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**Research Article**

# EVALUATION OF S.T.O.N.E. NEPHROLITHOMETRY SCORING IN PREDICTING OUTCOMES OF PERCUTANEOUS NEPHROLITHOTOMY

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**A R T I C L E I N F O**

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**A B S T R A C T**

**Aim:** To correlate S.T.O.N.E. Nephrolithometry Score with success and complications after Percutaneous Nephrolithotomy (PCNL).

**Materials and Methods:** A prospective study conducted at Institute of Urology, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai, from January 2015 to December 2015. After obtaining informed consent, all patients who underwent PCNL were selected, followed up, their success and complications recorded. Patient with prior treatment for renal calculi , Renal calculi suitable for other modalities of therapy, Patients with contraindications for PCNL, patients who didn't undergo NCCT KUB in pre-op workup, age <18yrs, BMI >30 were excluded. From NCCT KUB, stone burden, tract length, presence or absence of hydronephrosis, number of calyces involved and stone essence (density) were calculated. This was used to derive the STONE nephrolithometry score. Primary aim was complete clearance of renal calculi by single attempt at PCNL. Operative time, number of tracts dilated, length of hospital stay, postoperative complications and ancillary procedures for complete clearance of calculi were recorded. The data was statistically analyzed.

**Results:** Complete stone clearance was possible in 147 cases in first session. All cases with score 6, 7 had complete clearance of the calculi. None of the patients with score of 11 or 12 had complete clearance. Mean score of patients who had complete clearance of calculi was 7.46 while those who had incomplete clearance was 10.35. STONE score had a sensitivity of 89.12% and specificity of 98.46% in predicting complete clearance. STONE score was significantly associated with predicting stone free status ($p < 0.0001$). Correlation between STONE score and perioperative parameters was found to be statistically significant. Mean operating time, number of tracts dilated, grade of complications and length of stay all had a positive correlation with total STONE score.

**Conclusion:** STONE Nephrolithometry scoring is simple and effective bed side tool in determining the chance of achieving stone free status by a single session of PCNL.
Total score, Stone burden, Number of calyces involved were the most important predictors of success after PCNL.



## INTRODUCTION

Renal calculi are one of the most common afflictions of modern society. Westernization of global culture has migrated site of stone formation from lower tract to upper tract. Lifetime probability of being affected by renal calculi varies from 1 – 15% in various studies. From high morbidity & mortality associated with open surgery in the past, today modern stone surgeries have very minimal morbidity and rarely any mortality.Various techniques of management of renal stone disease includes percutaneous nephrolithotomy (PCNL), Flexible ureteroscopy (Flexi-URS) and open surgeries (Pyelolithotomy, nephrolithotomy) and Extracorporeal Shockwave Lithotripsy (SWL).Since the advent of PCNL, standard PCNL & various miniature modification of PCNL have become the most common modality of renal stone management. With advent of such advanced endoscopic techniques with minimal morbidity, the chance of complete stone clearance after a single procedure has become a goal. This may not be possible in all cases. Hence, various scoring systems have been developed to preoperatively stratify the difficulty of PCNL. One such system is S.T.O.N.E. Nephrolithometry scoring system. In our study, we attempt to segregate patients based on this scoring system and predict for whom stone clearance may not be possible in a single attempt.

## AIMS & OBJECTIVES

To correlate S.T.O.N.E. Nephrolithometry Score with Success and Complications after Percutaneous Nephrolithotomy (PCNL).

