Original Article

A Comprehensive Comparison of Guy's Stone Score, CROES Nomogram, S.T.O.N.E. Nephrolithometry, and the Seoul Renal Stone Complexity Scoring System in Predicting Perioperative Outcomes after Percutaneous Nephrolithotomy

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Background: Various nephrolithometry scoring systems (NSS) are proposed to determine the structural configuration of kidney stones. Nevertheless, evidence of the comparison among these scoring systems in anticipating postoperative outcomes after percutaneous nephrolithotomy (PCNL) are limited.

Objective: To compare the correlation of four NSS with stone-free rates and perioperative results following PCNL.

Materials and Methods: The authors examined a retrospective study of patients with kidney stones who received PCNL. One hundred seventy-two patients admitted for surgery at Ramathibodi Hospital were assessed. Four NSS were compared, Guy's Stone Score (GSS), the Clinical Research Office of the Endourological Society nephrolithometric nomogram (CROES), S.T.O.N.E. Nephrolithometry (STONE), and the Seoul National University Renal Stone Complexity (S-ReSC) scoring system. The authors evaluated the correlations between these four scoring systems with stone-free rates and postoperative outcomes.

Results: The stone-free status was 53.5%. There were significant differences in the mean scores of the four systems between the stone-free group and the not stone-free group (1.97 versus 3.70, $p<0.05$ in GSS; 242.40 versus 159.28, $p<0.05$ in CROES; 6.64 versus 9.08, $p<0.05$ in STONE; and 3.44 versus 8.41, $p<0.05$ in S-ReSC). Multivariate analysis revealed only S-ReSC as independent preoperative factors for PCNL success ($p<0.001$). Moreover, each scale had a significant correlation with blood loss, length of hospital stay, and operative time. Three scoring systems, all except STONE, were significantly associated with percentage change in estimated glomerular filtration rates (eGFR). There was no significant association among all four scoring systems with postoperative complications.

Conclusion: All four NSS represent excellent predictors for stone-free rates and correlate well with surgical outcomes.

Keywords: GSS, CROES, STONE, S-ReSC, Percutaneous nephrolithotomy

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Nephrolithiasis affects around 5% to 15% of the people around the world[1]. Recurrence rates reach 50%[2], and the budget for treatment and prevention of urolithiasis is expensive. Percutaneous nephrolithotomy (PCNL) has emerged as the gold standard for large renal calculi surgery. It should be given favorable management over anatrophic nephrolithotomy (ANL) if it is technically feasible[3]. To enhance the risk stratification of the kidney calculi before the percutaneous endoscopic surgery, the anatomy-based NSS have emerged[4-7]. At present, four distinct scoring systems are practiced extensively in urology. S.T.O.N.E. nephrolithometry

(STONE) is calculated from the burden of kidney calculi, percutaneous tract length, the severity of the obstruction, the total calyces involved, and the density of calculi as derived from computerized tomography (CT)[5]. Clinical Research Office of the Endourological Society nephrolithometric nomogram (CROES) assesses PCNL complexity by evaluating total patients per year, the location of calculi, the existence of staghorn stones, previous stone treatment, total stone size, and number of stones[6]. Guy's Stone Score (GSS) consists of four grades and was advanced through a consolidation of expert opinion, published literature analysis, and repetitive measurement[7]. S-ReSC depends on kidney calculi allocation in the pelvocalyceal system and does not consider characteristics of the patient or basic kidney anatomy[4]. There is still no standardized test of the existing scoring scales regarding their predictive value for postoperative results. The purpose of the present research was to comprehensively analyze the GSS, CROES, STONE, and S-ReSC scoring systems. The respective tools were their significances in predicting surgical outcomes after PCNL.

Materials and Methods

The study was conducted in agreement with the ethical principles of the Declaration of Helsinki and ethical approval for the research was permitted from the Institutional Review Board of the Faculty of Medicine, Ramathibodi Hospital (COA MURA2019/830). Patients' data were collected from the electronic medical records system. The study exclusion criteria were being below 18 years of age, having deficient preoperative CT imaging, the presence of tubeless nephrostomy, and patients with insufficient clinical data. The authors involved 282 patients admitted for PCNL at Ramathibodi Hospital between 2011 and 2019, but 110 patients were excluded. The patients' characteristics and preoperative imaging such as CT and surgical outcomes were collected. Complications were determined using the Clavien-Dindo classification with a follow-up of a minimum of one month. Additionally, operation time (OT), estimated blood loss (EBL), and length of stay (LOS) were analyzed to assess the performance of the scoring system in predicting postoperative results. Preoperative and postoperative estimated glomerular filtration rates (eGFR) were evaluated using the Modification of Diet in Renal Disease Study equation.

Statistical analysis

All statistical analyses were achieved using the SPSS Statistics for Windows, version 11.5 (SPSS Inc., Chicago, Ill, USA). Patient demographics and clinical characteristics were comprised using descriptive statistics. Continuous variables were shown as means and standard deviations and calculated with an independent sample t-test. After univariate analysis, variable with p-value of less than 0.05 were selected for multivariate analysis. Logistic regression analyses were used to investigate potential associations between the GSS, CROES, STONE, S-ReSC, and stone-free status. Correlated investigations were assessed using the Pearson correlation coefficient (r). Statistical significance was expressed as a two-tailed p-value of less than 0.05.

