Validation of STONE nephrolithometry scoring system in the management of large renal stones by percutaneous or open nephrolithotomy

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Objective

To assess the validity of STONE nephrolithometry scoring system in the prediction of surgical outcome following percutaneous nephrolithotomy (PCNL) for large renal stones and for the first time we further tested its applicability in open stone surgery (OSS).

Patients and methods

The STONE score was retrospectively calculated from preoperative noncontrast computed tomography of 100 adult patients treated for more than or equal to 20 mm renal stones with either PCNL (65 patients) or OSS (35 patients) from January 2019 till July 2020. Correlations of STONE score with operative time, estimated blood loss, primary stone-free rate (SFR), complications, and hospital stay within each group were assessed.

Results

The OSS group was older than the PCNL group (mean, 53 ± 11 vs. 47 ± 12 years, P=0.008), had higher stone size (mean, 7.1 ± 2.7 vs. 3.1 ± 1.5 cm, P<0.001), and STONE score (median, 10 vs. 7, P<0.001), respectively.

STONE score showed an inverse correlation (P<0.001) with primary SFR within PCNL and OSS (r=−0.581 and r=−0.567, respectively). Primary SFR was more than 90% with STONE score less than or equal to 8 in PCNL and less than or equal to 10 in OSS. STONE score also directly correlated with intraoperative estimated blood loss within PCNL (r=0.389, P=0.001) and OSS (r=0.355, P=0.036) and with the operative time (r=0.400, P=0.001) only in the PCNL group. However, the score was not correlated with postoperative hospital stay or complications in both groups.

Conclusions

The STONE nephrolithometry score is a valid tool in the prediction of surgical outcomes following both PCNL and OSS. Additional validation of this scoring system is important particularly to confirm its general applicability for OSS.

Keywords:
nephrolithiasis, renal calculi, renal calculus, urolithiasis

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Introduction

Urinary stone disease is one of the most common diseases of the urinary tract all over the world [1]. It affects ~5–15% of the world population with a high incidence in young adults between the third and fourth decades of life [2,3]. Approximately 15–20% of all patients with renal stones need invasive intervention [4].

Currently, percutaneous nephrolithotomy (PCNL) is the treatment of choice for most large renal stones [5]. However, open stone surgery (OSS) still has its importance in some large complex stones. In developed countries, OSS represents 1–5.4% of stone surgeries as compared with up to 14% in developing countries [6,7].

Prediction of surgical outcome for large renal stones is important for surgical planning and proper patient counseling. Multiple scoring systems have been proposed utilizing different metrics to enable extensive patient orientation, more effective surgical planning, better evaluation of treatment outcomes, and uniform academic reporting.

Recently, three different scoring systems were used for objective assessment of kidney stones and prediction of outcomes: The Guy's Stone Score, the Clinical Research Office of the Endourological Society nomogram, and STONE nephrolithometry score [8–10]. These were compared and showed similar predictive accuracy of stone-free rate (SFR) and the STONE score had additional value in predicting the operative time [11].

Our objective was to assess the validity of STONE nephrolithometry scoring system in the prediction of surgical outcome following PCNL for large renal stones and for the first time we further tested its applicability in OSS.

Patients and methods

The study was conducted retrospectively from data obtained for clinical purposes with an informed consent and an Institutional Research Ethics Committee approval. In all, 100 adult patients aged more than 18 years treated for more than or equal to 20 mm renal stones with either PCNL (65 patients) or OSS (35 patients) by two expert endourologists between January 2019 and July 2020 with complete medical records were included in this study.

Patients with single functioning kidney, bleeding diathesis, or with another renal pathology as renal masses, perinephric abscess, or renal congenital anomalies were excluded from this study. Second-look PCNL procedures were also excluded as per the original study by Okhunov *et al.* [10].

