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Original Article

Surgery Section

S.T.O.N.E Score versus Guy's Stone Score in the Prediction of Stone Clearance in Percutaneous Nephrolithotomy: A Cross-sectional Study

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ABSTRACT

Introduction: Percutaneous Nephrolithotomy (PCNL) has become the standard of care for large renal calculi. The aim of the surgery is to achieve maximum stone clearance with minimal postoperative complications. Various scoring systems have been described to predict both of these outcomes. S.T.O.N.E. Score and Guy's Stone Score (GSS) are two of the most widely used scoring systems. S.T.O.N.E. Score comprises of Size of the stone, Tract length, degree of Obstruction of the urinary system, Number of stones, and Essence.

Aim: To compare the predictive power for stone clearance and postoperative complications of the two scoring systems, namely S.T.O.N.E. Score and GSS.

Materials and Methods: This cross-sectional study was conducted at the Department of Genitourinary Surgery at Government Medical College, Kottayam, Kerala, India from March 2019 to August 2020. All patients above 18 years undergoing PCNL were included. A total of 122 patients were studied by calculating the preoperative S.T.O.N.E. Score and GSS and comparing them with post-PCNL stone clearance and complications. The association of both S.T.O.N.E. Score and GSS with stone clearance was estimated by plotting the Receiver Operating Curve (ROC) curve using Statistical Package for Social Sciences (SPSS) version 20, International Business Machines (IBM) SPSS Statistics windows, version 20.0 (Armonk, NY: IBM Corp.). A p-value <0.05 was considered statistically significant.

Results: The mean age of the subjects was 49.8±12.47 years. A total of 76 males and 46 females were included in the present study. The mean S.T.O.N.E. Score among the study subjects was 7.12±1.57, and the mean GSS was 2.09±0.48. Complete stone clearance was achieved in 96 (78.7%) patients. A total of 22 (18%) patients had postoperative complications. Both scores had a significant association with stone clearance (p<0.001 for both) and postoperative complications (p-value for S.T.O.N.E. Score was 0.019 and GSS was 0.007).

Conclusion: Both the S.T.O.N.E. Score and GSS can predict post-PCNL stone clearance and complications with comparable efficacy.

Keywords: Fluoroscopy, Kidney calculi, Renal calculi, Reciever operating curve, Staghorn calculi

INTRODUCTION

The PCNL is the recommended treatment option for complex kidney stones and cases with a large stone burden. The number of patients with renal stones is increasing day by day, leading to a global increase in PCNL rates. The objective of PCNL is to achieve better stone clearance while minimising postoperative complications. Various preoperative factors, including patient factors, stone characteristics, and anatomical variations, can influence the surgical outcomes. To predict and compare the outcomes of PCNL for preoperative planning and patient counselling, several nomograms and scoring systems have been developed [1].

Guy's Stone Score (GSS) [1] was developed in 2011. It classifies renal stones into four grades based on the stone number, location, and kidney abnormalities. Similarly, the S.T.O.N.E. score [2] was developed in 2013. It comprises five variables represented by the acronym "S.T.O.N.E." for stone size, tract length (skin-to-stone distance), degree of obstruction (presence of hydronephrosis), number of involved calyces, and essence of calculus (measured in Hounsfield Units). Both scores have been validated in multiple studies [1,3,4], although there are fewer cross-comparative studies [5-7]. In the present study, authors aimed to compare GSS and the S.T.O.N.E. Nephrolithometry Score in predicting the stone-free rate and post-PCNL complications. The present study is the first study conducted in South India where ultrasonic lithotripsy was utilised in PCNL.

MATERIALS AND METHODS

This cross-sectional study was conducted in the Department of Genitourinary Surgery at Government Medical College, Kottayam, Kerala, India from March 2019 to August 2020. Institutional ethical clearance was obtained (IRB No. 24/2019).

