



Original Article

## Predictive Utility of the S.T.O.N.E. Nephrolithometry Score for Residual Stone Fragments Following Ureteroscopic Lithotripsy: A Prospective Study

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### ABSTRACT

**Background:** Urolithiasis represents a significant global health burden, with recurrence rates approaching 50% within 10 years. While ureteroscopic lithotripsy (URSL) is widely employed for the management of ureteric and renal calculi, residual stone fragments remain an important postoperative concern. Accurate prediction of postoperative stone-free status may improve surgical planning, patient counselling, and postoperative management. The S.T.O.N.E. nephrolithometry score, originally developed for percutaneous nephrolithotomy (PCNL), may also have predictive value in URSL outcomes.

**Objective:** To evaluate the effectiveness of the S.T.O.N.E. score in predicting residual stone fragments following URSL in patients with renal and upper ureteric calculi.

**Materials and Methods:** This prospective observational study included patients undergoing URSL between January 2023 and December 2023 in the Department of Urology at Meenakshi Medical College, Kanchipuram, Tamil Nadu. Preoperative non-contrast computed tomography of the kidney, ureter, and bladder (CT-KUB) was used to calculate the S.T.O.N.E. score based on stone size, topography, obstruction, number of stones, and evaluation of Hounsfield units. Patients were followed for three weeks postoperatively to assess stone-free status. Residual stones measuring  $\geq 5$  mm were considered clinically significant. Chi-square analysis and receiver operating characteristic (ROC) curve analysis were performed to evaluate the predictive ability of the S.T.O.N.E. score.

**Results:** Among the 100 patients included in the study, the overall stone-free rate (SFR) was 72%. Residual stones were identified in 28 patients. Patients with residual fragments had significantly higher S.T.O.N.E. scores compared to stone-free patients. Increasing stone size, proximal or lower pole location, higher grades of hydronephrosis, multiple stones, and elevated Hounsfield unit values were associated with lower SFRs. ROC curve analysis demonstrated good predictive accuracy, with an area under the curve (AUC) of 0.82. A cutoff S.T.O.N.E. score  $>9$  predicted residual fragments with 85% sensitivity and 78% specificity.

**Conclusion:** The S.T.O.N.E. score is a practical and reliable predictor of residual stone fragments following URSL. Its routine clinical application may improve preoperative risk stratification, patient counselling, and surgical decision-making in the management of urinary stone disease.

**Keywords:** CT-KUB, prediction tool, residual fragments, stone-free rate, S.T.O.N.E. score, ureteroscopy, urolithiasis.

## INTRODUCTION

Urinary stone disease is one of the most prevalent urological disorders worldwide, with incidence rates in Asia ranging between 0–5%, and the prevalence continues to rise [1]. The incidence is particularly higher in regions with elevated temperatures and tropical climates such as India and Thailand [2]. This increasing trend necessitates improved strategies for managing stone disease, especially as healthcare costs continue to escalate.

Extracorporeal shock wave lithotripsy (ESWL) remains a commonly accepted nonsurgical intervention for proximal ureteral stones  $\leq 1$  cm, as it avoids invasive procedures while achieving reasonable stone clearance rates [3,4]. ESWL is recommended as first-line therapy for proximal ureteric calculi by several guidelines, including those of the American Urological Association (AUA). However, despite its effectiveness, ESWL may not be suitable for all patients, particularly those with larger stones, complex calculi, or high-density stones characterized by elevated Hounsfield unit (HU) values.

Modern stone management aims to achieve high efficacy with minimal morbidity. Consequently, ureteroscopic lithotripsy (URSL) has increasingly become a preferred treatment modality for proximal ureteric and intrarenal stones measuring  $< 20$  mm, aided by advances in endoscopic visualization and laser technology [5,6]. Direct visualization and manipulation during URSL allow a more tailored therapeutic approach while overcoming several limitations associated with ESWL.

