SHA.LIN Renal Stone Scoring System for Predicting Stone Free Status and Postoperative Outcomes after Percutaneous Nephrolithotomy

Kai Zeng
Huazhong University of Science and Technology
Tao Wang
Huazhong University of Science and Technology
Shaogang Wang
Huazhong University of Science and Technology
Zhangqun Ye
Huazhong University of Science and Technology
Xiaoyong Zeng
Huazhong University of Science and Technology
Jihong Liu (jhliutjmu@126.com)
Huazhong University of Science and Technology

Research Article

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Abstract

Objective: To introduce a novel renal stone scoring system (SHA.LIN) for percutaneous nephrolithotomy (PCNL) and compare the predictive power of SHA.LIN, Guy's, and S.T.O.N.E. scoring systems for postoperative outcomes.

Methods: Six reproducible parameters available from preoperative computed tomography were measured: stone burden (S), hydronephrosis (H), anatomic distribution (A), length of tract (L), indicator of CT (I), and number of involved calics (N). We retrospectively reviewed data of patients who underwent PCNL from May 2018 to January 2021. SHA.LIN, S.T.O.N.E. and Guy's scores correlation with stone free-status (SFS), Hemoglobin change, estimated blood loss (EBL), operation time (OT), and postoperative hospitalization time (PHT) was evaluated using standard statistical methods.

Results: The overall SFS was 69.7% (248/356), and complications occurred in 110 (30.9%). In patients with stone-free group vs. non stone-free group, the median (IQR) of Guy's score was 2 (1-2) and 3 (2-3), S.T.O.N.E. score was 6 (6-8) and 8 (7-9.5), and SHA.LIN score was 7 (7-9) and 11 (10-12.5), respectively (each $p < 0.001$). Regression analysis showed that three scoring systems were significantly associated with SFS and OT. None of them was significantly correlated with PHT. EBL and hemoglobin change were found significantly correlated with SHA.LIN. Receiver Operating Characteristics (ROC) curves showed three scoring systems had comparable predictive accuracy for SFS and complications, with SHA.LIN having highest Area Under the ROC Curve (AUC) value (0.852 and 0.774). ROC analysis area AUC demonstrated more accurate prediction of EBL based on the SHA.LIN (0.807) than the other two scoring systems.

Conclusion: SHA.LIN scoring system can accurately predict postoperative outcomes of PCNL and can be used as an adjuvant tool for surgical planning. Three scoring systems are well associated with SFS and OT and in addition, SHA.LIN is also significantly associated with surgical bleeding risk.

Introduction

The prevalence of urolithiasis is around 1 to 15%, varying with age, gender, diet, and geographical environment and epidemiological data indicate that the number is increasing at the global scale [1]. With the development of minimally invasive surgical techniques, surgical treatment of upper urinary stones has evolved from traditional open surgery to minimally invasive approaches. For the treatment options of urolithiasis, the latest recommendations of the European Association of Urology (EAU) guidelines recommend percutaneous nephrolithotomy (PCNL) as the first-line surgical option for upper urinary stone with a diameter greater than 20 mm [2]. Although PCNL operation has higher stone-free status (SFS) than Ureteroscopic lithotripsy and extracorporeal shockwave lithotripsy, it also has a higher procedural complication rate, such as infection, organ injury, bleeding requiring blood transfusion, and even mortality risk [3, 4]. The most important questions for urologist to consider before surgery are operation strategy and stratification of patient surgical risk factors, particularly in the context of improving surgical safety and increasing stone-free rate. In response to these problems, several renal stone scoring systems have been developed to provide information about stone complexity, reduce adverse outcomes, provide proper operation counseling for patients, and optimize surgery planning and decision-making [5–7]. Guy's stone score is convenient to use, can provide fast and easy classification information of stones in four grades based on preoperative imaging and correlates well with the complications and SFS. However, it fails to take into account density and size of renal stones. Okhunov et al. developed another scoring system named the S.T.O.N.E. score that contains 5 parameters: renal stone size, tract length, obstruction, number of involved calyces, and stone density [5]. A higher score correlates with a lower stone free rate and higher surgical difficulty. However, the S.T.O.N.E. score fails to take into account the distributional complexity of stones locations in the pelvicalyceal system and only includes the number of involved calyces and staghorn stone. At present, most scholars generally believe that there is still a lack of a universally accepted gold standard scoring system for the evaluation of stone complexity [8–10].