Inclusion and Exclusion criteria: All patients above 18 years undergoing PCNL who provided consent to participate in the study were included. Patients with radiolucent renal stones, renal anomalies, previous history of renal surgery on the same side, serum creatinine levels greater than 1.6 mg/dL, and patients with heart disease or coagulopathy were excluded. Patients who underwent any simultaneous additional endoscopic, laparoscopic, or open procedures along with PCNL were also excluded.

Study Procedure

A detailed questionnaire was used to collect data from the patients, including age, sex, stone characteristics, and postoperative complications. The stones were evaluated preoperatively using Computed Tomography (CT scan) conducted within four weeks prior to surgery. The STONE score and GSS for each patient were calculated based on the preoperative CT scan. Stone burden was calculated in square millimetres using the ellipsoid formula [7]: length×width×ϖ/4, where ϖ is the mathematical constant equal to 3.14.

The S.T.O.N.E. Score [2] was calculated using five variables obtained from preoperative non contrast CT.

1. **Size:** The stone size was calculated as the product of the two largest dimensions (in millimetres) in any plane from the CT scan. It was scored from 1 to 4 based on the calculated area: 0-399 mm^2, 400-799 mm^2, 800-1599 mm^2, and more than 1600 mm^2.
2. **Tract length or skin-to-stone distance:** It was calculated as the mean vertical distance between the centre of the stone and the skin on the CT film at 0°, 45°, and 90°. It was scored as one if it was less than 100 mm and two if it was more than 100 mm.
3. **Obstruction:** The degree of hydronephrosis was scored based on the severity of dilatation of the pelvi-calyceal system. One point was given if there was no obstruction or mild obstruction, and two points were given if there was moderate to severe obstruction.
4. **Number of calyces involved:** A score of 1 was given if only a single calyx was involved, a score of 2 if 2 to 3 calyces were involved, and a score of 3 if more than three calyces were involved, as in a stag horn calculus.
5. **Essence:** It measured the radiodensity of the stone on the CT scan. A score of 1 was assigned if the stone was less than 950 Hounsfield Units (HU), and a score of 2 was assigned if it was 950 HU or more.

The S.T.O.N.E. score was categorised into three risk groups: low (5-6), moderate (7-8), and high (9-13).

The **GSS** [1] was calculated based on the stone burden and complexity of renal anatomy observed on the non contrast CT.

- Grade I: A single calculus in the mid/lower pole or renal pelvis with simple renal anatomy.
- Grade II: A single calculus in the upper pole with simple renal anatomy, or multiple calculi in a patient with simple renal anatomy, or any solitary stone in a patient with abnormal anatomy.
- Grade III: Multiple calculi in a patient with abnormal anatomy, or stones in a calyceal diverticulum, or a partial staghorn calculus.
- Grade IV: Staghorn calculus or any stone in a patient with spina bifida or spinal injury.

All patients underwent PCNL in the prone position performed by the same surgeon under general anaesthesia. Access was obtained under C-arm fluoroscopy using the triangulation technique with an 18-gauge needle. The tract was dilated with Amplatz dilators up to 30 F size. A "Percutaneous Universal Nephroscope" size 24 Fr with a 20° angle of view (Richard Wolf GmbH™) was used. Ultrasonic lithotripter was used for fragmenting the stone. The fluoroscopy time for each patient was recorded.

Stone clearance was defined using a CT-Kidney-Ureter-Bladder (KUB) after four weeks of surgery, indicating that the patient was either stone-free or had Clinically Insignificant Residual Fragments (CIRF) measuring less than or equal to 4 mm. Postoperative complications were graded according to the modified Clavien-Dindo scoring system for PCNL [8].

STATISTICAL ANALYSIS

Both scoring systems were compared with stone clearance and complications using the Chi-square test to assess their predictive capacity for the primary outcomes. The Area Under the Curve (AUC) was calculated for both scoring systems using the Receiver Operating Curve. The association of both the S.T.O.N.E score and **GSS** with stone clearance was estimated by plotting the ROC curve using SPSS version 20 (IBM SPSS Statistics, Armonk, NY: IBM Corp.). A value of $p<0.05$ was considered statistically significant.