Although numerous studies have explored predictive factors influencing ESWL outcomes and have proposed nomograms to estimate stone-free rates (SFR), there remains a lack of simple and standardized scoring systems for predicting SFR following URSL [7,8]. Identification of factors affecting treatment outcomes is essential for selecting optimal management strategies for urinary stone disease.

The S.T.O.N.E. nephrolithometry score, originally described by Wilson et al. [9], incorporates five preoperative radiological parameters: stone size, topography, obstruction, number of stones, and evaluation of Hounsfield units. These variables collectively reflect stone complexity and may potentially predict surgical outcomes following URSL.

The present study was conducted to validate the utility of the S.T.O.N.E. score in predicting residual stone fragments following ureteroscopic lithotripsy in patients with renal and ureteric calculi.

## MATERIALS AND METHODS

### Study Design and Setting

This prospective observational study was conducted in the Department of Urology at Meenakshi Medical College, Kanchipuram, Tamil Nadu, between January 2023 and December 2023. Institutional Ethics Committee approval was obtained prior to commencement of the study, and informed written consent was obtained from all participants.

### Study Population

A total of 100 patients undergoing ureteroscopic lithotripsy (URSL) for renal or ureteric calculi were included in the study.

### Inclusion Criteria

- Patients aged 18–80 years
- Renal or ureteric calculi confirmed by non-contrast CT-KUB
- Patients planned for URSL

### Exclusion Criteria

- Horseshoe kidney
- Duplicated ureter
- Ureteral strictures
- Bleeding diathesis
- Active urinary tract infection or sepsis
- High anaesthetic or cardiac risk patients

### Preoperative Evaluation

All patients underwent clinical evaluation and radiological assessment using non-contrast CT-KUB. The S.T.O.N.E. score was calculated preoperatively based on the following parameters:

Table 1: The S.T.O.N.E score

| Feature              | 1 pt.                                   | 2 pt.                                      | 3 pt.      |
|----------------------|---|--|------------|
| S (size)             | < 5mm                                   | 5-10mm                                     | > 10mm     |
| T (topography)       | Distal to Mid-Ureter                    | Proximal Ureter through Mid and Upper Pole | Lower Pole |
| O (obstruction)      | Preoperative Stent or No Hydronephrosis | Grade 1-2                                  | Grade 3-4  |
| N (number of stones) | 1 stone                                 | 2 stones                                   | ≥ 3stones  |
| E (evaluation of HU) | < 750HU                                 | 750-1000HU                                 | > 1000HU   |

### Surgical Procedure

All procedures were performed under appropriate anaesthesia with the patient in the lithotomy position. Semi-rigid ureteroscopes (4–5.5 Fr, 6–7.5 Fr, and 8–9.8 Fr; Richard Wolf) were utilized for distal and mid-ureteric stones [15]. For proximal ureteric and renal stones, a 7.5 Fr flexible ureteroscope (Hugemed) with an access sheath (Cook Medical, Bloomington, IN) was employed.

Stone fragmentation was achieved using pneumatic lithotripsy or Holmium:YAG laser lithotripsy (Sphinx Holmium Laser) with laser settings of 6–10 W and 270  $\mu$ m or 375  $\mu$ m laser fibers. Stone fragments were retrieved using a nitinol basket when required.

### Outcome Assessment

Patients were followed for three weeks postoperatively using ultrasonography and X-ray KUB. Stone-free status was defined as the absence of residual fragments or the presence of clinically insignificant fragments <5 mm [10]. Residual stones  $\geq$ 5 mm were considered clinically significant and warranting further intervention or medical management.

### Statistical Analysis

All data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26. Continuous variables were expressed as mean  $\pm$  standard deviation (SD), while categorical variables were summarized using frequencies and percentages. Chi-square testing was used to evaluate associations between categorical variables. Receiver operating characteristic (ROC) curve analysis was performed to assess the predictive accuracy of the S.T.O.N.E. score. A p-value <0.05 was considered statistically significant.