In a previous study, Chinese scholars reviewed the literature from 1976 to 2015 and combined surgical experience to identify clinically relevant and reproducible variables that could affect the outcomes of PCNL. In 2016, they designed the SHA.LIN scoring system and demonstrated that it can effectively predict stone free status. However, there is a paucity of data regarding which stone score is better compared to present scoring systems. External validation and comparison of the three scoring systems may ultimately facilitate the development of a more universal and widely accepted scoring system.

The aim of this study was to introduce a new stone scoring system (SHA.LIN) and compare the accuracy of SHA.LIN, S.T.O.N.E., and Guy's stone score in predicting PCNL outcomes stone free status and complications.

Material And Methods

Ethics statement and SHA.LIN stone score

This study was approved by Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology ethics committee. The SHA.LIN stone score contains 6 variables available from preoperative noncontrast-enhanced computed tomography scans (NECT) and 3D reconstruction. In Chinese traditional medicine, SHA.LIN means urolithiasis. Six reproducible variables include stone burden (S), hydronephrasis (H), anatomic distribution (A), length of tract (L), indicator of CT (I), and number of involved calics (N). The stone burden was calculated by combining the measures of the stone longest width and length in square millimeters. It was scored from 1 to 4 point according to cross-sectional area of 0-399, 400–799, 800–1599, and ≥ 1600 mm^2, respectively. Hydronephrosis is scored according to the degree of dilatation of the renal pelvis [11, 12]. No caliceal or pelvic dilatation is assigned 1 point. Pelvic dilatation or caliceal dilatation is assigned 2 point. Severe caliceal dilatation or accompanied by renal parenchymal atrophy is assigned 3 point. The third variable is the distributional complexity of stone locations in the pelvicalyceal system. Stone in renal pelvis or mid/lower calyx is assigned 1 point. Stone in the upper calyx is assigned 2 point. Stone in a calyceal diverticulum or partial staghorn stone is assigned 3 point. Full staghorn stone is assigned 4 point. The length of tract measures the skin to the center of the stone distance on NECT film. The fifth variable is the CT value of stone (Hounsfield units, Hu), which represents the stone density. The last variable is the number of renal calyces containing stones. The specific assignment of each variable is presented in Table 1. The total stone burden was the sum of all stone cross-sectional area. The stone density was evaluated using the circle region of interest incorporated into the largest stone area in NECT. The score can range from a minimum of 6 to a maximum of 17. A higher score denotes a more complex stone.

Table 1
Summary of SHA.LIN Stone score

variable	Score			
	1	**2**	**3**	**4**
Stone size (mm^2)	0–399	400–799	800–1599	≥ 1600
Hydronephrosis	None or mild	Moderate	Severe	
Anatomic	Pelvis or mid/lower calyx	Upper calyx	Calyceal diverticulum or partial staghorn stone	Staghorn stone
Length of tract(mm)	≤ 100	> 100		
Indicator of CT (Hu)	≤ 950	> 950		
Number of involved calices	0–2	≥ 3		
CT, Computed tomography; HU, Hounsfield units;				

Clinical information

Patients who underwent PCNL for renal stones from May 2018 to January 2021 were retrospectively enrolled in this study. Exclusion criteria for the study included age under 18 years and no available preoperative NECT.Patients were excluded if they had a percutaneous nephrostomy tube or ureteric double J (DJ) stent before surgery. Patients who had any open, endoscopic, or laparoscopic surgery on the ipsilateral kidney were also excluded.We chose one side at random when a patient underwent bilateral PCNL. For patients undergoing staged surgery, we only selected the first stage procedure in the present study analysis. All patients were evaluated with laboratory (complete blood count, coagulation parameters, serum creatinine, plasma electrolytes, urinalysis, urine culture and sensitivity) and imaging examinations (kidney, ureter, and bladder x-ray (KUB), urinary tract ultrasound, intravenous pyelogram and CT). The demographic characteristics, age, gender, body mass index, stone burden, location, operation time (OT), postoperative hospitalization time (PHT), estimated blood loss (EBL), SFS, and postoperative complications were all collected and analyzed. Estimated blood loss was measured by subtracting the amount of irrigation fluids used from the amount of total collecting fluids (blood plus irrigation fluid) [13]. In this study, patients were divided into two groups according to the blood loss cut-off amount of 250 cc [13]. The complications were graded using the modified Clavien-Dindo classification system (3).

Preoperative NCCT was performed and three scoring system scores were calculated as previously by two experienced urologists. Guy's (grade I, II, III, and IV) and SHA.LIN scores (6–8, 9–11, 12–14, and 15–17) were divided into four groups each, and S.T.O.N.E. scores into three groups (5–6, 7–8, and 9–13).

