ORIGINAL RESEARCH
Endourology

Doi: 10.4274/jus.galenos.2024.2024-3-11
J Urol Surg 2024;11(3):179-186

Guy's, S.T.O.N.E., CROES Nomograms in Percutaneous Nephrolithotomy Can Predict the Stone-Free Rate Similarly: A Retrospective Study of Thousand Patients

Taha Çetin[1], Mehmet Yiğit Yalçın[2], Mert Hamza Özbilen[3], Çağdaş Bildirici[4], Erkin Karaca[4], Tufan Suelozgen[4], Hayal Boyacıoğlu[5], Gökhan Koç[4]

[1]*University of Health Sciences Turkiye, İzmir Bozyaka Training and Research Hospital, Clinic of Urology, İzmir, Turkiye*
[2]*Şanlıurfa Training and Research Hospital, Clinic of Urology, Şanlıurfa, Turkiye*
[3]*University of Health Science Turkiye, Adana City Training and Research Hospital, Clinic of Urology, Adana, Turkiye*
[4]*University of Health Science Turkiye, İzmir Tepecik Education and Research Hospital, Clinic of Urology, İzmir, Turkiye*
[5]*Ege University Faculty of Medicine, Department of Statistics, İzmir, Turkiye*

What's known on the subject? and What does the study add?

Some scoring systems are known to predict stone-free percutaneous nephrolithotomy. All three of the Guy's stone score, S.T.O.N.E. and CROES nomograms predicted stone-free percutaneous nephrolithotomy.

Abstract

Objective: To compare the Guy's, S.T.O.N.E, and CROES nomograms for predicting stone-free status in patients who underwent percutaneous nephrolithotomy for renal stones.

Materials and Methods: The data of 1114 patients who underwent percutaneous nephrolithotomy for renal calculi between 11/2008 and 08/2018 in our clinic were retrospectively reviewed. Various parameters evaluated by preoperative computed tomography and the scoring systems of the patients and postoperative stone-free status were compared.

Results: Out of 1000 patients who met the study criteria. Gender, body mass index, and stone density were not statistically different between the group with residual stones and the stone-free group. However, stone size, number of renal accesses, duration of fluoroscopy usage, duration of operation, number of stones, and complication rate were significantly higher in the group with residual stones than in the stone-free group. A statistically significant correlation was found between the postoperative stone-free rate and scoring systems. The applicability and preoperative prediction ability of all three systems were evaluated by receiver operating characteristic analysis. The area under the curve (AUC) was detected in the Guy's, CROES, and S.T.O.N.E scoring system (AUC: 0.642, 0.665, 0.592 respectively).

Conclusion: In this study, where the perioperative and postoperative results of 1000 patients were evaluated, we found that all three scoring systems could predict the stone-free rate. "We believe that the use of these scoring systems before surgery can guide surgeons."

Keywords: Complications, endourology, kidney stone

Correspondence: Taha Çetin MD, University of Health Science Turkiye, İzmir Bozyaka Training and Research Hospital, Clinic of Urology, İzmir, Turkiye
Phone: +90 506 286 54 86 **E-mail:** tahacetin88@gmail.com **ORCID-ID:** orcid.org/0000-0003-0330-4854
Received: 25.03.2024 **Accepted:** 01.06.2024

Cite this article as: Çetin T, Yalçın MY, Özbilen MH, Bildirici Ç, Karaca E, Suelozgen T, Boyacıoğlu H, Koç G. Guy's, S.T.O.N.E., CROES Nomograms in Percutaneous Nephrolithotomy Can Predict the Stone-Free Rate Similarly: A Retrospective Study of Thousand Patients. J Urol Surg. 2024;11(3):179-186.

Introduction

There are many invasive and non-invasive methods in the current treatment of urinary system stone disease. Because of advances in endoscopic approaches together with developing medical technology, open surgery is required in a very small proportion of urinary system stones. Today, minimally invasive treatments are mostly used in urinary system stones (1,2). In the 1950s, with the use of percutaneous needle aspiration treatment and antegrade pyelography in kidneys with hydronephrosis, percutaneous interventions on the kidney became widespread (3,4). Percutaneous nephrolithotomy (PNL) for the treatment of kidney stones was first described by Fernström and Johansson in 1976 (5).

Despite advances in surgical techniques and technology, there is an increase in the number of complications in parallel with the number of surgeries (6,7). There have been ongoing studies for years on preoperative variables that can predict PNL success and complication rates. However, there is no preoperative variable that can be accepted as a standard yet (8-10).

