965 (0.905-1.029)	.281		
Stone location				
Lower pole	Ref.		Ref.	
Middle pole	0.492 (0.276-0.878)	**.016**	0.496 (0.290-0.849)	**.011**
Upper pole	0.512 (0.167-1.568)	.241	0.550 (0.181-1.665)	.290
Proximal ureter (U1)	0.399 (0.150-1.063)	.066	0.409 (0.157-1.061)	.066
Middle ureter (U2)	0.227 (0.062-0.825)	**.024**	0.238 (0.067-0.844)	**.026**
Stone density	1.001 (1.001-1.002)	**<.001**	1.001 (1.001-1.002)	**<.001**
Stone area	1.008 (1.006-1.009)	**<.001**	1.008 (1.006-1.009)	**<.001**
Number of stones				
Single stone	Ref.			
Multiple stones	1.026 (0.543-1.937)	.938		

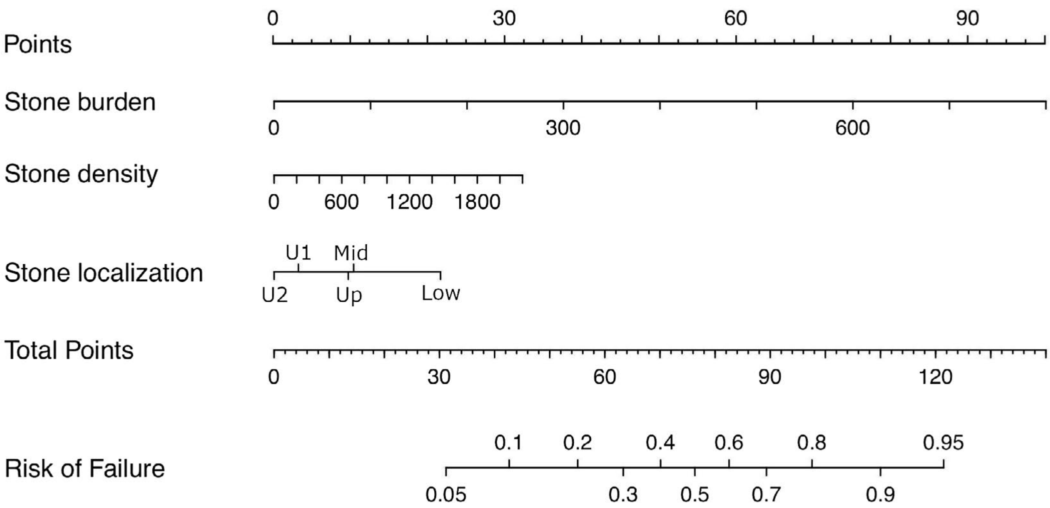
Abbreviation: CI, confidence interval.

Bold font indicates statistical significance *P* < 0.05.

<.001 for each scoring system. The cut-off value and sensitivity-specificity results for each scoring system are shown in Table 3. The modified T.O.HO. created by adding stone volume was statistically significantly superior to the original version (ROC curve comparison, *P* < .001).

4 | DISCUSSION

The current European Association of Urology (EAU) and American Association of Urology (AUA) guidelines recommend PCNL for the treatment of renal stones sized >2 cm.[1] However, because of the potential advantages of fURS (eg not causing renal parenchymal damage and severe bleeding, applicability in patients with bleeding diathesis or those receiving anticoagulant therapy, short length of hospitalisation, and daily work routine not being restricted) and its ability to access almost all calyceal stones as a result of improvements in deflection, fURS has become a preferred method for the treatment of both proximal ureteral and renal stones.[2,20] In a recent meta-analysis, the final SFR was reported to be 89.4% in an average of 1.4 procedures performed in 2-3 cm stones, and this rate was stated to be comparable with PCNL.[21] Although complication rates of up to 16% have been reported in previous studies, most were classified as minor. In addition to the development in fURS technology, increasing surgical experience has reduced the rate of major complication from 5.01% between 1990 and 2011 to 1.48% between 2011 and 2016 and increased the success of treatment.[22] While semi-rigid URS is sufficient in most patients in the treatment of ureteral stones, performing a procedure without fURS in the treatment of middle and upper ureteral stones creates problems in terms of medicolegal aspects. In a study published by the Clinical Research Office of the Endourological Society ureteroscopy study group in 2014, it was reported that middle and proximal stones were both larger and difficult to reach compared with distal stones. In the same study, it was emphasised that the risk of perforation as a result of impaction was high in middle ureteral



