Role of Guy's Stone Score (GSS), S.T.O.N.E. Score and CROES Nomogram in Prognosticating Outcomes after Percutaneous Nephrolithotomy for Renal Stones: A Prospective Study

Nakul Aher[1], Amrit JW[2], Gayathri Thiruvengadam[3], Velmurugan Palaniyandi[1], Hariharasudhan Sekar[1], Sriram Krishnamoorthy[1]

1. Department of Urology and Renal Transplant, Sri Ramachandra Institute of Higher Education and Research, Chennai, India.
2. Department of Urology, Sri Muthukumaran Medical College and Hospital, Chennai, India.
3. Department of Allied Health Sciences, Sri Ramachandra Institute of Higher Education and Research, Chennai, India.

Corresponding author: Amrit JW nakulaher7988@gmail.com

Abstract

Introduction: Percutaneous nephrolithotomy (PCNL) is a preferred treatment for large and complicated kidney stones. We aim to compare the predictive accuracy of the scoring systems, including the Guy's Stone Score (GSS), S.T.O.N.E. score, and CROES nomogram, for successful outcomes following PCNL.

Methods: The prospective study was done in a tertiary health care center from January 2023 to January 2024. Participants with renal calculi who were scheduled for PCNL in the Department of Urology and Renal Transplantation were included. Demographic information, stone characteristics, and related renal abnormalities were among the variables examined. Preoperative GSS, S.T.O.N.E., and CROES scores were studied in all the participants. Evaluating stone-free status and complications was the main goal of the study.

Results: A total of 104 patients were studied of which, 82 patients (78.9%) achieved stone-free status (SFS), while 22 patients (21.1%) did not achieve SFS. CROES Nomogram Score had the highest Area Under the curve (AUC) of 0.887, balanced sensitivity (81.82%) and specificity (79.27%), and the highest overall accuracy of 79.81%. These findings suggest that the CROES Nomogram is the most reliable tool for predicting successful PCNL outcomes. When we compared the occurrence of complications and distribution of complication grades, no significant differences were observed in both groups.

Conclusions: Among the various scoring systems used to predict the success of PCNL, the CROES Nomogram is considered the most reliable and provides the most accurate predictions of successful outcomes.

Keywords: Percutaneous Nephrolithotomy (PCNL), Guy's Stone Score (GSS), S.T.O.N.E. nephrolithometry, CROES nomogram.

Introduction

Globally, renal stones are becoming more common regardless of age, race, or gender.[1] Percutaneous nephrolithotomy (PCNL) is the most widely accepted modality of treatment for patients with large-volume stone disease.[2] According to the literature, PCNL has a stone-free rate (SFR) ranging from 56% to 76%.[3] However, comparing the results across different studies is difficult due to the absence of common grading for stone complexity.[4]

Miniaturization in PCNL is gaining popularity, with the use of advanced energy sources to break the stones, have shown high rates of stone removal and low risks. Computed tomography (CT) has largely transformed the preoperative assessment of renal stones with its prompt assessment of the overall stone burden and the calyceal

anatomy.[5] It also helps us to pre-operatively recognize the congenital anatomical abnormalities of the kidney that may affect the overall PCNL results.[5],[6]

Stone-free results have increased due to significant advancements in medical technology and techniques. These include combining PCNL with extracorporeal shock wave lithotripsy (ESWL), the use of flexible devices, and notable improvements in lithotripsy technology. However, these methods are associated with problems like bleeding and extended hospital stays. [7-9]

Different scores have been developed to predict the effectiveness of PCNL in achieving stone-free status (SFS). These include Guy's Stone Score (GSS), S.T.O.N.E. nephrolithometry, and the CROES nomogram. [10-12] Thomas et al. reported that the GSS is a simple and repeatable method for classifying renal calculi according to their quantity, location, and morphological abnormalities.[10] This system's applicability to plain X-ray films makes it distinctive and increases its usefulness in outpatient settings.