Surgical Technique

PCNL was carried out under general anesthesia and in the prone position. After a target calyx was identified on ultrasound, the nephrostomy needle was accurately positioned under real-time ultrasound guidance and a guide wire was inserted. Tract dilation was then performed through a percutaneous catheter, which gradually dilate the access tract and established working tract. The size of working tract is generally 24-F. An 18-Fr standard nephroscope was used in all patients. Fragmentations were performed with pneumatic or lithotripsy. A DJ stent was stented routinely, and a 14-Fr nephrostomy tube was placed in the renal collecting system at the end of the procedure. KUB was used for assess postoperative SFS and residual stone with a diameter < 4 mm was defined as SFS [14, 15].

Statistical analysis

Categorical variables were expressed as numbers and percentages and compared by the chi-square test (or the Fisher exact test when appropriate). Continuous variables were expressed as mean and standard deviation and compared using an independent t-test. For non-normally distributed continuous variables, Mann-Whitney U-test was performed. Logistic regression analysis was used to assess the possible association between three stone scores and haemoglobin change, SFS, EBL. Linear regression analysis was used to examine the possible association between three stone scores and OT, PHT. Receiver operating characteristic (ROC) curves were drawn to assess the predictive value of three scoring systems on postoperative outcomes. The area under curve (AUC) of the ROC was calculated for each stone score. The p value < 0.05 was considered statistically significant. All data and statistical analyses were performed using the Statistical Package of Social Sciences for windows version 21 (SPSS, Chicago, IL).

Results

356 patients were available data for three stone scores and were included in this study. All patients received successful PCNL operation. The demographic and clinical data of the patients are presented in Table 2. All patients were divided into two groups based on postoperative stone-free status, and the stone-free rate was 69.7% (248/356). No significant differences were found in the two groups in terms of patients age, gender, BMI, stone laterality, haemoglobin change, OT, and PHT. Among the six potential variables in SHA.LIN stone score, an increasing length of tract ($p = 0.003$), increasing size of stone ($p < 0.001$), and stone anatomic locations in the renal pelvis ($p = 0.005$) were associated with residual stone. However, the number of stones ($p = 0.064$), stone density ($p = 0.311$), and degree of hydronephrosis ($p =$

0.642) were not statistically significant residual stones. Three stone scores were significantly associated with stone-free status. In stone-free group and non stone-free group, the median (IQR) of SHA.LIN score was 7 (7-9.5) vs 11 (10-12.5), Guy's score was 2 (1–2) vs 3 (2–3), and S.T.O.N.E score was 6 (6–8) vs 8 (7-9.5) (each $p < 0.001$), respectively.

Table 2
Patient demographic and clinical data

Variable	Stone-free (n = 248)	Non stone-free (n = 108)	*p* Value
Age, mean (SD)	49.3 ± 11.535	48.44 ± 11.103	0.449#
Gender (%)			
Male	144 (58.1)	71 (65.7)	0.336*
Female	104 (41.9)	37 (34.3)	
BMI (Kg/m^2)	24.4 (22.0–26.8)	24.3 (22.0–26.75)	0.901*
Side(%)			
Left	121 (48.8)	61 (56.5)	0.111
Right	127 (51.2)	47 (43.5)	
Stone burden (mm^2), median(IQR)	1015 (774–1104)	1111 (876–1616)	< 0.001##
Stone HU, median(IQR)	897 (680–1107)	986 (742–1099)	0.311##
Hydronephrosis (%)			
None or mild	173 (69.8)	70 (64.8)	0.642*
Moderate	54 (21.8)	28 (25.9)	
Severe	21 (8.5)	10 (9.3)	
Anatomic (%)			
Pelvis or mid/lower calyx	145 (58.4)	44 (40.7)	0.005*
Upper calyx	52 (21.0)	28 (26.0)	
Calyceal diverticulum or Partial staghorn stone	35 (14.1)	19 (17.6)	
Staghorn stone	16 (6.5)	17 (15.7)	
Number of stone			
0–2	142 (57.3)	50 (46.3)	0.064*
≥ 3	106 (42.7)	58 (53.7)	

t test; ## Mann-Whitney-U test; * Chi squared test; SD, standard deviation; IQR, Interquartile Range; BMI, Body Mass Index; HU, Hounsfield units; EBL, Estimated Blood loss; OT, Operation time; PHT, Postoperative hospitalization time;