The STONE (Stone Size, Tract length, Obstruction/hydronephrosis, Number of involved calyces, Essence/Hounsfield units) nephrolithometry scoring system was calculated from preoperative noncontrast computed tomography (CT) as follows: the stone size was estimated by combining the measures of length and width in square millimeters and was scored from 1 to 4 according to a calculated area (0–399, 400–799, 800–1599, and ≥1600 mm^2). The tract length evaluated the skin-to-stone distance, which was defined as the vertical distance from the center of the stone to the skin measured on a supine noncontrast CT film. The tract length was scored 1–2 according to a cutoff length of 10 cm that corresponds with a BMI of 30 kg/m^2, which is an accepted cutoff for obesity. The third variable, obstruction, evaluates the degree of hydronephrosis and was assigned 1–2 points (no/mild dilation or moderate to severe dilation). The fourth component assessed the number of calices involved by stones and was assigned 1–3 points (single calyx, 2–3 calices, or full staghorn calculus). The last variable is the stone essence, which evaluates the stone density measured on preoperative CT imaging and was assigned 1–2 points according to a radiodensity threshold of 950 Hounsfield units. The scores from each variable were summed to determine the STONE nephrolithometry score that can vary from a minimum of 5 to a maximum of 13 [10].

The SFR was defined as the absence of residual stones or the presence of asymptomatic clinically insignificant residual fragment of less than 4 mm on the noncontrast CT in the next 30 days postoperatively. Accordingly, a plain abdominal radiograph of the kidneys, ureters and bladder was done for all patients on postoperative days 2 and 30, and another noncontrast CT was done on the postoperative day 30 for definite evaluation of residual stones and SFR.

Postoperative complications were recorded and graded using the modified Clavien-Dindo classification system [12]. Demographic, stone characteristics, and operative and postoperative data were compared between both groups using the independent *t* test, χ^2 test, and Mann–Whitney tests. Correlations of STONE score with operative time, estimated blood loss (EBL), primary SFR, complications, and hospital stay within each group were assessed. *P* value less than 0.05 was considered statistically significant.

Surgical techniques

Percutaneous nephrolithotomy

PCNL was done in the prone position in 63/65 (97%) cases and in the supine position in 2/65 (3%) cases. Under fluoroscopic guidance, 57/65 (88%) cases had a single puncture tract and 8/65 (12%) cases had double puncture tracts. Tract dilatation was done using serial semirigid Amplatz dilators (Cook Medical, Bloomington, Indiana, USA) and a 30-Fr Amplatz working sheath was used. Stone fragmentation was accomplished using a pneumatic lithoclast system. At the end of the procedure, a double-J ureteric stent was inserted in 44/65 (68%) cases and ureteric catheter was left in 21/65 (32%) cases. A nephrostomy tube (26 F) was inserted in 59/65 (91%) cases.

The ureteric catheter was removed on postoperative day 1. The nephrostomy tube was removed 48 ± 8 h after surgery. The DJ stent was removed 43 ± 17 days after surgery. It was kept longer in place in the case of shockwave lithotripsy or another session of PCNL was planned for residual stones.

Open stone surgery

The kidney was exposed through a flank incision over the 11th intercostal space. The stones were retrieved through pyelotomy. Additional nephrotomy incisions were done for separate unreachable stones in 8/35 cases. At the end of the procedure, ureteric stent and

Jackson-Pratt drain were placed in all cases. Foley's catheter was removed 4 ± 1 days postoperatively. The drain was removed 5 ± 1 days after surgery and the ureteric stent was removed 38 ± 15 days after surgery.

Results

The OSS group were older (P=0.008) than the PCNL group (53 ± 11 vs. 47 ± 12 years, respectively). There was no statistically significant difference in terms of sex, BMI, and medical and surgical history. Out of the 35 patients who underwent OSS, 26 (74%) had complete staghorn stones as compared with 6/65 (9%) of the PCNL group. Compared with the PCNL group, OSS had statistically significant (P<0.05) higher stone size (mean, 7.1 ± 2.7 vs. 3.1 ± 1.5 cm), operative time (mean, 2.9 ± 0.9 vs. 2.1 ± 0.6 h), intraoperative EBL (mean, 128 ± 53 vs. 102 ± 52 ml), and hospital stay (mean, 5.2 ± 1 vs. 3.5 ± 0.8 days). STONE score was higher (P<0.001) in OSS versus PCNL group [median, 10 (range, 7–12) vs. 7 (range, 6–11), respectively]; however, primary SFR remained higher (P=0.021) in OSS versus PCNL (mean, 97.5 vs. 90.2%, respectively) with a lower rate (P=0.049) of secondary procedures (11 vs. 29%, respectively). There was no difference in intraoperative blood transfusion or complication rates (Table 1).