Okhunov et al identified five variables based on non-contrast computed tomography (NCCT). These variables greatly helped in the early prediction of the outcomes of this surgical procedure. These five variables include the size of the calculi, the length of the tract to be traversed, the extent of obstruction and the degree of hydronephrosis, the number of calyces holding the stones, and the hardness of the stone (identified as essence). The system was more predictive of the SFR than any of the individual variables alone, with a projected accuracy of 83.1%.[11]

Smith et al., through a wide analysis of a global database containing 5,830 patients, developed the Clinical Research Office of the Endourological Society (CROES) nephrolithometry nomogram. This tool is based on six precisely selected criteria,

which provide a well-established model for predicting the probability of achieving an SFS after undergoing PCNL. The nomogram's precision and reliability have been validated, showing its significant potential in clinical decision-making and patient outcomes in the management of nephrolithiasis.[12] However, nomogram calculation is often a tedious and time-consuming process.

Our research compares the predictive accuracy of the scoring system including the GSS, S.T.O.N.E. score, and CROES nomogram, as opinions on the most reliable and extensively used tool for successful surgical outcomes following PCNL are divided. It would be useful to have a standardized approach for prognosticating SFR following PCNL. We aim to improve surgical preparation, patient outcomes, and preoperative counseling by prospectively evaluating these grading systems.

Patients and Methods

We conducted this prospective study from January 2023 to January 2024 at a tertiary care hospital in South India. A total of 104 patients were included in the study. Patients with renal stones planned for PCNL in the Department of Urology and Renal Transplantation were included. Patients with stone diameters smaller than 1 cm, those under 16 years old, those with skeletal abnormalities, those with radiolucent stones on preoperative imaging, and those having double J (DJ) stents or PCN tubes inserted before surgery were excluded.

Demographic data including body mass index (BMI) and related comorbidities were recorded. Stone characteristics such as burden, size, number, position, presence of staghorn, and related renal abnormalities were also documented. Non-contrast whole abdomen CT scan (NCCT) was performed for preoperative radiological

assessment. Preoperative GSS, S.T.O.N.E., and CROES scores were studied for all participants.

Conventional PCNL was performed on each patient under fluoroscopic guidance. After two weeks, the DJ stent was taken out. After a month, postoperative follow-up involved NCCT. The existence of < 4mm postoperative residual fragments (clinically insignificant) or a state in which there were no stones at all indicated the effectiveness of the treatment. We used the modified Clavien grades to categorize the complications.

In our study, the statistical analysis was done using the IBM SPSS version 19.0. Continuous data was presented as Mean ± SD. The comparison of mean difference was performed by student's t-test. Similarly, categorical data was examined by the chi-square test or Fischer exact test. To predict efficacy, the scoring tool's sensitivity and specificity were calculated. At p-value < 0.05, statistical significance was deemed to be reached.

Results

A total of 104 patients were studied of which, 82 patients (78.9%) achieved stone-free status (SFS), while 22 patients (21.1%) did not achieve SFS. Pre-operative and baseline characteristics of the SFS-achieving and non-SFS-achieving groups are summarized in Table 1. Our study findings revealed that patients who successfully achieved SFS (mean age of 33.8 ± 2.3 Vs 36.14 ± 2.25 years) were significantly younger (p-value <0.001). The difference in BMI and gender-wise distribution was statistically insignificant between the two groups, with those achieving SFS having a BMI of 22.15 ± 3.55 Vs 24.18 ± 3.45 without SFS (p = 0.967) and males comprised 81.3% of the SFS group and 72.4% of the non-SFS group (p = 0.318).

Table 1: Pre-operative and baseline characteristics of the SFS-achieving and non-SFS-achieving groups.

Variable	Sub-Group	Stone-free Status Achieved N=82	Stone-free Status Not achieved N=22	P-Value
Age (years) Mean±SD		33.8± 2.3	36.14±2.25	<0.001
BMI (Kg/m^2) Mean±SD		22.15 ±3.55	24.18±3.45	0.967
Gender N (%)	Male	61 (81.3%)	14 (18.7%)	
	Female	21 (72.4%)	8 (27.6%)	0.318
Stone Size(mm) Mean±SD		18.13 ±2.23	23.09±1.48	<0.001
Stone number	Single	51 (87.9%)	7 (12.1%)	
N (%)	Multiple	28 (77.8%)	8 (22.2%)	<0.001
	Staghorn	3 (30%)	7 (70%)	
Side N (%)	Right	60 (81.1%)	14 (18.9%)	
	Left	22 (73.3%)	8 (26.7%)	0.381
Hydronephrosis	None	59 (80.8%)	14 (19.2%)	
N (%)	Mild	9 (75%)	3 (25%)	
	Moderate	10 (76.9%)	3 (23.15)	0.840
	Severe	4 (66.7%)	2 (33.3%)	
Scores	GSS	2.18±0.631	2.0±0.309	0.06
Mean±SD	STONE score	8.70±0.871	8.95±0.785	0.209
	CROES nomogram score	219.011±3.92	300.05±50.27	<0.001