	1 pt	2 pts	3 pts	4 pts	5 pts
S(T)one burden, mm^2	<120	120-240	240-360	360-480	>480
(O)ccupied lesion	Ureter	Middle and Upper pole	Lower pole		
(HO)unsfied Units evaluation	<620	620-1100	>1100		

FIGURE 1 New nomogram created by adding stone burden and the modified T.O.HO. scoring system based on the effect size of stone volume on stone-free status

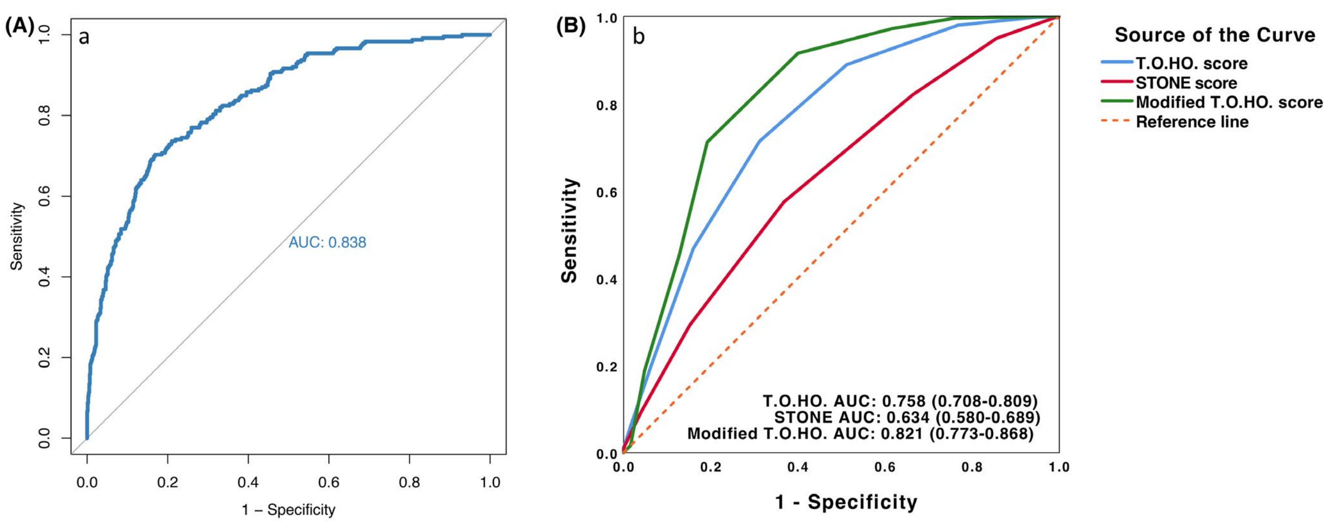


FIGURE 2 (a) ROC curve based on the created nomogram (AUC = 0.838, 95% CI: 0.810-0.867), (b) results of the ROC analysis of the T.O.HO., STONE and modified T.O.HO. scores in predicting treatment failure

stones and low-calibre URS should be used.[23] fURS, which has a wide range of treatment options in terms of both localisation and stone burden and is even preferred in much larger stones to avoid PCNL-related complications, requires further investigation in terms of how to predict its outcomes. Almost all the scoring systems used in fURS have been developed for renal stones, and STONE, which is an option for ureteral stones in which fURS will be performed,[11,12,14,15] is based on low stone burden and use of old devices. Hori et al identified this gap in the literature and defined a scoring system, which they named T.O.HO., including the stone diameter, localisation and density parameters and covering patients with larger stones that are planned to undergo fURS.[16] The

TABLE 3 Cut-off, sensitivity, specificity and AUC values of the T.O.HO., STONE and modified T.O.HO. scoring systems in predicting treatment failure

	Cut-off	Sensitivity (%)	Specificity (%)	AUC (95% CI)
T.O.HO.	8	71.4	68.8	0.758 (0.708-0.809)
STONE	11	57.5	63.2	0.634 (0.580-0.689)
Modified T.O.HO.	7	71.2	80.8	0.821 (0.773-0.868)

Abbreviation: AUC, area under the curve.

authors reported that T.O.HO. had better predictive value than STONE (AUC = 0.833 and 0.633, respectively).