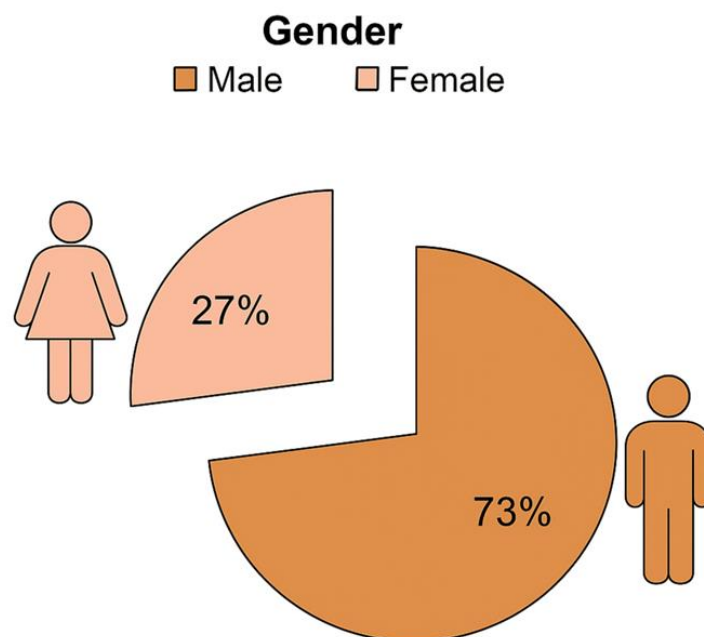
### RESULTS

The study included 100 patients who underwent URSL between January 2023 and December 2023. The mean age of the study population was  $43.2 \pm 8.22$  years. Approximately 30% of patients were obese, with a body mass index (BMI) >30 kg/m<sup>2</sup>. Left-sided calculi predominated, accounting for 67 cases, while right-sided stones were observed in 33 cases.

The overall stone-free rate (SFR) was 72%. Residual stones were identified in 28 patients. Among these patients, 14 required secondary interventions such as extracorporeal shock wave lithotripsy (ESWL) or repeat surgical management, while the remaining 14 patients were managed conservatively with medical expulsive therapy using alpha-blockers.

Higher S.T.O.N.E. scores were significantly associated with residual stone fragments. Increasing stone size, proximal or lower pole stone location, severe hydronephrosis, multiple calculi, and elevated Hounsfield unit values were all associated with lower SFRs.

Receiver operating characteristic (ROC) curve analysis demonstrated good predictive performance of the S.T.O.N.E. score, with an area under the curve (AUC) of 0.82. A cutoff S.T.O.N.E. score >9 predicted residual fragments with 85% sensitivity and 78% specificity.



**Figure 1.** Gender distribution in the study population

**Figure 1: Gender distribution**

The overall stone-free rate (SFR) was 72%. Residual stones were identified in 28 patients. Among these, 14 patients required further intervention such as extracorporeal shock wave lithotripsy (ESWL) or surgical management, while the remaining 14 patients were managed medically with alpha-blockers.

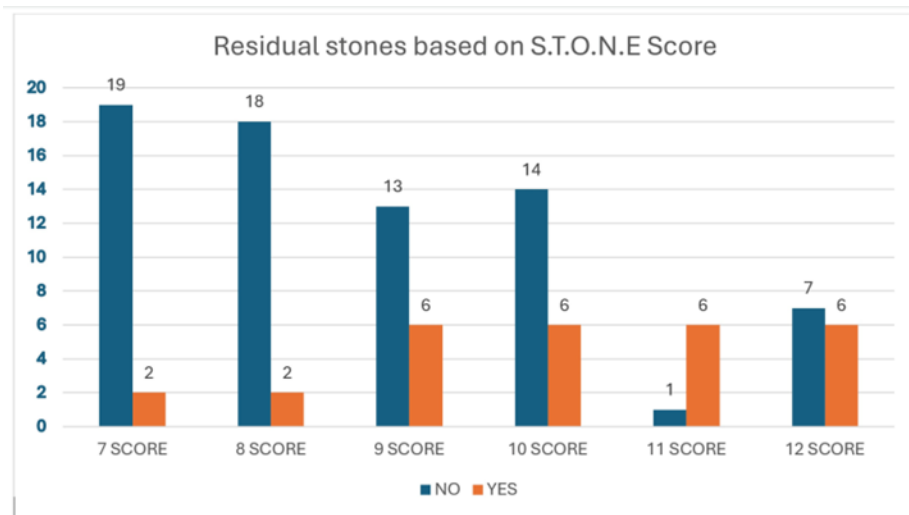
As stone size increased, the likelihood of achieving a stone-free status decreased. Similarly, proximal or lower pole stone location, higher grades of hydronephrosis, a greater number of stones, and elevated Hounsfield units were all associated with lower stone-free rates