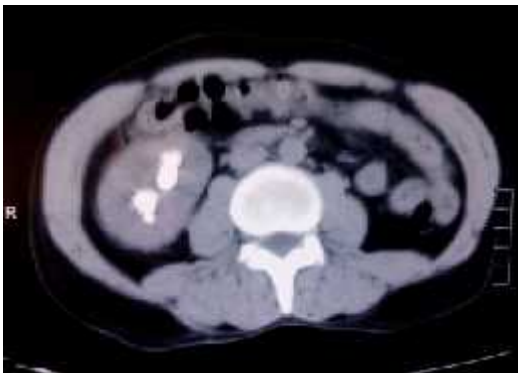
## MATERIALS AND METHODS

This was a Prospective and retrospective study conducted in the Institute of Urology, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai from January 2015 to December 2015 (1year) with a sample size of 212 cases. All patients admitted for PCNL during the study period were included after strictly applying the below mentioned exclusion criteria.Patients with prior treatment for renal calculi (SWL, RIRS, PCNL, Open Stone surgeries, DJ Stents, PCN), Renal calculi suitable for other modalities of therapy (SWL, RIRS, Open Surgery), Patients with contraindications for PCNL, Patients who didn't undergo Non Contrast CT in pre-op workup, Age <18yrs and BMI >30 were excluded from my study.Non – Contrast CT was done in all patients. From the images, stone burden, tract length, presence or absence of hydronephrosis, number of calyces involved and stone essence (density) were calculated. This was used to derive the STONE nephrolithometry score.

***Stone burden***

**Stone Burden ($mm^2$) = Max. Length (mm) X Max. Width (mm)**

| Stone Burden | Score |
|---|---|
| 0 – 399 $mm^2$ | 1 |
| 400 – 799 $mm^2$ | 2 |
| 800 – 1599 $mm^2$ | 3 |
| 1600 $mm^2$ and above | 4 |



***Tract length***

Based on skin stone distance (SSD) on preoperative CT, tract length was estimated as follows. From the center of the stone, horizontal line was drawn to the skin surface. This was taken as SSD1 (mm). From the center of stone a vertical line was drawn to skin, the length of which was taken as SSD2 (mm). From the center of stone, a line was drawn obliquely at 45 degrees to towards the skin. This was taken as SSD3 (mm). Estimated tract length was the average of the three distances.

**Tract length (mm) = (SSD1 + SSD2 +SSD3) / 3**

| Tract Length | Score |
|---|---|
| Less than / equal to 100mm | 1 |
| Above 100mm | 2 |

***Obstruction***

| Obstruction | Score |
|---|---|
| No or minimal Hydronephrosis | 1 |
| Moderate to severe Hydronephrosis | 2 |

Presence or absence of hydronephrosis was recorded and scored as follows.

***Number of calyces involved***

| Number of calyces involved | Score |
|---|---|
| 1-2 | 1 |
| 3 | 2 |
| Staghorn | 3 |

***Stone Essence (Density)***

| Essence | Score |
|---|---|
| Less than or equal to 950HU | 1 |
| More than 950HU | 2 |

***S.T.O.N.E. Nephrolithometry score***

Sum of the above values will give the STONE score for the particular patient.

**STONE score = Stone Burden score + Tract length score + Obstruction score + Number of calyces score + Stone Essence score**

| STONE Variable | Score 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Stone Size ($mm^2$) | 0-399 | 400-799 | 800-1599 | 1600 and above |
| Tract Length (mm) | Up to 100 | Above 100 | | |
| Obstruction | None/Mild | Moderate/Severe | | |
| Calyces | 1-2 | 3 | Staghorn | |
| Essence (HU) | Up to 950 | Above 950 | | |
| | **Minimum score 5** | | **Maximum score 13** | |

***Procedure***

Standard PCNL was done in all cases as described previously.

***Peri and Postoperative data***

Data regarding the patient were collected and recorded in a prospective and retrospective fashion. These include
Patient details such as Name, Age, Sex, ASA score, Stone laterality

***STONE score:*** Stone burden, Tract length, Obstruction, Number of calyces involved, Stone essence (density)
Intraoperative factors: Number of tracts created,Operative time,Stone completely cleared or not,Need for ancillary / repeat procedures Postoperative complications as per modified Clavien – Dindo grading,Length of stay Postoperatively patients were followed up for maximum of 30days and any complication that developed during this time was recorded.

Primary aim was to correlate the score with completeness of stone clearance. Secondary aim was to correlate the score with grade of complications.

***Statistical Analysis***

Using the Medcalc software (version 16.2.1) data collected was analyzed. Chi – square test, ANOVA, Correlation coefficients, receiver operatingcharacteristic curves (ROC Curves) were used for analysis. Sensitivity, specificity, correlation coefficient and statistical significance determined. $P < 0.05$ was determined to be statistically significant.

## RESULTS

Totally 246 cases of PCNL were done during the study period. Of these 34 were excluded as they did not meet the study criteria. 12 had undergone prior stone surgery (SWL, RIRS, PCNL, open stone surgery etc.), 8 didn't have preoperative CT-KUB for imaging, 14 were less than 18years of age .Remaining 212 cases were included in the study.