Results

Table 1 shows the demographic information and operative results of the PCNL surgery. PCNL was performed in 172 cases (71 male and 101 female). The median age was 58 years (interquartile range [IQR] 18 to 83 years) with an average body mass index (BMI) of 25.8 kg per m^2 (IQR 14.5 to 43.4 kg/m^2). The median kidney calculi burden was 563 mm^2 (IQR 32 to 2,346 mm^2). Median OT was 142 minutes (IQR 40 to 800 minutes), and EBL of 304 mL (IQR 10 to 2,000 mL).

The results for each NSS are shown in Table 2. The mean scores for GSS, CROES, STONE, and S-ReSC were 2.77 (range 1 to 4), 210.00 (range 128 to 258), 7.78 (range 5 to 12), and 5.31 (range 1 to 9), respectively. When estimating the data in accordance with the stone-free rate (SFR) and those with residual calculi, the mean for GSS was 1.97 and 3.70 ($p<0.001$), for CROES was 242.40 and 159.28 ($p<0.001$), for STONE was 6.64 and 9.08 ($p<0.001$), and for S-ReSC was 3.44 and 8.41 ($p<0.001$), respectively. Multivariate regression analysis demonstrated only S-ReSC as an independent preoperative factors for PCNL success ($p<0.001$) (Table 3). Furthermore, GSS, CROES, and STONE were not shown as a predictive factor for PCNL achievement in multivariate analysis ($p=0.334$, 0.170, and 0.222, respectively).

All scoring systems demonstrated a statistically significant correlation with OT, EBL, and LOS. Three scoring systems except STONE were associated with a change in eGFR. None of the NSS was statically correlated with complication rate ($p=0.673$ for GSS, $p=0.552$ for CROES, $p=0.687$ for STONE, and $p=0.862$ for S-ReSC), as shown in Table 4.

Table 1. Patient demographics and preoperative data

Variables	Mean (range)	Variables	Mean (range)
Number of patients	172	Blood loss (mL)	304 (10 to 2000)
Age (years)	58 (18 to 83)	Operative time (minute)	142 (40 to 800)
Sex (male:female)	71:101	Hospital stay (day)	7.7 (2 to 43)
Side of kidney stone (left:right)	98:74	Duration of nephrostomy (day)	4.3 (0 to 17)
BMI (kg/m^2)	25.8 (14.5 to 43.4)	Complications; n (%)	
Chief complaint; n (%)		Clavien grade I	22 (40.0)
Flank pain	82 (47.7)	Clavien grade II	19 (34.5)
Incidental findings	67 (38.9)	Clavien grade IIIa	4 (7.3)
Hematuria	12 (7.0)	Clavien grade IIIb	5 (9.1)
Urinary tract infection	11 (6.4)	Clavien grade IVa	5 (9.1)
Stone burden (mm^2)	563 (32 to 2,346)	Guy's Stone Score	2.77 (1 to 4)
Preoperative eGFR (mg/dL)	78.3 (6.1 to 123)	CROES nomogram	210.00 (128 to 258)
Postoperative eGFR (mg/dL)	79.6 (4.7 to 126)	S.T.O.N.E. nephrolithometry	7.78 (5 to 12)
Stone-free rate; n (%)	92 (53.5)	S-ReSC score	5.31 (1 to 9)

BMI=body mass index; CROES=Clinical Research Office of the Endourological Society; S-ReSC=Seoul National University Renal Stone Complexity

Table 2. Association between stone-free status and nephrolithometry score

Nephrolithometry scores	Stone free Mean±SD	Not stone free Mean±SD	p-value
Guy's Stone Score	1.97±0.91	3.70±0.46	<0.001
CROES nomogram	242.40±40.89	159.28±34.98	<0.001
S.T.O.N.E. nephrolithometry	6.64±1.25	9.08±1.29	<0.001
S-ReSC score	3.44±2.09	8.41±0.65	<0.001

CROES=Clinical Research Office of the Endourological Society; S-ReSC=Seoul National University Renal Stone Complexity; SD=standard deviation

Table 3. Multivariate analysis

Nephrolithometry scores	Odds ratio*	95% CI	p-value
Guy's Stone Score	0.70	0.35 to 1.43	0.334
CROES nomogram	4.29	0.54 to 34.33	0.170
S.T.O.N.E. nephrolithometry	1.02	0.99 to 1.04	0.222
S-ReSC score	0.14	0.05 to 0.36	<0.001

CROES=Clinical Research Office of the Endourological Society; S-ReSC=Seoul National University Renal Stone Complexity

* Logistic regression analysis

Table 4. The effect of scoring systems on perioperative data

Stone factor	GSS		CROES		STONE		S-ReSC	
	Rho	p-value	Rho	p-value	Rho	p-value	Rho	p-value
Estimated blood loss	0.22	0.010	–0.26	0.014	0.17	0.022	0.25	0.017
Complications	0.03	0.673	–0.05	0.552	–0.03	0.687	0.01	0.862
Hospital stay	0.16	0.041	–0.18	0.027	0.18	0.023	0.17	0.021
Operative time	0.19	0.017	–0.29	0.001	0.21	0.001	0.22	0.001