RESULTS

A total of 122 patients were included in the study after applying the inclusion and exclusion criteria. Among them, there were 76 males and 46 females. The mean age of the subjects was 49.8±12.47 years [Table/Fig-1].

Variables	Values	Values
Age distribution	20-30 years	9 (7.4%)
	31-40 years	19 (15.6%)
	41-50 years	42 (34.4%)
	51-60 years	27 (22.1%)
	61-70 years	19 (15.6%)
	71-80 years	6 (4.9%)
Sex	Male	76 (62.3%)
	Female	46 (37.7%)
Weight (kg)	Mean	67.39±11.09
Height (m)	Mean	1.62±0.093
BMI	Mean	25.77±4.22

[Table/Fig-1]: Demographic characteristics.

Out of the total patients, 73 (59.8%) had involvement of the left kidney. Although the stones involved multiple regions of the kidney, the renal pelvis was the most common location of the stone, seen in 60 subjects (26.55%). The average stone burden (length×width×ϖ/4) was 315.8 mm^2.

The S.T.O.N.E score (2) was calculated based on the preoperative CT scan. The maximum number of patients, 83 (68%), had a stone size between 0-399 mm^2. The majority of patients had only one calyx involved by the stone. Additionally, 78 (63.9%) patients had a hard stone with more than 950 HU [Table/Fig-2]. Among the subjects, 52 patients had a low S.T.O.N.E Score, 45 patients had a moderate S.T.O.N.E Score, and 25 patients had a high S.T.O.N.E Score.

Stone size (mm^2)	0-399	83 (68.0)
	400-799	23 (18.9)
	800-1599	14 (11.5)
	>1600	2 (1.6)
Tract length	<100 mm	81 (66.4)
	>100 mm	41 (33.6)
Obstruction	No/Mild	101 (82.8)
	Moderate/Severe	21 (17.2)
Number of calyces involved	1 Calyx	68 (55.7)
	2-3 Calyces	41 (33.6)
	Full staghorn calculus	13 (10.7)
Essence	≤950 HU	44 (36.1)
	>950 HU	78 (63.9)

[Table/Fig-2]: S.T.O.N.E scores.

The **GSS** (8) was calculated based on the stone characteristics and complexity of renal anatomy observed on the preoperative CT scan [Table/Fig-3]. The maximum number of patients belonged to the least complex stone burden of **GSS** Grade-1 (n=51), and the frequency of patients decreased progressively as the complexity increased [Table/Fig-3].

GSS	
Grade-1	51 (41.8%)
Grade-2	26 (21.3%)
Grade-3	28 (23.0%)
Grade-4	17 (13.9%)

[Table/Fig-3]: Guy's Stone Score.

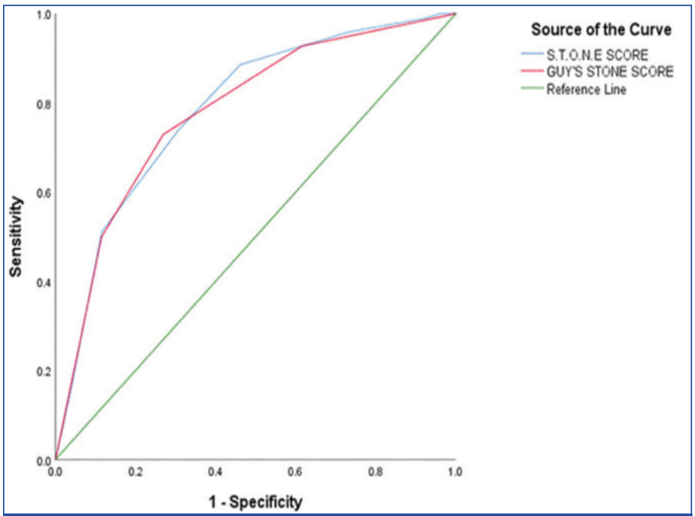
A total of 67 (54.9%) patients underwent totally tubeless PCNL (where no DJ stent or nephrostomy is used postoperatively), while 52 (42.6%) underwent tubeless PCNL (where a DJ stent is kept postoperatively). Nephrostomy tube was placed in only three patients. Complete stone clearance was achieved in 96 (78.7%) patients.