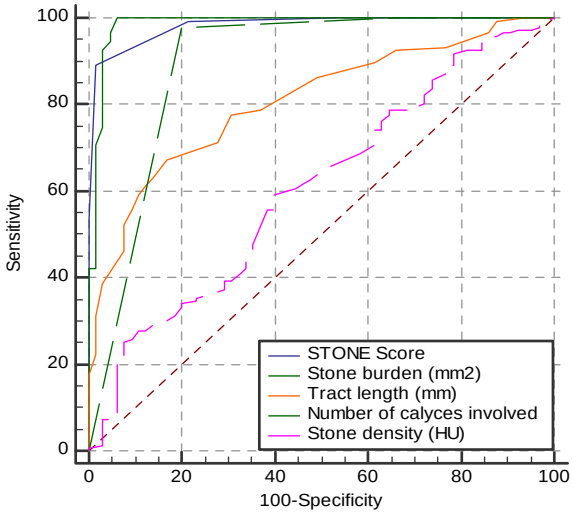
Complete stone clearance was possible in 147 cases in first session. Remaining 65 needed some form of ancillary procedure for complete stone clearance. Mean age group of patients in complete clearance was 43.71 yrs { 19 – 75 yrs } and in incomplete clearance was 45.65 yrs { 19- 71 } , P-value was insignificant. 93 (63.26%) of males &54 (36.74%) of females were completely cleared of the stone. 45 (69.23%) males & 20 (30.77%) females had incomplete stone clearance. Regarding Sex distribution P value was insignificant.Out of the 147 cases that achieved complete clearance, 136 (92.52%) were of ASA grade I, II and remaining 11 (7.49%) were of ASA III. Out of the 65 cases with incomplete clearance of calculi 59 (90.76%) were ASA I,II and 6 (9.24%) were ASA III. P- value was insignificant.

**Comparison of parameters between complete clearance and incomplete clearanc groups**

| Parameter | Complete stone clearance | Incomplete stone clearance | P - value |
|---|---|---|---|
| Number (n) | 147 (69.34%) | 65 (30.66%) | |
| Age (years) | 43.71 (19 - 75) | 45.65 (19 - 71) | 0.3091 |
| Sex | | | |
| Male (%) | 93 (63.26%) | 45 (69.23%) | |
| Female(%) | 54 (36.74%) | 20 (30.77%) | |
| ASA score | | | 0.1212 |
| 1,2 (%) | 136 (92.51%) | 59 (90.76%) | |
| 3 (%) | 11 (7.49%) | 6 (9.24%) | |
| Laterality | | | 0.4578 |
| Right (%) | 86 (58.5%) | 39 (60%) | |
| Left (%) | 61 (41.49%) | 26 (40%) | |

### *Stone Nephrolithometry Score*

Average stone burden among cases with complete stone clearance was 539.33 $mm^2$.Average stone burden in cases of incomplete clearance was 1151.35 $mm^2$.Stone burden had a sensitivity of 100% and specificity of 93.85% in predicting complete clearance. Stone burden was significantly associated with predicting stone free state (p <0.0001). Tract length in complete stone clearance cases was 104.12mm, while, in incomplete stone clearance it was 112.03mm.Tract length had a sensitivity of 67.35% and specificity of 83.08% in predicting complete clearance. Tract length was significantly associated with predicting stone free state (p <0.0001). Out of the 101 cases without obstruction, 67 (45.47%) had complete clearance while 34 (52.31%) had incomplete clearance. Of the 111 caes with obstruction, 80 (54.43%) had complete clearance while 31 (47.69%) had imcomplete clearance.Obstruction had a sensitivity of 61.47% and specificity of 55.64% in predicting complete clearance. Obstruction was not significantly associated with predicting stone free state (p = 0.062). Of the 147 cases that achieved complete clearance, only 3 cases had aof score of 2 (3 calyces). None of the cases with score 3 (Staghorn) in had complete stone clearance. 13 cases with score 1 and 30 cases with score 2 had incomplete tumor clearance. Mean score in complete clearance group was 1.02 while those with incomplete clearance had a mean score of 2.138.Number of calyces involved had a sensitivity of 97.96% and specificity of 80% in predicting complete clearance. Number of calyces involved was significantly associated with predicting stone free state (p <0.0001). Mean density of stone in those who achieved complete clearance was 913 HU.Mean density of stone in those who achieved incomplete clearance was 1022 HU.Stone essence (density) involved had a sensitivity of 59.18% and specificity of 60% in predicting complete clearance. Stone essence (density) was not significantly associated with predicting stone free status (P = 0.372). 65 (30.66%) cases failed to achieve stone free status with first attempt at PCNL. All these needed some form of ancillary procedures that prolonged their hospital stay. Most common ancillary procedure needed in our series, in descending order, was relook PCNL, SWL, relook PCNL with SWL, URS + DJ stenting, RIRS.All cases with score 6, 7 had complete clearance of the calculi. 52 cases with score of 8 had complete clearance while 1 case had incomplete clearance. Of cases with score of 9, 15 had complete clearance and 13 had incomplete clearance. Only 1 case with score of 10 had complete removal of stone, while 21 had residual calculi. None of the patients with score of 11 or 12 had complete clearance. Mean score of patients who had complete clearance of calculi was 7.46 while those who had incomplete clearance was 10.35. STONE score had a sensitivity of 89.12% and specificity of 98.46% in predicting complete clearance. STONE score was significantly associated with predicting stone free status (p <0.0001).