Until recently, there were no useful scoring systems that could predict success and complication rates in PNL. Guy's stone score (GSS), stone size, tract length, obstruction, number of involved calices, andessence/density (S.T.O.N.E), and the Clinical Research Office of the Endourological Society (CROES) nomograms have been recommended as preoperative assessment tools since 2011 (11-13). It has been shown in these studies that nomograms inform the surgeon about the stone-free rate and complication ratio. In addition, different studies have yielded results showing nomograms' use in daily practice. We conducted this study to contribute to the literature because it is one of the studies with the largest patient population in the literature and is a tertiary reference hospital.

In this study, we aimed to investigate the predictive ability and superiority of GSS, S.T.O.N.E, and CROES nomograms in a retrospective extensive patient group.

Materials and Methods

This study was conducted after the Ethics Committee approval of University of Health Sciences Turkiye, İzmir Tepecik Education and Research Hospital (IRB no: 2019/9-13). Informed consent was obtained from all patients. A total of 1114 patients who underwent PNL in our clinic between November 2008 and August 2018 were screened. Patients younger than 18 years of age with a solitary kidney or horseshoe kidney anomaly and who underwent endoscopic combined retrograde intratrenal surgery (eCIRS) were excluded from the study. The remaining 991 patients were included in the study.

A detailed anamnesis was taken from all patients before surgery, and physical was examined. An informed consent form was obtained from the patients before the procedure. Complete blood count, biochemical tests (kidney and liver function tests and electrolyte levels), bleeding parameters, and urine culture were evaluated. The medications of the patients using anti-aggregant or anticoagulant were discontinued in consultation with the relevant units, and appropriate treatment (low molecular weight heparin) was initiated when necessary. All patients were evaluated with a kidney-ureter-bladder X-ray and non-contrast enhanced computed tomography (NCCT) preoperatively. These protocols were routinely applied to all stone patients. All stone protocol NCCT were evaluated according to the S.T.O.N.E, GSS, and CROES nomograms. In the GSS, the location of the stone, number of stones, presence of partial or complete staghorn stones, and presence of anomalies in the kidney anatomy were evaluated and scored between 1 and 4 (Figure 1). In the CROES nomogram, six parameters including stone burden, stone location, previous intervention history, presence of staghorn stone, number of stones, and number of annual cases were evaluated (Figure 2). In the S.T.O.N.E nomogram, five parameters including the size of the stone (size), the distance of the stone from the skin (tract of length), the presence of hydronephrosis (obstruction), the number of calices in which the stone is located (number of calices), and the density of the stone (essence) were evaluated (Figure 3).

All procedures were performed under general anesthesia. A 6F open-ended ureteral catheter was inserted into the ureter in the lithotomy position. The patients were then placed in the prone position on a table compatible with the C-arm. Using fluoroscopy, the appropriate calyx was accessed with the triangulation technique using an 18G percutaneous access needle. A single-step Amplatz dilation technique was used. A 26-F nephroscope (Karl Storz GmbH, Tuttlingen, Germany) was used through the 30F Amplatz sheath, and the stones were broken with the help of a pneumatic and/or ultrasonic lithotripter. The residual stone status was evaluated by perioperative fluoroscopy. After the operation, a nephrostomy tube was placed and the procedure was terminated.

Operation time, number of percutaneous accesses, fluoroscopy time, intraoperative and postoperative complications, duration of nephrostomy catheterization, and length of hospital stay were evaluated. Residual stone status was assessed by perioperative fluoroscopy and NCCT 1 month after surgery. After PNL, residual fragments of 4 mm that did not cause obstruction or infection were considered "stone-free". Patients were evaluated according to three nomograms. Stone-free were defined as group 1, and residual stone was defined as group 2.