Major complications reported in PCNL were urinary fistula (one case, 1.5%) and chest pain (one case, 1.5%) while OSS encountered pleural injury with pneumothorax (one case, 2.9%) and infected gapped wound (one case, 2.9%).

The STONE score showed an inverse correlation (P<0.001) with primary SFR within PCNL and OSS (r=−0.581 and r=−0.567, respectively). Primary SFR was more than 90% with a STONE score less than or equal to 8 in PCNL and up to a score of 10 in OSS. SFR was less than 80% in both groups with a STONE score of 11–12. Primary SFR inversely correlated with stone size within PCNL (r=−0.367, P=0.003) and OSS (r=−0.399, P=0.018) but not with the number of involved calyces in both groups (Table 2).

The STONE score also directly correlated with intraoperative EBL within PCNL (r=0.389, P=0.001) and OSS (r=0.355, P=0.036) and with the operative time (r=0.400, P=0.001) and postoperative ureteric stent duration (r=0.366, P=0.036) only in the PCNL group but not in OSS. The score was not correlated with postoperative hospital stay or Clavien-Dindo grade of complications in both groups (Tables 3 and 4).

Discussion

In 2012, the STONE nephrolithometry scoring system was proposed by Okhunov *et al.* [10] to standardize reporting for PCNL and predict the SFR and perioperative parameters. The study included a total of 117 patients. The mean score was 7.7 (range, 4–11). The STONE score correlated with the postoperative SFR (P=0.001), EBL (P=0.005), operative time (P=0.001), and hospital stay (P=0.001).

The STONE nephrolithometry scoring system has the advantage of using parameters that are easy to calculate from noncontrast-enhanced CT images, the most common diagnostic modality used to evaluate patients for stone disease without specialized software [10].

It has been externally validated in several studies [11,13–16]. Akhavein *et al.* [13] validated the system as a reproducible and predictive model for treatment success after PCNL in 122 patients. Mean nephrolithometry scores for residual stones of 0–2, 3–4, and more than 4 mm were 8.9, 9.7, and 10.8, respectively (P<0.0001). Also, a multi-institutional study of 706 patients confirmed that the model was significantly associated with SFR, overall complications, EBL, operative time, and hospital stay after PCNL [16].

The purpose of the scoring system is to integrate the relevant variables into a comprehensive score that more accurately predicts the surgical outcome than the individual variables by themselves. While validation of the STONE nephrolithometry scoring system for PCNL is not a new topic, the present study is unique in that it explores its potential application to OSS as a standardized measure that can help urologists in selecting the optimum procedure for patients with large renal stones.

It is obvious that stone size and the number of involved calyces would intuitively affect SFR in OSS. Also, tract length corresponds with BMI which can impact operative time and perioperative complications in OSS. Dense large renal stones impose a more difficult lithotripsy that may raise the consideration of OSS. In a previous study, however, it was found that tract length, obstruction/hydronephrosis, and stone essence may not contribute to predicting SFR after PCNL [14].

In our study, OSS were older and had more complex stones. This is expected in a nonrandomized retrospective study. The STONE score was higher in OSS (median, 10;