In this study, the external validation of the T.O.HO. and STONE scores was performed, and SFS-related parameters after fURS were evaluated. The overall SFR was found to be 79.9%, and SFR in renal and ureteral stones was 77.6% and 90.5%, respectively. Our SFR was similar to the rate reported in the original study. In addition, in our study, the SFS prediction accuracy (AUC value) was calculated as 0.758 for T.O.HO. and 0.634 for STONE. The cut-off value of T.O.HO. was determined as 8, at which it had 71.4% sensitivity and 68.8% specificity in predicting SFS. STONE was able to predict SFS with 57.5% sensitivity and 63.2% specificity at a cut-off value of 11. When compared with the original T.O.HO. study, the modified T.O.HO. score had lower specificity but similar sensitivity (AUC = 0.758). This difference may be because of the large stone sizes in our study and the lower number of patients with ureteral stones compared with the original TOHO study. The modified T.O.HO. scoring system was observed to have better predictive value than the original version (AUC = 0.821 and 0.758, respectively). At a cut-off value of 7, the modified T.O.HO. scoring system was able to predict SFS with 71.2% sensitivity and 80.8% specificity.

Many studies in the literature have shown that stone burden is the most important parameter affecting SFS after fURS.[11,12,14,15] In the T.O.HO. scoring system, stone burden was reported to be the most important predictive value.[16] We also determined that stone burden was associated with SFS ($P < .001$). The effect size of stone burden was clearly demonstrated by the constructed nomogram (Figure 1). Stone diameter is widely used in clinical practice since it is simple and easy to obtain in the assessment of stone burden.[24] The EAU and AUA guidelines also include stone diameter in their recommendations concerning decision-making with regard to the treatment of urinary system stones.[1] Hori et al used stone diameter while evaluating stone burden and categorised it over 5 points based on the effect size obtained from the nomogram. They reported that treatment success decreased by <30% in patients with 5 points.[16] However, since stone diameter does not reflect the width and depth of the stone, it will naturally have certain limitations in predicting the results of the operation compared with stone volume. Ito et al, evaluating patients who underwent fURS, emphasised that stone diameter was able to accurately predict stone volume in <2 cm stones but it was necessary to directly calculate stone volume in stones larger than 2 cm.[24] Considering that stone volume increases exponentially as stone diameter increases, this result is expected. Today, with the developments in technology and increase in experience, it is possible to apply fURS treatment to larger stones; therefore, it would not be realistic to expect stone diameter alone to predict success. Supporting this, in our study, the rate of treatment success was 42% in the patients with 5 points in stone diameter (≥30 mm) according to the original T.O.HO. score while it was only 21% for those with 5 points (>480 mm^2) according to the modified T.O.HO. score, in which stone area rather than diameter was evaluated. Hori et al also stated that the STONE scoring system, which has different cut-off values, does not have predictive value for stone size classification.[16] Consistently, we found that the patients scoring 3 points (>10 mm) in the stone diameter of the STONE scoring system had a treatment success rate of 79%. This indicated that the stone size classification of the STONE scoring system was far from differentiating SFS.