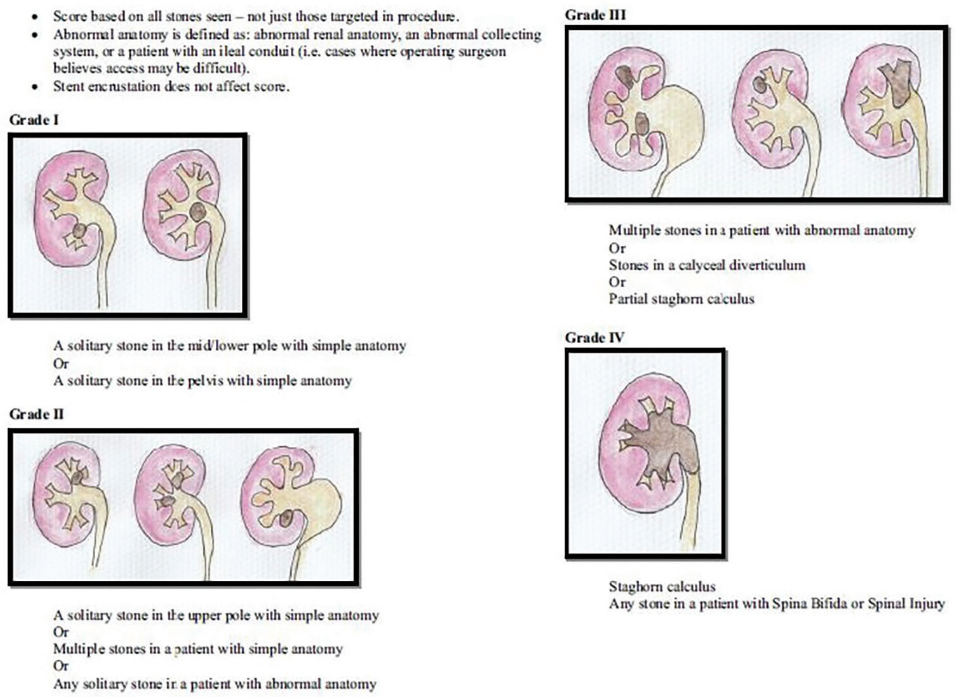

Figure 1. Guy's stone score

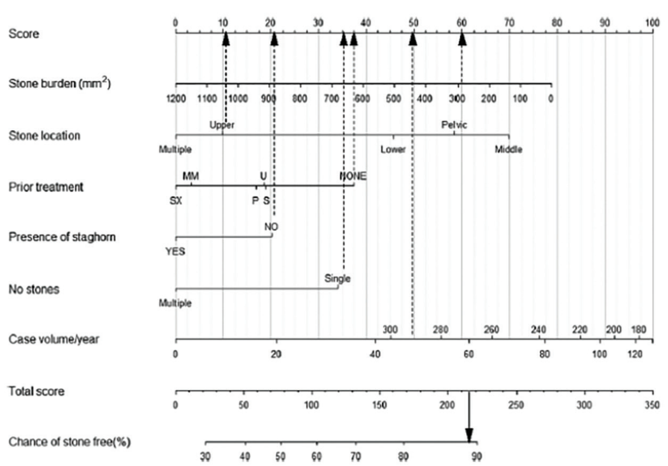

Figure 2. Nephrolithometry nomogram to predict treatment success using KUB after PCNL. Instructions for use: Draw 3 vertical lines to score axis to determine score attributable to each observed radiological characteristic. Sum scores for all radiological characteristics. Locate calculated sum of scores on total score axis. Draw vertical line to chance of stone-free axis to determine predicted chance of treatment success. Note that staghorn stones are scored under multiple group in stone location axis. Stone burden is estimated from stone dimensions in mm using formula Σ (0.785 + $length_{max}$ + $width_{max}$) (10). Example shows patient with no prior stone treatment and 1 upper calyceal stone with estimated stone burden of 300 mm^2 at center with average case volume of 45 patients per year. Total stone score of 212 predicts 87% chance of treatment success

MM: Multiple stone treatment modalities, U: Ureteroronoscopic stone treatment, SX: Pyelolithhotomy, P: PCNL, S: Extracorporeal shock wave lithotripsy, PCNL: Percutaneous nephrolithotomy

Statistical Analysis

The SPSS 15.0 package program (SPSS for Windows, 15.0, SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. Independent sample t-test, chi-square test, receiver operating characteristic (ROC) curve test, and correlation analysis were used to analyze the data. A p<0.05 was considered statistically significant.

Results

In our study, the patients' mean age was 49+13.2 (standard) years. 59% of the patients were male. The mean body mass index (BMI) was 28.3 (23-38). Hypertension, hyperthyroidism, and diabetes mellitus were detected in 16%, 11%, and 4% patients, respectively.

Perioperative and postoperative data of the patients and postoperative stone-free status are shown in Table 1. While the mean stone size of the patients before the operation in the stone-free group was 265 mm², it was calculated as 563 mm² in the patients with residual stones. The stone size was found to be statistically higher in patients with residual stones (p<0.001). According to the number of stones, a statistically significant difference was found between the groups (p<0.001). The mean stone density was not statistically significant difference between groups (Table 1).