Both the S.T.O.N.E Score and GSS showed a statistically significant association with stone clearance (p<0.001 for both) [Table/Fig-4]. The mean S.T.O.N.E. Score among the study subjects was 7.12±1.57, and the mean GSS was 2.09±0.48.

Scores	Stone clearance		p-value
	Yes	No	
Stone score			
5-6	49 (94.2)	3 (5.8)	<0.001*
7-8	36 (80.0)	9 (20.0)	
9-13	11 (44.0)	14 (56.0)	
Guy's score			
Grade-1	48 (94.1)	3 (5.9)	<0.001*
Grade-2	22 (84.6)	4 (15.4)	
Grade-3	19 (67.90)	9 (32.1)	
Grade-4	7 (41.2)	10 (58.8)	

[Table/Fig-4]: Comparison of GSS and S.T.O.N.E score in stone clearance.
*Statistically significant; Chi-square test was used

The association of both the S.T.O.N.E score and GSS with stone clearance was estimated by plotting the ROC curve [Table/Fig-5-7]. Both curves had almost equal AUC (AUC S.T.O.N.E Score- 0.684, AUC GSS- 0.679). Both scores showed a statistically significant association with stone clearance.



[Table/Fig-5]: ROC curve of GSS and S.T.O.N.E score.

Variables	Area	p-value	95% confidence interval of area
S.T.O.N.E score	0.786	<0.001*	0.684-0.888
GSS	0.781	<0.001*	0.679-0.882

[Table/Fig-6]: Area Under the Curve (AUC).
*Statistically significant

Variables	Value	Sensitivity	Specificity
S.T.O.N.E score	7.50	0.740	0.692
	8.50	0.885	0.538
	6.50	0.510	0.885
Guy's stone score	2.50	0.729	0.731
	1.50	0.500	0.885
	3.50	0.927	0.385

[Table/Fig-7]: Cut-off scores for ROC curve.

The total fluoroscopy time was 637 minutes 12 seconds, with an average time of 05:13 (±02:09) per patient. The average postoperative stay was two days. A total of 22 (18%) patients experienced postoperative complications as shown in [Table/Fig-8].

The association of both scores with postoperative complications was assessed, and both showed a significant association [Table/Fig-9].

Grade	Complications	Frequency
1	• Fever (>38ºC) • Transient elevation of serum creatinine (>0.5 mg/dL)	6 (4.9%)
2	• Blood transfusion • Urine leakage <24 hours. Infections requiring additional antibiotics • Wound infection • Urinary tract infection • Pneumonia	4 (3.3%)
3a	• Renal haemorrhage requiring angioembolisation • Postoperative DJ stent placement for urine leakage • Haemo/pneumothorax requiring chest tube insertion • Retention due to blood clots	1 (0.8%)
3b	• Ureteric calculus • Collecting system perforation • Infundibular stricture urethral stricture • Retained Percutaneous Nephrostomy (PCN) tube requiring removal • Perinephric abscess	8 (6.6%)
4a	• Neighbouring organ injury • Myocardial infarction • Acute renal failure	0
4b	• Sepsis	2 (1.6%)
5	• Death	1 (0.8%)

[Table/Fig-8]: Clavien-Dindo grading of postoperative complications.