Variable	Stone-free (n = 248)	Non stone-free (n = 108)	*p* Value
Length of tract (%)			
< 10 cm	153 (61.7%)	49 (45.4)	0.003*
> 10 cm	95 (38.3)	59 (54.6)	
Hemoglobin change (mg/dl), median(IQR)	1.9 (1.3–2.3)	2.1 (1.5–2.3)	0.082##
Estimated Blood loss (%)			
> 250 cc	38 (15.3)	35 (32.4)	0.001*
< 250 cc	210 (84.7)	73 (67.6)	
OT (min)	70 (60–80)	78 (60–93)	0.163##
PHT (d)	7 (6–9)	7.5 (6–9)	0.928##
Complications	57 (22.9%)	54 (50.0%)	< 0.001##
Guy's score	2 (1–2)	3 (2–3)	< 0.001##
S.T.O.N.E. score	6 (6–8)	8 (7–9.5)	< 0.001##
SHA.LIN score	7 (7–9)	11 (10–12.5)	< 0.001##

t test; ## Mann-Whitney-U test; * Chi squared test; SD, standard deviation; IQR, Interquartile Range; BMI, Body Mass Index; HU, Hounsfield units; EBL, Estimated Blood loss; OT, Operation time; PHT, Postoperative hospitalization time;

There was a positive association between the three stone scores and complications, SFS (Table 3). Figure 1A shows the AUC for the three stone scores in predicting SFS. SHA.LIN score revealed the highest accuracy in predicting SFS. The estimated AUC for SHA.LIN stone score was 0.829 compared to 0.789, and 0.731 for S.T.O.N.E and Guy's stone scores. According to the Clavien-Dindo complication system, 111 experienced postoperative complications, including Clavien grade I in 49, Clavien grade II in 38, Clavien grade III in 21, and Clavien grade IV in 3. As the score increases of three stone scores, so does the incidence of complications. ROC analysis area AUC (Fig. 1B) demonstrated the SHA.LIN stone score predicting the postoperative complications yielded an AUC of 0.817, which was greater than Guy's score (0.630) and S.T.O.N.E. score (0.620) .

Table 3
Stone free and complication rates of three stone score

Stone Scores	No. Stone free / Total (%)	No. Complications / Total (%)
Guy's score		
I	91 / 107 (85.0)	26 / 107 (24.3)
II	119 / 153 (77.8)	35 / 118 (29.7)
III	37 / 69 (53.6)	34 / 69 (49.3)
IV	1 / 27 (3.7)	16 / 27 (59.3)
S.T.O.N.E. score		
5–6	130 / 144 (90.3)	34 / 145 (23.4)
7–8	94 / 140 (67.1)	44 / 140 (31.4)
9–13	24 / 72 (33.3)	33 / 72 (45.8)
SHA.LIN score		
6–8	174 / 186 (93.54)	23 / 186 (12.3)
9–11	53 / 101 (52.47)	45 / 101 (41.6)
12–14	18 / 57 (31.5)	37 / 57 (64.9)
15–17	3 / 12 (25.0)	9 / 12 (75.0)

When three stone scores were individually assessed for their association with SFS, haemoglobin change, EBL, OT, and PHT (Table 4), regression analysis showed that both stone scores were significantly associated with SFS and OT. None of the three stone scores was significantly correlated with PHT. EBL and haemoglobin change were found significantly correlated with SHA.LIN stone score. ROC analysis area AUC (Fig. 1C) demonstrated a more accurate prediction of blood loss based on the SHA.LIN stone score (AUC = 0.744) in comparison with Guy's stone score (AUC = 0.573) and S.T.O.N.E. score (AUC = 0.564).

Table 4
The association between three stone scores and stone-free status, complications, Hemoglobin change, EBL, OT, and PHT.

Stone Scores	B-coefficient	Odds-ratios	95% CI		*p* Value
			Lower	Upper	
Stone free status					
Guy’s score	−1.159	0.314	0.231	0.427	< 0.001*
S.T.O.N.E. score	−0.800	0.450	0.370	0.547	< 0.001*
SHA.LIN score	−0.560	0.571	0.505	0.647	< 0.001*
EBL (mm)					
Guy’s score	−0.263	0.768	0.589	1003	0.053*
S.T.O.N.E. score	−0.099	0.905	0.787	1.042	0.166*
SHA.LIN score	−0.309	0.734	0.663	0.812	< 0.001*
Hemoglobin change (mg/dl)					
Guy’s score	0.077	-	−0.002	0.156	0.056#
S.T.O.N.E. score	0.024	-	−0.018	0.066	0.264#
SHA.LIN score	0.083	-	0.057	0.109	< 0.001#
OT (min)					
Guy’s score	4.715	-	2.322	7.108	< 0.001#
S.T.O.N.E. score	1.837	-	0.551	3.123	0.005#
SHA.LIN score	0.854	-	0.044	1.684	0.005#
PHT (d)					
Guy’s score	0.160	-	0.262	0.581	0.457#
S.T.O.N.E. score	−0.028	-	−0.253	0.196	0.806#
SHA.LIN score	0.044	-	−0.010	0.188	0.604#