The overall stone-free rate of the patients was 81.6%. When stone-free rates were evaluated according to GSS grades, the stone-free rate was 89.6% in grade 1, 77.2% in grade 2, 72.5% in grade 3, and 71.4% in grade 4. While the stone-free rate was 84.8% in the group with S.T.O.N.E score of 5-7, it was 74.4% in the group with 8-10 and 60.9% in the group with 11-13. In the CROES scoring system, stone-free rates were 92.7% in the 276-340 score, 89.7% in the 211-275 score, 76.6% in the 146-210 score, and 71.3% in the 80-145 score (Table 2).

S.T.O.N.E	1 Point	2 Point	3 Point	4 Point
Size	0-399	400-799	800-1599	≥1600
Tract of Lenght	≤100	>100		
Obstruction	None or light	Moderate or severe		
Number of Calyx	1-2	3	Staghorn	
Essence (HU)	≤950	>950		
Total Score				

Figure 3. S.T.O.N.E. nephrolithometry score

S.T.O.N.E: Stone size, tract length, obstruction, number of involved calices, andessence/density, HU: Hounsfield unit

Scoring systems and the relative risk of residual calculi were evaluated as risk groups.

The GSS was determined as grade 1 low, grade 2 moderate, grade 3 high, and grade 4 very high-risk groups. With the S.T.O.N.E nephrolitometry score, 5-7 were determined as low risk, 8-10 as medium risk, and 11-13 as high risk. The CROES nephrolitometry score was also divided into four groups according to the risks. It was determined as low risk between 276 and 340, medium risk between 211-275, high risk approximately 146-210 and very high-risk group between 80 and 145 (Table 3). All Three scoring systems were found to be significant on logistic regression analysis. The odds ratio and confidence index are shown in Table 3.

Table 1. Demographic, perioperative and postoperative data of the patients and their postoperative stone-free status

	Total	**Stone free % (n)**	**Residual calculi % (n)**	**p**
Patients (n)	991	807	184	
Age mean (year), STD	49+**13.2**	48.6+**13.3**	50.2+**12.7**	0.082[€t]
Sex	0.044*			
Male	596	83.6 (498)	16.4 (98)	
Female	385	78.5 (310)	19.5 (75)	
BMI (mean) kg/m², STD	28.3+**45.7**	28.8+**44.6**	25.8+**50.5**	0.598[€t]
Stone size (mm²)	320+**544.9**	265+**366.3**	563+**973.2**	<0.001[€t]
Stone density (HU)	825+**528.7**	822+**534.0**	838+**505.5**	0.295[€t]
Number of tracts	<0.001			
1	866	83 (719)	17 (147)	
2	105	67.6 (71)	32.4 (34)	
3	20	90 (18)	10 (2)	
Fluoroscopy time (second)	153.1+**161.6**	147+**147.2**	177+**213.3**	0.034[€t]
Operation time (min.)	63.4+**51.8**	59.4+**48.1**	81+**62.8**	<0.001[€t]
Number of stone	<0.001*			
Single	416	90.6 (377)	9.4 (39)	
Multiple	575	75 (431)	25 (144)	
Stone location	<0.001*			
Calix	223	171	52	
Renal pelvis	312	287	25	
Both	456	350	106	
Clavien classification	<0.001*			
0	816	688	128	
1	73 (7.3%)	56	17	
2	75 (7.5%)	43	32	
3a	5 (0.5%)	4	1	
3b	4 (0.4%)	2	2	
4a	18 (1.8%)	14	4	

[€t]: Independent sample t-test, *: Chi-square test, STD: Standard, HU: Hounsfield unit, BMI: Body mass index

All stone nomograms gave statistically significant results in predicting stone-free status. GSS p<0.001 [95% confidence interval (CI) 0.598-0.686, area under the curve (AUC): 0.642], S.T.O.N.E p<0.001 (95% CI 0.544-0.640, AUC: 0.592), CROES p<0.001 (95% CI 0.622-0.708, AUC: 0.665). A comparison of scoring systems for stone-free status is shown in Table 4. Simultaneously, the predictive capabilities of the scoring systems were compared by calculating the area under the curve with ROC analysis (Figure 4). The optimal cut-off score values, AUC, sensitivity, and specificity score are shown in Table 4.

Considering the complications, fever was observed in 73 patients, bleeding or urinary leakage not exceeding 12 h in 75 patients, pneumothorax requiring intervention in 5 patients, arteriovenous fistula in 4 patients, and colon injury in 18 patients. The overall complication rate was 17%. The complication rates according to Clavien classification are given in Table 1.