| Parameter | Complete stone clearance | Incomplete stone clearance | P - value |
|---|---|---|---|
| STONE BURDEN (mm2) | 539.33 (228 - 780) | 1151.35 (522 - 2254) | <0.0001 |
| TRACT LENGTH (mm) | 104.12 (85 - 118) | 112.03 (98 - 121) | <0.0001 |
| Obstruction | | | 0.062 |
| Absent | 67 (45.57%) | 34 (52.31%) | |
| Present | 80 (54.43%) | 31 (47.69%) | |
| Number of calyces | 1.02 (1-2) | 2.138 (1 - 3) | <0.0001 |
| Essence (density; hu) | 913.25 (440 - 1600) | 1022 (450 - 1600) | 0.372 |
| S.T.O.N.E score | 7.46 (6 - 10) | 10.35 (8 - 12) | <0.0001 |

### *Receiver Operating Characteristic curves (ROC Curves)*

From the ROC curves, STONE score, stone burden, number of calyces involved had high sensitivity and specificity and were statistically significant in predicting a stone free state. Tract length had a low sensitivity and specificity, but was statistically significant in predicting stone free status. Stone Essene (density) was neither sensitive or specific nor statistically significantly associated with predicting stone free status.

STONE score, stone burden, tract length and number of calyces involved had statistically significant association at predicting stone free status.Most sensitive parameter for predicting stone free status was stone burden. Most specific parameter predicting stone free status was STONE score.Degree of obstruction and stone essence had no role in predicting stone free status.

***Perioperative Parameters and Stone Score***

Cases with stone score of 11 & 12 only needed 3 tracts for complete stone clearance. Cases with score of 6 – 10 were mostly managed with single tract and occasionally only needed 2 tracts. Mean number of tracts created in complete clearance group was 1.11 while, in the incomplete clearance group was 1.55. Thus, the higher the STONE score greater will be the number of tracts needed for complete clearance. There was a significant correlation between number of tracts needed and STONE score (P <0.0001). With increase in STONE score, the mean operative time also gradually increased. For patients with a score of 6 had surgery completed in 55.6min while, those with score of 12 needed 123.8 min on an average. There was a significant correlation between mean operating time and STONE score (P <0.0001).All complications were graded according to modified Clavien – Dindo Grade for postoperative surgical complications. 48 cases in complete clearance group and 28 cases in incomplete clearance group developed complications. There were no deaths (Gr 5 complication) in the study. There were only 3 cases with Gr 4 complications all of whom had incomplete removal of their calculus. With increasing STONE score, the grade of complications also increased. None of the patient with a score of 6 had Gr 3 complication while, only those with score of 10 – 12 had Gr 4 complication. There was a significant correlation between incidence of any complication and STONE score (P <0.0001).With increasing score the length of hospital stay also increased. Mean duration of stay for cases with score of 6 was 3.29 days while, those with STONE score of 10-12 had average of 6 days of hospitalization. There was a significant correlation between length of hospital stay and STONE score (P <0.0001).