Patients who achieved SFS had significantly smaller stones (18.13 ± 2.23 mm Vs 23.09 ± 1.48 mm, p <0.001). The majority of study participants with single stones achieved SFS (87.9%) compared to those with multiple stones or staghorn calculi (70% of whom

did not achieve SFS), with a p-value of <0.001. The degree of hydronephrosis showed no significant impact on achieving SFS (p = 0.840). The analysis revealed, significant differences between the two groups when comparing the mentioned scoring system. Among these, the CROES nomogram showed the most pronounced distinction, with a p-value of less than 0.001, demonstrating a highly significant difference. It advocates that the CROES nomogram may be a particularly sensitive indicator in differentiating between the groups.

A comparison of surgical outcomes and postoperative variables by SFS Achievement Status is summarized in Table 2. The average operative time was markedly shorter for patients who achieved SFS (mean duration of 30.09 ± 1.27 Vs 37.18 ± 1.37 minutes, p<0.0001) than no SFS patients. A single tract was used in 83.3% of patients with SFS compared to only 16.7% in the non-SFS group, p<0. 001. For the SFS group (55.57 ± 1.1 hours) compared to the non-SFS group (58.09 ± 1.82 hours) mean hospital stay was shorter (p-value <0.001). Furthermore, when we compared the occurrence of complications and distribution of complication grades, no significant differences were observed in both groups.

Table 2: Comparison of Surgical Outcomes and Post-Operative Metrics by SFS Achievement Status

Variable	Sub-Group	**Stone free status (SFS) Achieved N=82**	**Stone free status Not achieved N=22**	**P-Value**
Operative time(min) Mean±SD		30.09±1.27	37.18±1.37	<0.001
Number of PCNL Tracts N (%)	**1** **>1**	80 (83.3%) 2 (25%)	16 (16.7%) 6 (75%)	<0.001

Hospital stay (hours) Mean±SD		55.57±1.1	58.09±1.82	<0.001
Complications N (%)	**Yes**	16 (72.7%)	6 (27.3%)	
	No	66 (80.5%)	16 (19.5%)	0.557
Modified clavien-Dindo grade	**Grade 1**	10 (71.4%)	4 (28.6%)	
	Grade 2	4 (80%)	1 (20%)	
	Grade 3	2 (66.7%)	1 (33.3%)	0.834
	Grade 4	0	0	
	Grade 5	0	0	

Table 3: Comparative Analysis of Area Under the Curve (AUC), Sensitivity, and Specificity in Predicting PCNL Effectiveness for Renal Stones

Scoring tool	**Guy's stone score**	**STONE score**	**CROES nomogram score**
Area	0.552	0.560	0.887
Asymptotic Significance	0.459	0.388	<0.001
Curve coordinates cut-off	>= 3	>= 8	>= 222
Sensitivity	18.18% (5.19%,40.28%)	100% (84.56%,100%)	81.82% (59.52%,94.81%)
Specificity	85.37% (75.83%,92.2%)	10.98% (5.14%,19.8%)	79.27% (68.89%,87.43%)
Positive predictive value	25% (10.6%,48.29%)	23.16% (21.83%,24.54%)	51.43% (39.9%,62.81%)
Negative predictive value	79.55% (75.8%,82.84%)	100% (66.37%,100%)	94.2% (86.93%,97.54%)
Accuracy	71.15% (61.45%,79.62%)	29.81% (21.23%,39.57%)	79.81% (70.81%,87.04%)