Discussion

Since its definition, PNL has become the first-line treatment option for large, complex, and staghorn stones. The main goal for treating kidney stones is to provide maximum benefit with minimal harm. Although there are many scoring systems predicting stone-free status after PNL, there is no standard method that is widely accepted.

Table 2. Stone free rate and scoring system groups

		Stone free	Residual calculi	Stone free rate
GSS	**Grade 1**	397	46	89.6%
	Grade 2	244	72	77.2%
	Grade 3	111	42	72.5%
	Grade 4	55	22	71.4%
S.T.O.N.E.	**5-7**	617	110	84.8%
	8-10	166	57	74.4%
	11-13	25	16	60.9%
CROES	**276-340**	51	4	92.7%
	211-275	334	38	89.7%
	146-210	296	90	76.6%
	80-145	127	51	71.3%

GSS: Guy's stone score, CROES: Clinical Research Office of the Endourological Society, S.T.O.N.E: Stone size, tract length, obstruction, number of involved calices, andessence/density

Table 3. Scoring systems and relative risk for residual calculi and risk group

		p	Odds ratio (95% CI)	Risk group
GSS	**Grade 1**	<0.001		Low
	Grade 2	**<0.001**	**2.547 (1.702, 3.810)**	Intermediate
	Grade 3	**0.001**	**2.046 (1.360, 3.078)**	High
	Grade 4	**0.047**	**1.704 (1.007, 2.883)**	Very high
S.T.O.N.E.	**5-7**	**<0.001**		Low
	8-10	**<0.001**	**2.469 (1.549, 3.936)**	Intermediate/high
	11-13	**0.943**	**0.987 (0.685, 1.421)**	Very high
CROES	**276-340**	<0.001		Low
	211-275	0.016	4.514 (1.322, 15.412)	Intermediate
	146-210	0.033	3.711 (1.113, 12.365)	High
	80-145	0.954	1.037 (0.300, 3.583)	Very high

CI: Confidence interval, GSS: Guy's stone score, CROES: Clinical Research Office of the Endourological Society, S.T.O.N.E: Stone size, tract length, obstruction, number of involved calices, andessence/density

Table 4. Area under the curve of the three scoring systems predicting stone-free status

	AUC	Cut-off value	Sensitivity	Specifity	p	95% CI
GSS	0.642	2	74.4%	50.7%	<0.001	0.598, 0.686
S.T.O.N.E.	0.592	7	41%	75%	<0.001	0.544, 0.640
CROES	0.665	206.5	81.5%	47.5%	<0.001	0.622, 0.708

GSS: Guy's stone score, CROES: Clinical Research Office of the Endourological Society, AUC: Area under the curve, CI: Confidence interval, S.T.O.N.E: Stone size, tract length, obstruction, number of involved calices, andessence/density

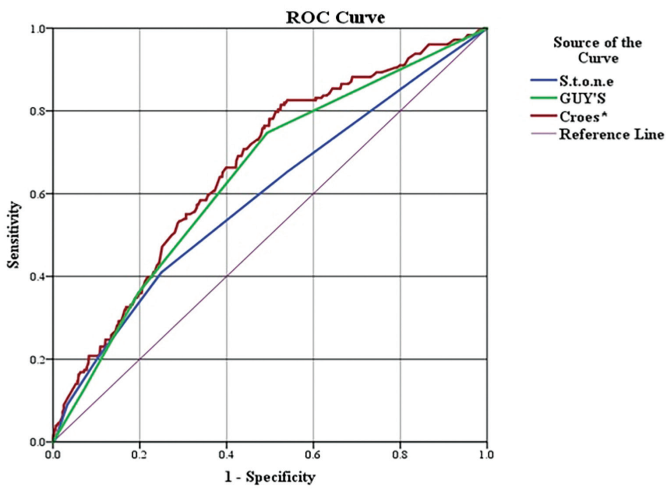

Figure 4. ROC curve for stone-free predicting, Guy's stone score, S.T.O.N.E., and CROES nomogram

ROC: Receiver operating characteristic, S.T.O.N.E: Stone size, tract length, obstruction, number of involved calices, andessence/density

Among these scoring systems, GSS, S.T.O.N.E, CROES, Seoul National University Renal Stone Complexity and acute angle, complicated calyx and stone size are frequently discussed in the literature. In recent years, the importance of systematic and standard reporting of results after various endourological surgeries, including PNL, has been emphasized (14-16). GSS, CROES, and S.T.O.N.E are the nomograms most frequently used recently.