**Correlation between perioperative parameters and STONE score**

| Correlation with stone score | Correlation coefficient r | 95% Confidence interval for r | Significance level |
|---|---|---|---|
| Operative Time | 0.9188 | 0.8948 to 0.9374 | P<0.0001 |
| Number of tracts dilated | 0.5113 | 0.4044 to 0.6044 | P<0.0001 |
| Complications | 0.145 | 0.01043 to 0.2744 | P<0.0001 |
| Length of stay | 0.7579 | 0.6941 to 0.8100 | P<0.0001 |

Correlation between STONE score and perioperative parameters was found to be statistically significant. Mean operating time, number of tracts dilated, grade of complications and length of stay all had a positive correlation with total STONE score.

## DISCUSSION

PCNL has become the standard of care for renal stone worldwide. In our study, we tried to identify those parameters that help predict success and patient morbidity preoperatively. This information could help in making informed decisions by the patient and the treating urologist.

Many ways of classifying the stone burden in a given case exists.Staghorn calculi have been traditionally classified as partial or complete which did not give much information with respect to planning management.Guy's stone score was developed based on expert opinions and published data. This system was reproducible and predicted the stone free status. However, it was useful only for staghorn calculi. Another disadvantage is that the Guy's score can be predicted using various imaging modalities like X-Ray KUB, IVU or even USG. But none is as accurate as CT imaging in assessing all parameters relating to the stone.The European Association of Urology recommends CT based 3D - reconstructed stone volume measurement as the most accurate way to measure the stone burden. Construction of a 3D model of stone can help in comprehensive planning of PCNL. This was associated with a 93% stone free rate.Mishra *et al*. described a CT morphometry based classification system. Based on 3D reconstruction, total stone volume (TSV) was determined. From CT – Urogram images, unfavorable calyx stone percentile volume (UFCSPV) was determined. A calyx was considered unfavorable if it formed acute angle with the planned calyx of entry and had a infundibular diameter of <8mm. The combination of TSV and UFCPSV successfully predicted the number of tracts needed and number of PCNLs needed in the management of renal calculi. This system is very complicated and confusing for urologists unaware of this system. Zhu *et al*. developed a normogram based on stone burden, stone location, presence of staghorncalculi, and degree of hydronephrosis in predicting success of Mini – PCNL. It was time consuming to calculate based on this normogram. More importantly, this system developed for Mini – PCNL could not be generalized to standard PCNL.Except for the Guy's scoring system all others needed sophisticated software and 3D CT reconstruction to determine the complexity of PCNL and its success. None of them were practically applicable at the bed side.

S.T.O.N.E. Nephrolithometry system used in this study was developed by Arthur Smith Institute. It was developed as a system that could be easily used at the bed side to determine the complexity of PCNL. It also predicted the chances at achieving stone free statusin a single attempt.This system was not specific for staghorn calculus and could be used for any renal calculi. All components could be easily determined by a simple non – contrast CT of the KUB region. Stone burden, tract length, presence of obstruction, number of calyces involved and stone density could be easily deduced from the CT scan images. In our study, the best predictors for stone free rate was stone burden, number of calyces involved and STONE score. Stone density, presence of obstruction did not have any predictive value with respect to stone free status.

Overall, STONE score had an excellent sensitivity of 89.12% and specificity of 98.46% at predicting the possibility of stone free status. It was also statistically significant in predicting stone free status (P < 0.0001). STONE score was found to be the most specific in predicting stone free status in a single attempt of PCNL.

For any scoring system to be successful, it must fulfill three factors:

1. Score should be easy to derive from available preoperative radiologic studies
2. Detailed information about each case should be provided by the scoring system
3. Should predict postoperative outcome in terms of success and complications

From our study, STONE Nephrolithometry scoring successfully predicted stone free status. It also predicted perioperative and postoperative events. This system is also easy to use and derives all needed details from simple non contrast CT – KUB taken in preoperative setting. Thus it fulfills all criteria needed for a successful scoring system for management of renal calculi.

## CONCLUSION

STONE Nephrolithometry scoring is simple and effective bed side tool in determining the chance of achieving stone free status by a single session of PCNL.Total score, Stone burden, Number of calyces involved were the most important predictors of success after PCNL. STONE Nephrolithometry scoring also correlates well with mean operating time, number of tract needed, complications and length of hospital stay.

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