* Logistic regression analysis; # linear regression analysis; CI, Confidence interval; EBL, Estimated Blood loss; OT, Operation time; PHT, Postoperative hospitalization time;

Discussion

The PCNL is well established as the first-line treatment for complex and high volume upper urinary stones, with stone clearance rates ranging from 60 to 90% [16, 17]. The ultimate goal of the operation is to reach a stone-free status with minimal morbidity. However, Just as all other surgical interventions, PCNL confers differing risks of complications and residual stone. Preoperative stratification of risk factors and reliable surgical planning remain of utmost priority for patients and urologists, particularly in the context of weighing the benefits of operation against potential risks and adverse effects. More and more scholars have taken advantage of perioperative factors to predict SFS and risk of complications after PCNL. To date, multiple attempts have been made to elaborate a scoring system that benefits from patients. However, none of the proposed scoring system have been generally adopted as a standard owing to their limited predictive accuracy, lack of validation and clinical utility.

In a previous study, Chinese scholars proposed SHA.LIN stone score for assessing the stone-free rate of PCNL and investigated the clinical value in patients undergoing PCNL. However, unlike Guy's or S.T.O.N.E. scoring system, SHA.LIN score has not been universally known to urologists and is still pending validation. This study aimed to introduce the SHA.LIN score and compare the accuracy to S.T.O.N.E. and Guy's stone scores in predicting postoperative outcomes. Compared to previously proposed stone scoring systems, the SHA.LIN stone score uses variables that are easily calculated from NECT and do not require specialized software. The stone score variables were defined based on operation experience and draws on extensive literature reviews and existing stone scoring systems [5–7].

The predictive accuracy of Guy's and S.T.O.N.E. scoring systems has been summarized and compared in published works. Study results have varied, however. As we know, Guy's score is reproducible and is simple to apply in routine clinical practice for assessing surgical risk. However, it does not account for critical variables such as stone burden, calyceal involvement and stone density [6]. Most research reported that these parameters have an important influence on postoperative outcomes [10, 15, 18]. In addition, Guy's score has four grades limiting the ability to evaluate the complexity of stone characteristics. Although S.T.O.N.E. and SHA.LIN scores have common parameters, such as stone burden, tract length, degree of hydronephrosis, and stone essence, the definitions of these parameters are still different [5]. For instance, stone burden is an essential parameter in two scoring systems, whereas in SHA.LIN score, stone burden was estimated by combining stone length and maximum length in CT slice in square millimeters. If stone is multiple, the SHA.LIN score calculate the sum of every stone area. The S.T.O.N.E. score only calculated the largest stone by combining the measures of length and width in square millimeters. We believe that the stone burden of SHA.LIN can better reflect the complexity of stone characteristic. In the S.T.O.N.E. score, the definition of calyx and imaging plane is not standardized. Stone size/number of calices involved is also not standardized and is variable between different observers [8, 9]. Hydronephrosis degree score is subjective and does not have a clear definition in S.T.O.N.E. score [8]. In SHA.LIN score, the author not only refined the number of calices containing stones, anatomic distribution of stones and number of involved calices but also made a clear definition of each variable. Thus, urologists can perform a standardized evaluation of every patient with a CT scan, increasing the reliability of the outcome assessments.