Many factors have been defined that predict the stone-free rate after PNL, such as stone burden, stone type, number and location of the stone, HU, BMI, stone skin distance, and abnormal kidney anatomy. However, a single parameter that predicts stone-free status has not yet been identified. Therefore, nomograms in which many factors are combined have been developed by the authors (15-17). Numerous studies have attempted to validate these scoring systems. However, most studies are retrospective, and the stone size definition of residual stone, method, and timing of imaging after PNL are different. This has made it impossible for scoring systems to be accepted as a standard (18-25).

Although the parameters evaluated by the scoring systems are different from each other, all of them can help the surgeon in predicting stone-free status and operation-related complications. There are several important differences between the aforementioned scoring systems. While S.T.O.N.E is based entirely on data from preoperative NCCT, GSS and CROES also include patient variables. Because the definition of full staghorn or partial staghorn is not clear and subjective, its effects on scoring systems are suspicious. Some authors classify staghorn stones as follows: "borderline", stones filling the pelvis and calyx; "partial", stones filling the pelvis and extending into the two calyces; "complete", stones filling ≥80% of the pelvicalyceal system, extending to the pelvis and all major calyces; and "huge", stones filling the entire pelvicalyceal system accompanied by dilatation (26,27). Since the number of calyx filled by the stone is one of the parameters in the S.T.O.N.E scoring system, it can evaluate the staghorn stone status more objectively than other systems.

Spina bifida or spinal injury history of the patient, stone burden, and calyceal anatomy were evaluated using GSS (15). Studies have reported that GSS is important for predicting stone-free status. In addition, the stone-free rate was found to be associated with an increase in GSS grade (GSS grade 1 81%, GSS grade 2 74.2%, GSS grade 3 35%, GSS grade 4 29%). However, no significant correlation was found between GSS and postoperative complications.

The GSS symptom score has some limitations. The use of different imaging methods other than CT in the evaluation of stone-free status can be considered as a weakness of the scoring system because the sensitivity of imaging methods in showing residual stones is not the same. In our study, all patients were evaluated with NCCT postoperatively, and GSS could again predict stone-free status significantly.

In the S.T.O.N.E. scoring system, 4-5 were defined as low, 6-8 as medium and 9-11 as high-risk groups, and it was shown that the success of the operation decreased as the S.T.O.N.E score increased. In the study, the S.T.O.N.E score was the best predictor of stone-free status, whereas the second most effective factor was found to be stone size. Complication rates were given in the study, and it was determined that only stone size was associated with complications. The small number of complications prevented detailed analysis of the complications (28). In our study, it was observed that the success rate decreased with the increase in the number of scores. In the S.T.O.N.E scoring system, calyx stones and pelvis stones affect the scoring system equally, with a score of "1". However, the stone-free rates of pelvic and calyx stones are not the same in the literature (29).

In addition to stone parameters and patient characteristics, the experience of the clinic was evaluated using the CROES nomogram (30). When the stone volume calculation in the CROES study is used as maximum length maximum width x π x 0.25, it is valid for round and oval stones, but unfortunately it is not possible to give the same exact result for large, complex, staghorn stones. Similar to stone burden, HU is not applicable to large/staghorn stones. The reason for this is that the density is different in the periphery and center of the stone because of its lamellar structure.

Stone scoring systems are also used in solitary kidney stone disease. The authors concluded that stone burden was associated with SFR and complication rate. Moreover, the CROES score was the only independent factor associated with SFR status in their study. Also, this study has shown correlation with the literature (31).

Unlike the GSS, the CROES nomogram is difficult and time consuming for clinical applicability. However, in our study, it was shown that the AUC in CROES is better than the GSS and S.T.O.N.E scores (Table 4).

Our study was retrospective. In addition, evaluation of scoring systems by a single urologist and performing surgeries by different surgeons are limitations of our study. However, the evaluation of a larger patient population than that of many studies in the literature can be shown as the strength of the study.

Conclusion

It was determined in our study with a large patient population that the three scoring systems could predict stone-free rates significantly. Because of the weak correlation with the complication rates, a clear opinion on this issue could not be declared yet. However, it is possible to say that all three methods are suitable and usable for preoperative planning in PNL. For scoring systems to be widely used in daily practice, there is a need for large prospective studies and elimination of their weaknesses.