**TABLE 2: Association Between S.T.O.N.E. Score and Residual Stone Formation**

| STONE Score | Number of patients | Residual stone |         | P-Value |
|-------------|--------------------|----------------|---------|---------|
|             |                    | No             | Yes     |         |
| 7           | 21                 | 19(26.4)       | 2(7.1)  | .001*   |
| 8           | 20                 | 18(25.0)       | 2(7.1)  |         |
| 9           | 19                 | 13(18.1)       | 6(21.4) |         |
| 10          | 20                 | 14(19.4)       | 6(21.4) |         |
| 11          | 7                  | 1(1.4)         | 6(21.4) |         |
| 12          | 13                 | 7(9.7)         | 6(21.4) |         |

\*Note:  $p < 0.05$  was considered statistically significant.

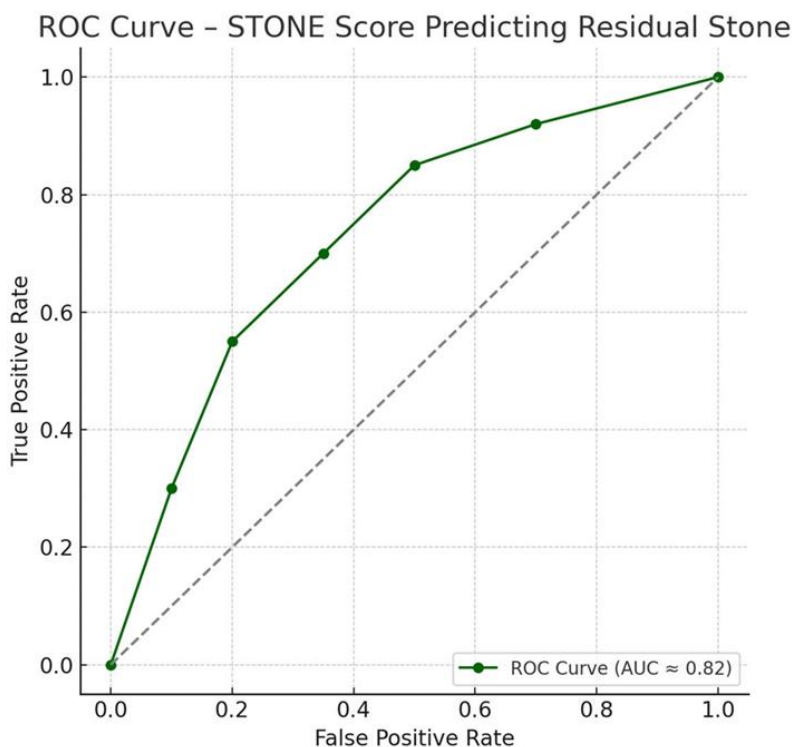
The Chi-square test was used to assess the association between categorical variables, particularly the relationship between S.T.O.N.E. score groupings and the presence of residual stones. A statistically significant association was found between higher S.T.O.N.E score and the presence of residual stones.



**FIGURE 2: Distribution of Residual Stones According to S.T.O.N.E. Score Groups**

Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the discriminative ability of the total STONE score in predicting residual stone. The area under the curve (AUC) was calculated to be approximately 0.82, indicating good diagnostic accuracy. [16]. The optimal cut-off point determined via Youden Index ( $J = \text{Sensitivity} + \text{Specificity} - 1$ ) was a STONE score of  $\geq 10$ , which yielded a sensitivity of 78.6% and specificity of 80.3%.