Another component of the T.O.HO. scoring system is stone localisation. Studies have shown that stone localisation is an independent marker in the treatment of ureteral and renal stones, and especially lower pole stones are associated with fURS treatment failure.[11,12,14,15,25] For practical use, T.O.HO. classified renal stone localisations as upper, middle and lower pole and ureteral stones as proximal, middle and distal. In our study, it was observed that the rate of SFS was 71.2% in lower pole stones and 66.7% in multicalyceal stones, while it was 89.5%, 91.2% and 87.9% for middle ureteral, proximal ureteral and pelvic stones, respectively. However, the authors that developed T.O.HO. did not specify how multi-calyceal were graded in this scoring system. In order to continue the validation process, we scored multi-calyceal stones containing those with middle and upper pole localisations and similar SFR as the upper and middle pole group, and multi-calyceal stones with low SFR located in the lower calyx as the lower pole group. According to the T.O.HO. score based on stone localisation, the worst SFR was in the lower pole, and this was at a statistically significant level ($P < .001$). In the multivariate analysis, it was determined that the middle ureter and middle pole stones provided an increase of 76.2% and 50.4% in the operation success, respectively, compared with the lower pole stones. In the original T.O.HO. study, lower SFR (51.6%) was reported in the upper pole stones than in the lower calyceal group, whereas in our study, higher SFR (82.4%) was found in the upper pole stones similar to the middle pole stones. This difference was attributed to the small number of patients with upper pole stones in both studies and presumably different stone sizes.

As an important parameter in the treatment of urinary system stones, stone density is also a component of the T.O.HO. scoring system. The relationship of stone density with SFS has been shown in many studies.[12,26] Hussain et al[27] used the cut-off value of T.O.HO. stone density as 1100 HU and graded the patients over 3 points. In our study, it was observed that stone density was an independent marker for SFS in the multivariate analysis, and the cut-off value was calculated as 1125 HU. A 100 HU increase in stone density increased treatment failure by 1.1 times. The STONE scoring system, which has a different cut-off value for stone density, was also found to have similar predictive value for SFR (AUC = 0.570 for STONE and TOHO for and 0.581). In our study, according to the stone density score, SFR was determined as 83.7%, 84.0% and 72.2% for 1, 2 and 3 points, respectively. There was no difference between 1 and 2 points in terms of SFS ($P > .05$). We consider that the HU value can be reduced to 2 points for a practical scoring system. However, in the current study, we left the HU prediction values as in the original system since it would not further increase the predictive value of the modified system.

In addition to the three main parameters explained above, many other parameters have been defined in the literature to be associated with SFS after fURS, such as the number of stones, preoperative stenting, presence of hydronephrosis, and operator experience.[11,12,14,15] The STONE scoring system uses preoperative stent application, number of stones, and presence of hydronephrosis as predictive factors.[12] In the original T.O.HO. study, Hori et al reported both parameters to be associated with SFS but found no independent marker in the multivariate analysis.[16] Similarly, in our study, the presence of multiple stones was statistically significantly associated with SFS, but it was observed that there was no independent marker in the multivariate analysis. Since stone burden is directly related to the number of stones, the latter loses its importance. We did not determine preoperative stenting to be associated with SFS. There are publications in the literature stating that preoperative stenting increases the success of ureteral access sheath and is not associated with SFS.[28,29] Another parameter included in the STONE scoring system is the presence of hydronephrosis. Hori et al did not evaluate the presence of hydronephrosis. In our study, although the presence of hydronephrosis was high in patients with residual stones, it was not found to be a statistically significant parameter. In the nomogram developed by Ito et al, the presence of hydronephrosis had very low power but it was not used as a marker in other scoring systems.[15] The same authors also used operator experience as a marker in their nomogram. Since all surgical procedures in our study were performed by experienced endourologists, similar to the original T.O.HO. study, this marker is not discussed further.

Our study has certain limitations. The main limitations are retrospective design, relatively small number of patients, and lack of data on second-session attempts in patients with residual stones and final success rates. Another important limitation is the lack of stone composition that may affect SFS.

5 | CONCLUSION

In predicting SFS after fURS, the T.O.HO. score has better predictive ability than the STONE score. The modified T.O.HO. score, which was created by adding the stone area parameter, was able to better predict SFS after fURS. Based on these results, we consider that the modified T.O.HO. score can be used effectively in ureteral and renal stones without losing its practicality. Our study proved the efficacy of the modified T.O.HO. score in predicting SFS but there is a need for large-series studies with a prospective design to validate it.

DISCLOSURES

None declared.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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