Table 1 Patient characteristics and perioperative data

	PCNL group (*N*=65)	OSS group (*N*=35)	Test value	*P* value
Age (years)				
Mean±SD	47±12	53±11	–2.699[b]	0.008
Range	17–76	35–70		
Sex [*n* (%)]				
Females	33 (50.8)	13 (37.1)	1.701[a]	0.192
Males	32 (49.2)	22 (62.9)		
BMI (kg/m^2)				
Mean±SD	29.65±5.97	29.34±5.53	0.254[b]	0.800
Range	21.82–55.25	21.48–45.7		
Stone size (cm)				
Mean±SD	3.1±1.5	7.1±2.7	–10.534	<0.001
Range	2–8	3–13		
STONE score				
Median (IQR)	7 (7–8)	10 (9–10)	–6.495[c]	<0.001
Range	6–11	7–12		
Surgical history [*n* (%)]				
Recurrent cases	29 (44.6)	10 (28.6)	2.462[a]	0.117
Operative time (min)				
Mean±SD	123.5±34.6	175.7±55.1	–5.818[b]	<0.001
Range	55–200	120–360		
Intraoperative blood loss (ml)				
Mean±SD	102.1±51.8	128.3±52.9	–2.394[b]	0.019
Range	50–300	70–250		
Intraoperative blood transfusion [*n* (%)]				
No	58 (89.2)	28 (80.0)		
One packed RBCs	7 (10.8)	5 (14.3)	4.174[a]	0.124
Two packed RBCs	0	2 (5.7)		
Complications (Clavien-Dindo grade) [*n* (%)]				
Grades 1 and 2	63 (96.9)	33 (94.2)		
Grade 3	0	1 (2.8)	0.454[b]	0.975
Grade 4	2 (3.0)	1 (2.8)		
Grade 5	0	0		
Postoperative hospital stay (days)				
Mean±SD	3.52±0.84	5.23±1.00	–8.959[b]	<0.001
Range	3–8	4–8		
Primary stone-free rate (%)				
Mean±SD	90.18±18.22	97.54±4.25	–2.350[b]	0.021
Range	0–100	78–100		
Secondary procedures [*n* (%)]				
No	46 (70.8)	31 (88.6)		
SWL	16 (24.6)	2 (5.7)	7.851[a]	0.049
PCNL	1 (1.5)	2 (5.7)		
Chemodissolution	2 (3.1)	0		

[a]χ^2 test. [b]Independent *t* test. [c]Mann–Whitney test. OSS, open stone surgery; PCNL, percutaneous nephrolithotomy; SWL, extracorporeal shock wave lithotripsy. Significant P values (<0.05).

range, 7–12) versus PCNL (median, 7; range, 6–11). Yet, primary SFR was higher in OSS versus PCNL group (97.5 versus 90%, *P*=0.021) at the expense of a longer operative time and hospital stay due to the difference in surgical techniques. Complications remained minor within Clavien-Dindo grades 1 and 2 in both groups.

Achieving high primary SFR is important. An increased stone burden increases the chance of multiple procedures and the risk of surgery increases with each additional less invasive procedure [17]. Also, treatment cost increases with the added auxiliary and secondary procedures. It is essential to ensure that the patients are well informed with all the potential risks and benefits of each possible therapeutic modality highlighting the predicted primary SFR, the possible need for secondary or auxiliary procedures with its added surgical risks and costs.

Table 2 Correlation between primary stone-free rate with STONE score, stone size, and number of involved calyces

	PCNL (N=65)				OSS (N=35)			
	n (%)	Primary SFR % (mean±SD)	Test value	P value	n (%)	Primary SFR % (mean±SD)	Test value	P value
STONE score								
6	10 (15.4)	98.9±0.99	r=–0.581	<0.001	–	–	r=–0.567	<0.001
7	24 (36.9)	96.1±5			2 (5.7)	100±0		
8	22 (33.8)	93.1±9			3 (8.6)	99.3±1		
9	5 (7.7)	88.4±6			8 (23)	99.2±0.9		
10	3 (4.6)	78.7±5			20 (57)	96.8±3.4		
11	1 (1.5)	80			–	–		
12	–	–			2 (5.7)	77±1.4		
Stone size (cm)			r=–0.367	0.003			r=–0.399	0.018
Number of involved calyces								
1	20 (30.8)	98.5±1.8	2.57	0.062	0	99.7±0.8	1.96	0.157
2	27 (41.5)	91.1±19.6			7 (20.0)	100.0±0.0		
3	12 (18.5)	83.1±27.5			2 (5.7)	95.6±6.1		
Staghorn	6 (9.2)	82.0±5.7			26 (74.3)	96.7±5.6		

OSS, open stone surgery; PCNL, percutaneous nephrolithotomy; r, Spearman correlation coefficient; SFR, stone-free rate. Significant P values (<0.05).

Table 3 Correlation between STONE score and perioperative data

	PCNL (N=65)		OSS (N=35)	
	Correlation (r)	P value	Correlation (r)	P value
Operative time (minutes)	0.400	0.001	0.017	0.925
Intraoperative estimated blood loss (ml)	0.389	0.001	0.355	0.036
Postoperative hospital stay (days)	0.148	0.252	0.180	0.301
Postoperative ureteric stent duration (days)	0.366	0.036	–0.013	0.941

OSS, open stone surgery; PCNL, percutaneous nephrolithotomy; r, Spearman correlation coefficient. Significant P values (<0.05).