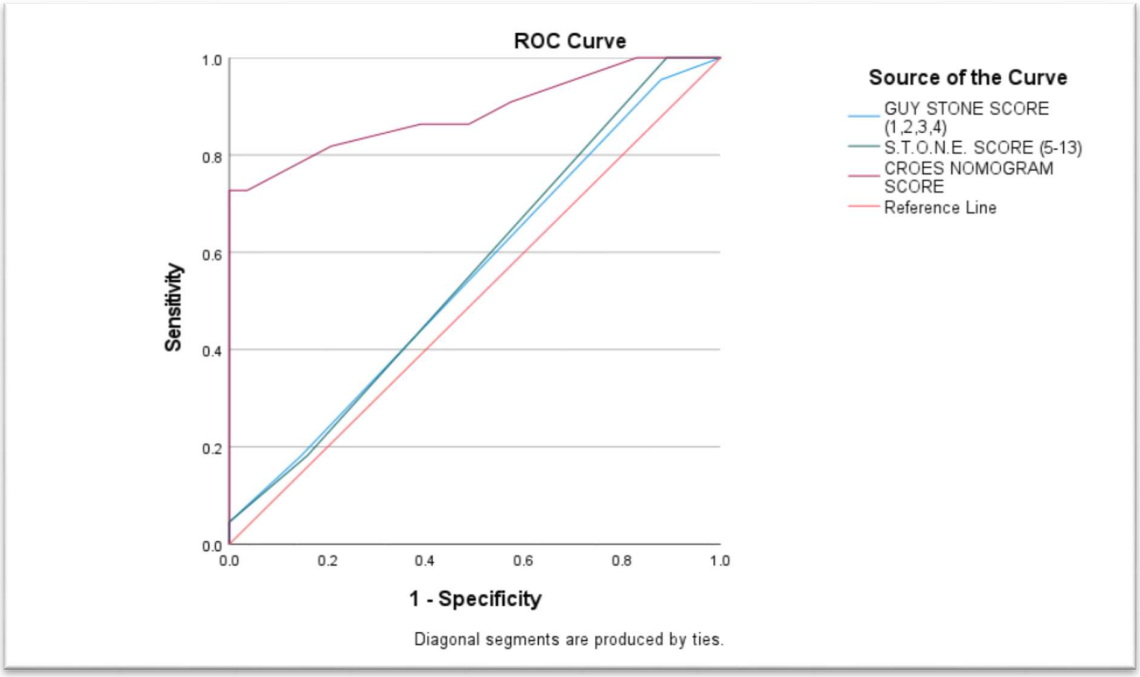

Figure 1: **ROC curve of scoring systems for predicting the effectiveness of PCNL for renal stones.** (y-axis: sensitivity; x-axis: 1-specificity; Diagonal segment is produced by ties) ROC: receiver operating characteristic; PCNL: percutaneous nephrolithotomy

We evaluated the predictive accuracy of three scoring systems for measuring the outcomes in PCNL. Guy's Stone Score had an Area Under the Curve (AUC)of 0.552, with low sensitivity (18.18%) but high specificity (85.37%), yielding an overall accuracy of 71.15%. The STONE Score demonstrated a perfect sensitivity (100%) but very low specificity (10.98%), resulting in a low overall accuracy of 29.81%. In contrast, the CROES Nomogram Score had the highest AUC of 0.887, balanced sensitivity (81.82%) and specificity (79.27%), and the highest overall accuracy of 79.81%. The above findings suggest that the CROES Nomogram is the most reliable tool for predicting successful PCNL outcomes.

Discussion

For large or complex kidney stone management, PCNL is a gold standard treatment. This minimally invasive procedure is effective and preferred in addressing difficult cases where other treatment modalities may be less effective.[2] Objective calculus complexity scores can be used for results benchmarking and auditing. Numerous writers have proposed scoring systems for nephrolithiasis considering several criteria. [10-12] It is important to understand that the GSS and S.T.O.N.E. scores are ordinal scores among the objective calculus complexity scores. Unlike CROES scores, they do not provide a predicted point estimate for SFR. [12] In a single-center patient cohort, our study assessed the predictive power of the three score systems for outcomes after PCNL. Our findings show that these rating system's predicted accuracy and usefulness vary significantly.