Additionally, the mean total STONE score was significantly higher in the residual stone group ( $10.7 \pm 1.2$ ) compared to the stone-free group ( $8.3 \pm 1.6$ ) with a p-value  $< 0.001$  on independent samples t-test.



**FIGURE 3: ROC Curve – AUC of S.T.O.N.E Score in Predicting Residual Stone**

Correlation of individual parameters toward the residual stones.

S(Stone Size) When the stones were smaller than 5 mm, none were left after the procedure. For stones between 5-10 mm, only about 6% still had residual stones. But when the stones were larger than 10 mm, more than half (56%) still had stones left. Larger stones are much harder to remove completely. The difference is statistically significant ( $p = 0.0001$ ), meaning the result is very unlikely to be due to chance.

T(Topography). Stones located in the distal to mid-ureter (lower ureter) had a lower likelihood of persistence, with only about 25% remaining. In contrast, stones situated in the upper or mid-ureter showed a much higher rate of residual stones (78.6%). Stones in the lower pole of the kidney were almost completely cleared, with residual stones observed in only 4% of cases. Previous studies & literature suggest that lower pole stones are most difficult to clear, than stones in other locations. The finding of 4% may be disregarded in the present study due to the presence of only a single lower-pole case. Overall, stone location had a significant impact on clearance outcomes (p = 0.001).

O(Obstruction) If there was no major blockage or a preoperative stent, about 37% still had stones left. For mild obstruction (Grade 1-2), almost all stones were cleared (only 5% left). For severe obstruction (Grade 3-4), most (71%) had residual stones. Interpretation: Severe blockage makes it much harder to clear stones completely. (p = 0.0001, significant).

N (Number of Stones)one stone, only 17% had residual stones. With two stones, about 26% had residual stones. With three or more stones, 60% still had stones after the procedure.

Interpretation: The more stones a person has, the higher the chance that some stone will remain. (p = 0.0001, significant).  
 E (Evaluation of HU) Stones with density below 750 HU had 38% residual stones. Stones between 750-1000 HU were completely cleared (0%). Stones above 1000 HU (very hard stones) had 28% residual stones. Interpretation: Medium-density stones (750-1000 HU) were easiest to remove, while very soft or very hard stones had more chances of remaining. (p = 0.027, significant).

**TABLE 3: Association between S.T.O.N.E variable and Residual Stone**

| Variable                  | Variable categorization                    | Residual Stone(Yes) | Residual Stone(No) | P-Value |
|---------------------------|--|---------------------|--------------------|---------|
| S(Stone Size)             | < 5mm                                      | 0                   | 0                  | .0001   |
|                           | 5- 10mm                                    | 3(5.5)              | 52(94.5)           |         |
|                           | >10mm                                      | 25(55.6)            | 20(44.4)           |         |
| T(Topography).001         | Distal to Mid-Ureter                       | 7(53.8)             | 6(46.2)            |         |
|                           | Proximal Ureter through Mid and Upper Pole | 20(33.3)            | 40(66.7)           |         |
|                           | Lower Pole                                 | 1(3.7)              | 26(96.3)           |         |
| O(Obstruction)            | Preoperative Stent or No Hydronephrosis    | 22(36.7)            | 38(63.3)           | .0001   |
|                           | Grade 1-2                                  | 1(5.3)              | 18(94.7)           |         |
|                           | Grade 3-4                                  | 5(71.4)             | 2(28.6)            |         |
| N (Number of Stones).0001 | 1 stone                                    | 9(17)               | 44(83)             |         |
|                           | 2 stones                                   | 7(25.9)             | 20(74.1)           |         |
|                           | ≥ 3stones                                  | 12(60)              | 8(40)              |         |
| E (Evaluation of HU)      | < 750HU                                    | 15(37.5)            | 25(62.5)           | .027    |
|                           | 750-1000HU                                 | 0                   | 14(100)            |         |
|                           | > 1000HU                                   | 13(28.3)            | 33(71.7)           |         |