In the present study, stone clearance with PCNL was 69.3%, whereas similar studies by Krishnendu[15] had SFS of 71.5%, Thomas[19] had SFS of 62.0%, Labadie[20] had SFS of 56.0%. Stone burden is the most crucial variable for predicting the SFS. In our study, there was a statistically significant difference in the mean size of stones in the two groups ($p < 0.001$). The presence of stones in multiple calyces was significantly associated with a decreased stone-free rate in comparison to single calyceal involvement. Staghorn stone had a significant association with SFS, with partial staghorn stone had 56.7% and complete staghorn stone had 48.5% SFS. Labadie[20] reported that staghorn renal stone had shown 40% SFR among operated patients. In Guy's score, partial staghorn as Grade III and complete staghorn as Grade IV, stone clearance rates were 35% and 25% respectively [6]. Research showed that stone distribution and location have an essential on SFS. There are two opposing opinions in the determination of stone distribution in S.T.O.N.E and Guy's scores [8]. The Guy's score similarly assigns categorizations according to anatomic distribution in the renal pelvis, lower calyx, middle calyx, and upper calyx. In contrast, S.T.O.N.E. score prioritizes the number of stones involved calyces, with an overall algorithm determining how much weight each location contributes to complication and SFS [8]. Whereas the SHA.LIN score was referred to the above two scoring systems. The authors not only considered the effect of staghorn stones on the stone clearance rate, but also redefined the distribution of stones in renal calyx. Stone in renal pelvis or mid/lower calyx is assigned 1 point. Stone in the upper calyx is assigned 2 point. Stones in a calyceal diverticulum or partial staghorn stone is assigned 3 point. Full Staghorn stone is assigned 4 point. We believe this classification method is more indicative of the complexity of stone characteristics. In the present study, three stone scores were significantly associated with SFS and operation time. These conclusions are consistent with previous reports [10, 21, 22]. We noted the comparable accuracy of the SHA.LIN score (AUC, 0.829), Guy's score (AUC, 0.731), and the S.T.O.N.E. score (AUC, 0.789) for predicting SFS. This can be interpreted as SHA.LIN had a higher power to predict the SFS after PCNL than the other two scoring systems.

Bleeding is one of the most unpredictable and threatening complications during PCNL. Published data showed that stone burden, degree of hydronephrosis and staghorn stone are associated with an increased risk of blood loss complication [23]. The variables of the SHA.LIN score include these risk factors. In recent studies, the relationship between EBL and stone scores was unclear [13, 15]. Akhavein reported that S.T.O.N.E. score had significant correlation with SFS, but did not find correlation with EBL in a study of 117 patients [24]. In previous study of 437 patients, they found there hadn't significant correlation between S.T.O.N.E. score and EBL [13]. Labadie, in a study of 246 patients who underwent PCNL, concluded that Guy's and S.T.O.N.E. scores had significant correlation with EBL [25]. The differences in these studies may be due to a low number of renal stone patients or poor universality of the scoring system. In the present study, EBL and haemoglobin change were significantly correlated with SHA.LIN stone score. ROC analysis area AUC demonstrated a more accurate prediction of blood loss based on the SHA.LIN stone score in comparison with the other two stone scores. However, the conclusion needs further validation. As a new scoring for stone characteristics, SHA.LIN can accurately predict SFS and can be used to assess surgical risk factors. However, it has limitations, including lack of accurate measurement of stone size and individual surgical experience. If these issues are resolved, the SHA.LIN stone score could be a more precise predictive tool for postoperative outcomes.

There are still some limitations in the present study. Firstly, this is a single center, small sample size and retrospective study. To solve these problems, we standardized clinical data collection and analysis procedures and used rigid parameter definitions. In China, SHA.LIN stone score is the first proposal of a predictive method for the SFS after PCNL. We only compare it to Guy’s and S.T.O.N.E. scores, not to Clinical Research Office the Endourological Society nephrolithometric nomogram. Further research should be performed to validate the results. Lastly, we did not use CT to detect the SFS randomly in all patients like other studies[5, 20] had done, which may cause bias in SFS calculation. To solve this problem, all patients received KUB and ultrasound every month for three months to detect SFS.

Conclusion

The SHA.LIN stone score can predict postoperative stone free status of PCNL and can be used as an adjuvant tool for surgical planning and patient counseling. Further, three stone scores, namely Guy’s, S.T.O.N.E. and SHA.LIN, are well associated with stone free status and operation time and in addition, SHA.LIN is also significantly associated with surgical bleeding risk. However, further validation of SHA.LIN score with external data is important to validate its accuracy and general applicability for PCNL.

Abbreviations

AUC
Area Under the ROC Curve
BMI
Body Mass Index
CT
Computed tomography
EBL
Estimated blood loss
EAU
European Association of Urology
HU
Hounsfield units
IQR
Interquartile Range
KUB
Kidney, ureter, and bladder x-ray
OT
Operation time
PHT
Postoperative hospitalization time
PCNL

Percutaneous Nephrolithotomy
ROC
Receiver Operating Characteristics
SD
Standard deviation
SFS
Stone-free status

Declarations

Ethical Statement: This study was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Human Ethics Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology. All recipients signed informed consent in the present study.

Consent for publication：Written informed consent for publication was obtained from all participants.