Ethics

Ethics Committee Approval: The research was approved University of Health Sciences Turkiye, İzmir Tepecik Education and Research Hospital (IRB no: 2019/9-13, date: 23.05.2019).

Informed Consent: Written informed consent was obtained from all patients.

Authorship Contributions

Surgical and Medical Practices: T.Ç., M.Y.Y., Ç.B., T.S., Concept: T.Ç., M.Y.Y., M.H.Ö., E.K., H.B., Design: T.Ç., Ç.B., H.B. T.S., G.K., Data Collection or Processing: T.Ç., M.Y.Y, M.H.Ö., T.S., E.K., G.K., Analysis or Interpretation: H.B., Literature Search: T.Ç., M.H.Ö., Ç.B., E.K., G.K., Writing: T.Ç.

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

Financial Disclosure: The authors declare that they have no relevant financial.

References

1. Winoker JS, Chandhoke RA, Atallah W, Gupta M. Morphometry scores: Clinical implications in the management of staghorn calculi. Asian J Urol. 2020;7:78-86. [Crossref]
2. Patel R, Daniel J. Lama ZO. Nephrolithometric Scoring Systems for Percutaneous Nephrolithotomy, WILEY, Online Library, 30.12.2018. [Crossref]
3. Ozgor F, Yanaral F, Savun M, Ozdemir H, Sarilar O, Binbay M. Comparison of STONE, CROES and Guy's nephrolithometry scoring systems for predicting stone-free status and complication rates after percutaneous nephrolithotomy in obese patients. Urolithiasis. 2018;46:471-477. [Crossref]
4. Pearle MS LY. Urinary lithiasis, etiology, epidemiology, and pathogenesis. In: Editor-in-chief, editor. Campbell-Walsh Urology. 10th ed ed: Elsevier Saunders 2012. p. 1257-1287. [Crossref]
5. Matlaga BR, Assimos DG. Changing indications of open stone surgery. Urology. 2002;59:490-493; discussion 493-494. [Crossref]
6. Kane CJ, Bolton DM, Stoller ML. Current indications for open stone surgery in an endourology center. Urology. 1995;45:218-221. [Crossref]
7. Bedir S, Tahmaz L, Alan C, Örs AÖ, Peker AF. Pekütan Renal Cerrahi (Ayın Kitabı), Gülhane Askeri Tıp Akademisi Basımevi, Ankara, Şubat 2007. (Turkish). [Crossref]
8. Bedir S. Perkütan Nefrolitotomi (Üriner Sistem Taş Hastalığında Cerrahi Tedavi Yöntemleri). Turk Urol Sem. 2011;2:75-81. (Turkish). [Crossref]
9. Fernström I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol. 1976;10:257-259. [Crossref]
10. Ghani KR, Sammon JD, Bhojani N, Karakiewicz PI, Sun M, Sukumar S, Littleton R, Peabody JO, Menon M, Trinh QD. Trends in percutaneous nephrolithotomy use and outcomes in the United States. J Urol. 2013;190:558-564. [Crossref]
11. Mirheydar HS, Palazzi KL, Derweesh IH, Chang DC, Sur RL. Percutaneous nephrolithotomy use is increasing in the United States: an analysis of trends and complications. J Endourol. 2013;27:979-983. [Crossref]
12. Mitropoulos D, Artibani W, Graefen M, Remzi M, Rouprêt M, Truss M; European Association of Urology Guidelines Panel. Reporting and grading of complications after urologic surgical procedures: an ad hoc EAU guidelines panel assessment and recommendations. Eur Urol. 2012;61:341-349. [Crossref]
13. Opondo D, Gravas S, Joyce A, Pearle M, Matsuda T, Sun YH, Assimos D, Denstedt J, de la Rosette J. Standardization of patient outcomes reporting in percutaneous nephrolithotomy. J Endourol. 2014;28:767-774. [Crossref]
14. Hyams ES, Bruhn A, Lipkin M, Shah O. Heterogeneity in the reporting of disease characteristics and treatment outcomes in studies evaluating treatments for nephrolithiasis. J Endourol. 2010;24:1411-1414. [Crossref]
15. Thomas K, Smith NC, Hegarty N, Glass JM. The Guy's stone score--grading the complexity of percutaneous nephrolithotomy procedures. Urology. 2011;78:277-281. [Crossref]
16. Okhunov Z, Friedlander JI, George AK, Duty BD, Moreira DM, Srinivasan AK, Hillelsohn J, Smith AD, Okeke Z. S.T.O.N.E. nephrolithometry: novel surgical classification system for kidney calculi. Urology. 2013;81:1154-1159. [Crossref]
17. Smith A, Averch TD, Shahrour K, Opondo D, Daels FP, Labate G, Turna B, de la Rosette JJ; CROES PCNL Study Group. A nephrolithometric nomogram to predict treatment success of percutaneous nephrolithotomy. J Urol. 2013;190:149-156. [Crossref]
18. Ingimarsson JP, Dagrosa LM, Hyams ES, Pais VM Jr. External validation of a preoperative renal stone grading system: reproducibility and inter-rater concordance of the Guy's stone score using preoperative computed tomography and rigorous postoperative stone-free criteria. Urology. 2014;83:45-49. [Crossref]
19. Vicentini FC, Marchini GS, Mazzucchi E, Claro JF, Srougi M. Utility of the Guy's stone score based on computed tomographic scan findings for predicting percutaneous nephrolithotomy outcomes. Urology. 2014;83:1248-1253. [Crossref]
20. Labadie K, Okhunov Z, Akhavein A, Moreira DM, Moreno-Palacios J, Del Junco M, Okeke Z, Bird V, Smith AD, Landman J. Evaluation and comparison of urolithiasis scoring systems used in percutaneous kidney stone surgery. J Urol. 2015;193:154-159. [Crossref]