In our study, 21.1% of cases had residual stones following PCNL, whereas 78.9% of cases were stone-free which was comparatively lower than the findings of Shaheem N et al. showing a stone-free percentage of 84.11%.[13] Comparable stone-free rates were noted in previous studies performed by Smith et al. who noted SFR (82%), Thomas et al. (62%), and Labadie et al. (56%).[10],[12],[14] Our study had an overall complication rate of 21.2%, of which the majority (18.2%) were minor problems. These findings were comparable with previous research work in which the author and their co-workers reported that a major complication incidence rate was noted in around 7% of cases and a minor complication rate was noted in approximately 25% of cases associated with PCNL.[15]

The impact of anatomical differences in the kidney on outcomes of kidney stone treatments remains a subject of debate in the literature. While some studies suggest

that abnormal anatomical features may not significantly worsen outcomes, others argue that these variations could have a detrimental effect.[16],[17] External validation studies of the S.T.O.N.E. score have not confirmed that factors such as stone density or the degree of hydronephrosis are major contributors to predicting treatment outcomes, contrary to the assertions made by the original developers of this scoring system.[18],[19],[20],[21] In contrast, research on calculus complexity scores consistently identifies "stone complexity/burden" as a crucial predictor of treatment outcomes. As per observations by Labadie et al. neither the Guys score, the S.T.O.N.E. score, nor the CROES score provided a superior prediction of stone-free rates (SFR) compared to assessing stone burden alone.[14]

With an AUC of 0.887, sensitivity of 81.82%, and specificity of 79.27%, CROES Nomogram did better in our study than the other two scoring systems. The CROES Nomogram appears to be the most accurate method for predicting favorable outcomes after PCNL, with an overall accuracy of 79.81%. On the contrary, Bozkurt et al. observed equivalent accuracies in GSS and CROES nomogram scores, but they used conventional radiography for assessing stone clearance post-PCNL.[22] Similar to our study, Labadie et al. used CT scanning to evaluate postoperative clearance.[14] Furthermore, the CROES score places a high value on the number of cases/years rather than the surgeon's ability, which leads to a higher anticipated SFR. Akcay et al. reported, in line with our research, that these three scoring systems could accurately estimate outcomes following PCNL, with the CROES nomogram having the highest predictive value.[23] Additionally, Kocaaslan et al. discovered a substantial association between the efficacy of PCNL and the CROES nomogram.[24]

Importantly, the CROES nomogram optimizes the nomogram based on the assumption that a residual calculus of ≤ 4mm indicates the absence of stones. If the stone-free status threshold is modified to < 2mm residual calculus there would be immediate calibration concerns with the current nomogram, necessitating revalidation and revising the projected SFR scale in the nomogram.[25],[26]

The results of our investigation presented that, the GSS had 18.18% and 85.37% sensitivity and specificity respectively. Also, our results showed an AUC of 0.552 with a total accuracy of 71.15%, suggesting moderate dependability. These findings were similar to previous research, which has highlighted, the high specificity but low sensitivity of the Guy's Stone Score, which makes it better suited for predicting situations in which PCNL is unlikely to succeed than for recognizing every possible success.[27] Conversely, Choi et al. found in a comparative analysis that only GSS could predict SFS after PCNL.[28]

The STONE Score yielded an overall accuracy of 29.81% and an AUC of 0.560 due to its higher sensitivity (100%) but much lower specificity (10.98%). Although this score was very good at identifying all patients who might become stone-free, it also incorrectly classified many patients who did not, indicating a lower specificity. This is in contradiction to the results of Noureldin et al., who had preferred GSS and S.T.O.N.E scores for their correlation with SFS.[29] The study done by Shaheem N et al. highlighted that the S.T.O.N.E. score is the most effective predictor of achieving stone-free status. Their research demonstrated that the S.T.O.N.E. score had an AUC of 0.844 when using a cutoff value of ≤7. This high AUC shows that the S.T.O.N.E. score possesses a considerable level of accuracy in predicting whether a patient will achieve a stone-free status following treatment.[13]

We conclude that, after PCNL, the CROES Nomogram is the most accurate scoring method for predicting successful outcomes, with Guy's Stone Score and STONE Score coming in second and third, respectively. These results highlight how crucial it is to employ a multifactorial strategy to accurately predict surgical outcomes, which will eventually help with more patient counseling and customized treatment planning.

Our study has some limitations including a small sample size and being conducted in a single centre. Despite these drawbacks, we think that our study would serve as a foundation for further investigations to forecast SFR following PCNL. Patients should receive more accurate preoperative counseling regarding the likelihood of postoperative stone removal.

Conclusions

Various scoring systems are used to predict the success of PCNL, among the three scoring systems studied, CROES Nomogram is considered the most reliable and provides the most accurate predictions of successful outcomes. Following the CROES Nomogram, the GSS, and the STONE score also offer valuable prognostic information, though they are slightly less precise in predicting the success of the procedure.

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