Availability of date: All data used or analysed during the current study are available from the corresponding author on reasonable request.

Conflict of interest: The authors declare that they have no competing interest.

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Authors' contributions: Conception and design: Kai Zeng, Jihong Liu; Administrative support: Tao Wang, Shaogang Wang, Zhangqun Ye, Xiaoyong Zeng; Collection and assembly of data: Kai Zeng; Data analysis and interpretation: Kai Zeng; Manuscript writing: All authors; All authors reviewed the manuscript.

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References

1. Sorokin I, Mamoulakis C, Miyazawa K, Rodgers A, Talati J, Lotan Y. Epidemiology of stone disease across the world. World journal of urology. 2017;35(9):1301–20.
2. Tzelves L, Türk C, Skolarikos A. European Association of Urology Urolithiasis Guidelines: Where Are We Going? Eur Urol Focus. 2021;7(1):34–8.
3. Wollin DA, Preminger GM. Percutaneous nephrolithotomy: complications and how to deal with them. Urolithiasis. 2018;46(1):87–97.
4. Knoll T, Daels F, Desai J, Hoznek A, Knudsen B, Montanari E, et al. Percutaneous nephrolithotomy: technique. World journal of urology. 2017;35(9):1361–8.

5. Okhunov Z, Friedlander JI, George AK, Duty BD, Moreira DM, Srinivasan AK, et al. S.T.O.N.E. nephrolithometry: novel surgical classification system for kidney calculi. Urology. 2013;81(6):1154–9.
6. Thomas K, Smith NC, Hegarty N, Glass JM. The Guy's stone score–grading the complexity of percutaneous nephrolithotomy procedures. Urology. 2011;78(2):277–81.
7. Smith A, Averch TD, Shahrour K, Opondo D, Daels FPJ, Labate G, et al. A nephrolithometric nomogram to predict treatment success of percutaneous nephrolithotomy. The Journal of urology. 2013;190(1):149–56.
8. Huynh LM, Huang E, Patel RM, Okhunov Z. Predictability and Practicality of Image-Based Scoring Systems for Patient Assessment and Outcome Stratification During Percutaneous Nephrolithotomy: a Contemporary Update. Curr Urol Rep. 2017;18(12):95.
9. Wu WJ, Okeke Z. Current clinical scoring systems of percutaneous nephrolithotomy outcomes. Nature reviews Urology. 2017;14(8):459–69.
10. Lai S, Jiao B, Jiang Z, Liu J, Seery S, Chen X, et al. Comparing different kidney stone scoring systems for predicting percutaneous nephrolithotomy outcomes: A multicenter retrospective cohort study. Int J Surg. 2020;81:55–60.
11. Ito Y, Kikuchi E, Tanaka N, Miyajima A, Mikami S, Jinzaki M, et al. Preoperative hydronephrosis grade independently predicts worse pathological outcomes in patients undergoing nephroureterectomy for upper tract urothelial carcinoma. The Journal of urology. 2011;185(5):1621–6.
12. Asai S, Fukumoto T, Watanabe R, Koyama K, Sawada Y, Noda T, et al. New classification of hydronephrosis on 18F-FDG-PET/CT predicts post-operative renal function and muscle-invasive disease in patients with upper urinary tract urothelial carcinoma. Jpn J Clin Oncol. 2018;48(11):1022–7.
13. Yarimoglu S, Polat S, Bozkurt IH, Yonguc T, Aydogdu O, Aydın E, et al. Comparison of S.T.O.N.E and CROES nephrolithometry scoring systems for predicting stone-free status and complication rates after percutaneous nephrolithotomy: a single center study with 262 cases. Urolithiasis. 2017;45(5):489–94.
14. Raman JD, Bagrodia A, Bensalah K, Pearle MS, Lotan Y. Residual fragments after percutaneous nephrolithotomy: cost comparison of immediate second look flexible nephroscopy versus expectant management. The Journal of urology. 2010;183(1):188–93.
15. Biswas K, Gupta SK, Tak GR, Ganpule AP, Sabnis RB, Desai MR. Comparison of STONE score, Guy's stone score and Clinical Research Office of the Endourological Society (CROES) score as predictive tools for percutaneous nephrolithotomy outcome: a prospective study. BJU Int. 2020;126(4):494–501.
16. Chen K, Xu K, Li B, Wang S, Xiang S, Li H. Predictive factors of stone-free rate and complications in patients undergoing minimally invasive percutaneous nephrolithotomy under local infiltration anesthesia. World journal of urology. 2020;38(10):2637–43.