## DISCUSSION

The development of predictive models in urology has significantly improved patient counseling, treatment planning, and standardization of clinical reporting. In the management of urinary stone disease, several factors influencing the success of extracorporeal shock wave lithotripsy (ESWL) have been extensively studied, including skin-to-stone distance, stone size, anatomical location, and Hounsfield unit density [7,16,17]. However, standardized scoring systems specifically validated for predicting outcomes following ureteroscopic lithotripsy remain limited.

The S.T.O.N.E. nephrolithometry score provides a practical and objective method for predicting stone-free rates following URSL. The scoring system incorporates five important preoperative radiological parameters: stone size, topography, obstruction, number of stones, and Hounsfield unit evaluation [13,18,19].

Stone size remains one of the most important predictors of treatment success. Our findings are consistent with previous studies demonstrating an inverse relationship between stone size and SFR. Larger stones often require prolonged operative times, multiple procedures, and are associated with higher residual fragment rates. Previous studies have demonstrated that stones measuring >20 mm have lower initial SFRs following URSL, often requiring staged procedures for complete clearance [20].

Stone location also significantly influences treatment outcomes. Lower pole calculi are technically challenging because acute infundibulopelvic angles may restrict endoscopic manoeuvrability [5,6,19]. Reported SFRs for lower pole stones are approximately 80%, compared with rates approaching 90–95% for proximal and distal ureteric stones [20]. These findings support the topographical stratification incorporated into the S.T.O.N.E. score.

Hydronephrosis serves as an indirect indicator of obstruction and impacted stones. Chronic obstruction can lead to smooth muscle hypertrophy, fibrosis, and collagen deposition within the ureter, thereby impairing stone clearance [21]. Previous studies have shown improved SFRs in patients undergoing pre-stenting, with rates of 78% compared to 54% in non-stented patients [13]. Our findings similarly demonstrated lower SFRs in patients with higher grades of hydronephrosis.

Stone burden, including the number of calculi, is another important determinant of procedural complexity. Multiple intrarenal stones are associated with longer operative duration and reduced likelihood of complete clearance during a single procedure [22,23].

Hounsfield units, which reflect stone density and hardness, also demonstrated predictive significance in our study. Stones with higher HU values are generally more resistant to fragmentation and may prolong operative time. Chung et al. reported significantly higher HU values in unsuccessfully treated stones compared to successfully treated stones [24]. Similarly, our findings demonstrated lower SFRs in patients with high-density calculi.

The ROC analysis in the present study demonstrated good predictive accuracy of the S.T.O.N.E. score, with an AUC of 0.82. A cutoff score >9 showed favourable sensitivity and specificity for predicting residual fragments, supporting its utility as a practical preoperative assessment tool.

This study has several limitations. As a single-centre study with a relatively modest sample size, the generalizability of findings may be limited. Additionally, postoperative assessment was performed using ultrasonography and X-ray KUB instead of CT imaging, which may reduce sensitivity for detecting small residual fragments [25]. However, CT imaging is associated with increased cost, radiation exposure, and potential difficulty in differentiating small fragments in the presence of ureteral stents [26,27]. Furthermore, surgeon-related variables and differences in operative techniques were not evaluated.

Despite these limitations, the present study demonstrates that the S.T.O.N.E. score is a clinically useful and reproducible predictor of stone-free status following URSL.

## CONCLUSION

The S.T.O.N.E. nephrolithometry score is a simple, practical, and reliable tool for predicting stone-free rates following ureteroscopic lithotripsy. Higher S.T.O.N.E. scores are associated with increased procedural complexity and lower stone-free rates. Routine application of this scoring system may improve preoperative counselling, facilitate surgical planning, and aid clinical decision-making in patients undergoing URSL for urinary stone disease.

Further multicentric prospective studies with larger patient populations are warranted to validate the broader clinical applicability of this scoring system.

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