21. Mandal S, Goel A, Kathpalia R, Sankhwar S, Singh V, Sinha RJ, Singh BP, Dalela D. Prospective evaluation of complications using the modified Clavien grading system, and of success rates of percutaneous nephrolithotomy using Guy's Stone Score: A single-center experience. Indian J Urol. 2012;28:392-398. [Crossref]

22. Choo MS, Jeong CW, Jung JH, Lee SB, Jeong H, Son H, Kim HH, Oh SJ, Cho SY. External validation and evaluation of reliability and validity of the S-ReSC scoring system to predict stone-free status after percutaneous nephrolithotomy. PLoS One. 2014;9:e83628. [Crossref]

23. Okhunov Z, Helmy M, Perez-Lansac A, Menhadji A, Bucur P, Kolla SB, Cho JS, Osann K, Lusch A, Landman J. Interobserver reliability and reproducibility of s.T.o.N.e. Nephrolithometry for renal calculi. J Endourol. 2013;27:1303-1306. [Crossref]

24. Akhavein A, Henriksen C, Syed J, Bird VG. Prediction of single procedure success rate using S.T.O.N.E. nephrolithometry surgical classification system with strict criteria for surgical outcome. Urology. 2015;85:69-73. [Crossref]

25. Noureldin YA, Elkoushy MA, Andonian S. Which is better? Guy's versus S.T.O.N.E. nephrolithometry scoring systems in predicting stone-free status post-percutaneous nephrolithotomy. World J Urol. 2015;33:1821-1825. [Crossref]

26. Rassweiler JJ, Renner C, Eisenberger F. The management of complex renal stones. BJU Int. 2000;86:919-928. [Crossref]

27. Di Silverio F, Gallucci M, Alpi G. Staghorn calculi of the kidney: classification and therapy. Br J Urol. 1990;65:449-452. [Crossref]

28. Knoll T, Wezel F, Michel MS, Honeck P, Wendt-Nordahl G. Do patients benefit from miniaturized tubeless percutaneous nephrolithotomy? A comparative prospective study. J Endourol. 2010;24:1075-1079. [Crossref]

29. Anastasiadis A, Onal B, Modi P, Turna B, Duvdevani M, Timoney A, Wolf JS Jr, De La Rosette J; CROES PCNL STUDY GROUP. Impact of stone density on outcomes in percutaneous nephrolithotomy (PCNL): an analysis of the clinical research office of the endourological society (CROES) pcnl global study database. Scand J Urol. 2013;47:509-514. [Crossref]

30. Karakan T, Diri A, Hascicek AM, Ozgur BC, Ozcan S, Eroglu M. Comparison of ultrasonic and pneumatic intracorporeal lithotripsy techniques during percutaneous nephrolithotomy. ScientificWorldJournal. 2013;2013:604361. [Crossref]

31. Çağlayan V, Öner S, Önen E, Avcı S, Kılıç M, Akgün U. Comparison of Stone Scoring Systems in Predicting Outcomes of Percutaneous Nephrolithotomy in Patients with Solitary Kidney. J Urol Surg. 2020;7:1-7. [Crossref]