17. Karalar M, Tuzel E, Keles I, Okur N, Sarici H, Ates M. Effects of Parenchymal Thickness and Stone Density Values on Percutaneous Nephrolithotomy Outcomes. Med Sci Monit. 2016;22:4363–8.
18. Jeong CW, Jung J-W, Cha WH, Lee BK, Lee S, Jeong SJ, et al. Seoul National University Renal Stone Complexity Score for Predicting Stone-Free Rate after Percutaneous Nephrolithotomy. PLoS One. 2013;8(6):e65888.
19. Thomas K, Smith NC, Hegarty N, Glass JM. The Guy's stone score–grading the complexity of percutaneous nephrolithotomy procedures. Urology. 2011;78(2):277–81.
20. Labadie K, Okhunov Z, Akhavein A, Moreira DM, Moreno-Palacios J, Del Junco M, et al. Evaluation and comparison of urolithiasis scoring systems used in percutaneous kidney stone surgery. The Journal of urology. 2015;193(1):154–9.
21. Choi SW, Bae WJ, Ha US, Hong S-H, Lee JY, Kim SW, et al. Prediction of stone-free status and complication rates after tubeless percutaneous nephrolithotomy: a comparative and retrospective study using three stone-scoring systems and preoperative parameters. World journal of urology. 2017;35(3):449–57.
22. 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 journal of urology. 2015;33(11):1821–5.
23. Keoghane SR, Cetti RJ, Rogers AE, Walmsley BH. Blood transfusion, embolisation and nephrectomy after percutaneous nephrolithotomy (PCNL). BJU Int. 2013;111(4):628–32.
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(1):69–73.
25. Lehman DS, Hruby GW, Phillips C, Venkatesh R, Best S, Monga M, et al. Prospective randomized comparison of a combined ultrasonic and pneumatic lithotrite with a standard ultrasonic lithotrite for percutaneous nephrolithotomy. Journal of endourology. 2008;22(2):285–9.

Figures

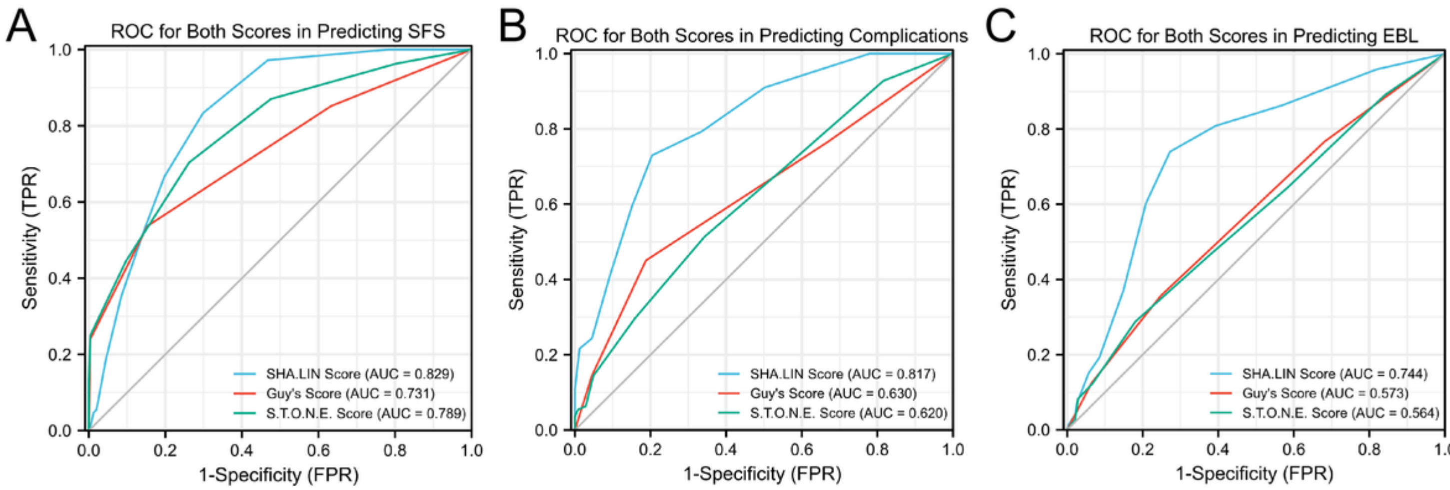

Figure 1

Receiver operating characteristic (ROC) curves for three scoring systems in predicting stone-free status(A), complications(B), and estimated blood loss(C).

Supplementary Files

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