Table 4 Correlation between STONE score and complications

	PCNL (N=65)				OSS (N=35)			
Complications (Clavien-Dindo grade)	n (%)	STONE score [median, IQR (range)]	Test value	P value	n (%)	STONE score [median, IQR (range)]	Test value	P value
Grade 1	58 (89)	7, 7–8 (6–11)			25 (71)	10, 9–10 (7–10)		
Grade 2	5 (7.7)	7, 7–7 (6–8)			8 (23)	10, 8–12 (8–12)		
Grade 3	1 (1.5)	8, 8–8 (8–8)	2.322[a]	0.508	1 (2.9)	9, 9–9 (9–9)	3.569[a]	0.312
Grade 4	1 (1.5)	8, 8–8 (8–8)			1 (2.9)	10, 10–10 (10–10)		
Grade 5	0	–			0	–		

OSS, open stone surgery; PCNL, percutaneous nephrolithotomy. [a]Kruskal–Wallis test.

We confirmed an inverse correlation of STONE score with primary SFR within PCNL. Primary SFR was more than 90% with STONE score less than or equal to 8 in PCNL, which is similar to the studies of Okhnuov who reported that stone-free patients had statistically significant lower scores than the patients with residual stones (6.8 vs. 9.7, respectively; P=0.002) [10] and in another study the mean STONE score for stone-free patients was 7.7 versus 9.1 for patients with residual stones, P value less than 0.001 [16]. STONE score also correlated with SFR after OSS; however, SFR remained high except for the highest score of 12.

In our study, 26/35 (74%) of OSS and 6/65 (9%) of PCNL had staghorn calculi (P<0.001). Primary SFR for staghorn calculi was higher (P<0.001) in OSS vs PCNL (mean, 96.7 vs. 82.0%, respectively). On the other hand, Al-Kohlany *et al.* [7] reported comparable SFR after PCNL and OSS in the treatment of staghorn stones (49 vs. 66%). Such difference may be due to the lack of uniform definition for staghorn stones that may affect the number of involved calyces and stone burden.

Our study further showed that STONE score correlated with EBL after OSS. It also directly correlated with intraoperative EBL and the operative time in the PCNL group which is similar to other studies [10,14–16]. However, the score was not correlated with postoperative hospital stay or Clavien-Dindo grade of complications in both groups. Similarly, Tailly *et al.*

[11] reported that the score was not an independent predictor of a longer length of stay or postoperative complications. Also, Noureldin *et al.* [14,15] showed no significant association between the scoring system and complications.

Despite the accuracy and feasibility of the STONE scoring system, we faced some issues in its application to our cases. First, calculation of stone size/burden is time-consuming for multiple stones. Second, the estimation of tract length is not specified in case of multiple stones. In these cases, we chose the stone in the center of the renal pelvis and measured its distance to skin on axial cuts to represent the skin-to-stone distance. Also, expressing tract length in only two categories (< or >10 cm) offered a limited reflection to the BMI. Third, the grades of hydronephrosis were subjective and not clearly demarcated especially in mild versus moderate dilation. Finally, the STONE score considers the number but not the location of calyces involved with stones although PCNL for upper calyceal stones has higher complication rates [18,19] than that for lower calyceal stones.

Our study has the limitations of a single institution nonrandomized retrospective study and the small patient numbers especially for the OSS group.

In conclusion, the STONE nephrolithometry score is a good predictive tool in both PCNL and OSS. It can be used as a guide for surgical planning and patient counseling. In PCNL it correlated with primary SFR, EBL, operative time, and postoperative ureteric stent duration. In OSS it correlated with primary SFR and EBL. The score was not correlated with postoperative hospital stay or Clavien-Dindo grade of complications in both groups.

This score can be classified into three categories ‘low’ score (≤8) where PCNL can be recommended expecting a primary SFR of more than 90%, ‘medium’ score ranges from 9 to 10 where OSS can achieve more than 90% primary SFR to be weighed against longer hospital stay and postoperative recovery period. With ‘higher’ scores (11–13), the patient will likely need additional secondary procedures for residual stones whatever be the selected procedure. Additional validation of this scoring system is important particularly to confirm its general applicability for OSS with possible refinement of scoring tools.

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There are no conflicts of interest.

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