Variables	Postoperative complications		p-value
	Present (n=22)	Absent (n=100)	
Stone score			
5-6	5 (9.6)	47 (90.4)	**0.019***
7-8	8 (17.8)	37 (82.2)	
9-13	9 (36.0)	16 (64.0)	
Guy's stone score			
Grade-1	3 (5.9)	48 (94.1)	0.007*
Grade-2	5 (19.2)	21 (80.8)	
Grade-3	7 (25.0)	21 (75.0)	
Grade-4	7 (41.2)	10 (58.8)	

[Table/Fig-9]: Association of postoperative complications with the scores.

DISCUSSION

Ever since PCNL became the standard of care for large renal stones, multiple attempts have been made to identify significant predictors for stone clearance after the procedure. Preoperative patient counselling also necessitates the development of an integrated scoring system to assess PCNL complexity for optimal decision-making. Scoring systems are also necessary for comparing the outcomes of the surgery [1].

A few studies have compared and contrasted the S.T.O.N.E score with GSS on post-PCNL stone clearance and complications. Most of these studies found that both the S.T.O.N.E score and GSS had similar capacity for predicting stone clearance [5,6,9-12]. For predicting postoperative complications, the S.T.O.N.E Score was found to be effective in two studies [6,9], while other studies found no significant difference [5,10-12].

The postoperative stone clearance rates in the present study were comparable to those reported in the published literature [Table/Fig-10,11] [1,2,5,10,13]. The minor variations in results reflect the differences in stone complexity among the study populations and the exclusive use of an ultrasonic lithotripter, as opposed to a pneumatic lithotripter used in other studies.

However, there are a few variables that are not clearly defined in these scoring systems. GSS classifies staghorn calculus into partial and complete, but it does not clearly define the distinction between these categories. In the S.T.O.N.E score, the number of calyces involved is not clearly specified. The staghorn status defined by the S.T.O.N.E score only refers to a full staghorn, and stones involving the renal pelvis and more than three calyces are not well-defined. In

S.T.O.N.E score	Present study N=122		Poudyal S et al., [10] N=104		Okhunov Z et al., [2] N=117		Labadie K et al., [5] N=244	
	%	Stone free=78.7%	%	Stone free=87.5%	%	Stone free=83.1%	%	Stone free=76.1%
5-6	42.6	94.2	34	91.6	20	97	14	71
7-8	36.9	80.0	43	97	46	88	33	66
9-13	20.5	44.0	23	62	32	44	53	46

[Table/Fig-10]: Comparison of S.T.O.N.E scores in different studies [2,5,10].

Guy's stone score	Present study N=122		Poudyal S et al., [10] N=104		Thomas K et al., [1] N=100		Labadie K et al., [5] N=244		Mandal S et al., [13] N=221	
	%	Stone free=78.7%	%	Stone free=87.5%	%	Stone free=62%	%	Stone free=56%	%	Stone free=76.1%
Grade-1	41.8	94.1	40.4	97.6	28	81	19	70	30.8	100
Grade-2	21.3	84.6	40.4	92	34	72	33	65	44	74
Grade-3	23	67.90	14.3	73.3	21	35	32	48	22	56
Grade-4	13.9	41.2	4.9	0	17	29	16	35.9	2.2	0

[Table/Fig-11]: Comparison of GSS in different studies [1,5,10,13].

GSS, there is disagreement between Grade-2 and 3 due to unclear definitions of partial staghorn stone and abnormal renal anatomy [1,14]. Additionally, the GSS was initially described using abdominal X-Ray, whereas the S.T.O.N.E score was formulated using CT scan (which is the imaging of choice for renal stones), thereby incorporating difficulties in comparing them.

Limitation(s)

The number of subjects in various Clavien-Dindo groups was very small, so it was not possible to calculate the association of each scoring system with the grade of postoperative complications.

CONCLUSION(S)

Both the S.T.O.N.E score and GSS can be used to predict post-PCNL stone clearance and complications. They can be judiciously and meaningfully used in planning the treatment of renal calculi. Additionally, they are useful for comparing postoperative outcomes.

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