GSS=Guy's Stone Score; CROES=Clinical Research Office of the Endourological Society; STONE=S.T.O.N.E. nephrolithometry; S-ReSC=Seoul National University Renal Stone Complexity; eGFR=estimated glomerular filtration rate

Discussion

PCNL was introduced around 40 years ago. In 1976, Fernstorm and Johansson announced the successful eradication of a kidney calculus through a nephrostomy tract for the first time[8]. In PNCL, it is best to expedite an attack on the stone, while the effect on the kidney and surrounding tissue is less traumatic compared to ANL. Therefore, a great deal of experience is mandatory for percutaneous access to the kidney and for stone removal. Following the

introduction of PCNL, recommendations for ANL definitely decreased. Open surgical operations are indicated in patients with complete staghorn calculi related to infundibular stenosis or distortion of intrarenal anatomy[9-11].

The anatomical description of kidney stones has developed over the last decade. Stone burden alone does not present enough complexity of kidney calculi. For this reason, NSS have been purposed to make reproducible and comparative descriptions of kidney calculi.

The aim of the present study was to evaluate the efficiency of GSS, STONE, CROES, and S-ReSC in predicting clinical outcomes of PCNL. Multiple studies have revealed results similar to the present study[5,7,12-14]. In the present research, all scoring systems significantly showed correlation with SFR (p=0.001, 0.001, 0.001, and 0.001, respectively), OT (p=0.01, 0.02, 0.02, and 0.02, respectively), EBL (p=0.01, 0.01, 0.01, and 0.01, respectively), and LOS (p=0.04, 0.02, 0.02, and 0.02, respectively). Thomas et al[7] created GSS and showed that it was a single predictive factor of SFR in comparison with total size of stone, comorbidity diseases of the patient, urine culture, age, and surgeon. Additionally, stone-free status was associated with a higher grade of score. Correspondingly, Mandal et al[15] and Ingimarsson et al[12] demonstrated a significant correlation between GSS and SFR (p=0.03 and 0.01, respectively). In addition, in a study of 100 prone PCNL, Khalil et al[16] illustrated that GSS had a significant association with SFR and re-treatment rate. CROES was developed by Smith et al following the operation of 2,806 PCNL cases in intercontinental hospitals around the world. CROES, which determines total calculi size, stone location, stone number, staghorn stone, number of patients, and previous calculi surgery achieved a high prediction of SFR[6]. Then, external validation was analyzed by Bozkurt et al[17], who showed that CROES was precisely associated with SFR as well as postoperative results such as complications, EBL, OT, and LOS.

The STONE scoring system was developed by Okhunov et al(5). The result was comparable to the present research. The article showed that the STONE score correlated well with SFR (p=0.001), LOS (p=0.001), OT (p=0.001), and EBL (p=0.005). Then, Akhevien et al[18] demonstrated that STONE was a predictive scaling system for treatment achievement (p=0.002) and was a reproducible tool after evaluating 117 PCNL patients.

The S-ReSC scale was published to forecast stone-free status after PCNL depending on assumptions about what influences surgical complexity and stone-free status. After the initial research, the score that predicted stone-free status was determined as 0.86[4]. Hereafter, Choo et al demonstrated results of 327 PCNL cases that were operated by four urologists and found that S-ReSC correlated well with SFR[19].

Multiple studies in the literature have shown the lack of effectiveness of the NSS in predicting PCNL complications. The poor correlation for GSS with postoperative PCNL complications is compatible with the initial article from Thomas et al[7]. Kumar et al[10] showed that neither GSS nor CROES was a predictor for PCNL complications. Correspondingly, Yarimoglu et al[20] demonstrated that both CROES and STONE lacked predictive value for PCNL complications (p= 0.501 and 0.562, respectively). Similarly, these studies illustrated that none of the NSS was correlated with PCNL complications (p=0.67 for GSS, p=0.55 for CROES, p=0.68 for STONE, and p=0.86 for S-ReSC).

The present research has multiple limitations. First, patients in the present study had PCNL performed by various surgeons. Second, the authors only performed a retrospective study. Although, there are limitations to the present research, the authors give a comprehensive comparison of the relevant scoring systems.

Conclusion

All four established scoring systems, GSS, CROES, STONE, and S-ReSC, are reproducible and show significant correlations with essential treatment outcome results.

What is already known on this topic?

Various NSS are developed to examine anatomical description of renal calculi. At this time, there has been no definite testing of current scoring systems. Examination and determination of these scores help the enhancements and clarifications in these NSS that may eventually assist the progress of establishment of a more extensive and generally agreed upon the scoring system.

What this study adds?

The authors assessed four scoring systems and proved that all NSS are outstanding predictors for stone-free rates and correlate significantly with surgical outcomes.

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Conflicts of interest

The authors declare no conflict of interest.

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