Original Article

External Validation of the Seoul National University Renal Stone Complexity Scoring System

Werayut Sirilarbyot, MD[1], Charoen Leenanupunth, MD[1], Yada Phengsalae, MSc[1], Premsant Sangkum, MD[1], Wachira Kochakarn, MD[1], Kittinut Kijvikai, MD[1], Chinnakhet Ketsuwan, MD[1]

[1] Division of Urology, Department of Surgery, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Background: Preoperative determination of patient characteristics and the complexity of renal calculi is essential for optimizing the outcomes of percutaneous nephrolithotomy (PCNL). The Seoul National University Renal Stone Complexity (S-ReSC) scoring system is a popular system for predicting stone-free rates (SFR).

Objective: To assess the predictive accuracy of the S-ReSC scoring system for PCNL in an external cohort.

Materials and Methods: The perioperative data of consecutive patients undergoing PCNL in the standard prone position from January 2011 until August 2020 and S-ReSC scores assigned preoperatively were retrospectively analysed.

Results: The study included 270 patients undergoing PCNL. The mean S-ReSC score was 5.4±2.9. The overall SFR was 60.7%. The SFRs in the low- (1 to 2), intermediate- (3 to 4), and high-score (5 to 9) groups were 100%, 97.8%, and 27.3%, respectively. Multivariate logistic regression showed that the S-ReSC score, stone size, number of stones, and operative time were independent predictors of the stone-free status after PCNL ($p<0.001$, $p=0.015$, $p=0.004$, and $p=0.015$, respectively). The area under the curve of the S-ReSC score was 0.949, indicating high predictive accuracy. Moreover, the S-ReSC score significantly correlated with estimated blood loss ($r=0.15$; $p=0.014$), and operative time ($r=0.14$; $p=0.025$).

Conclusion: The S-ReSC score is highly useful for nephrolithiasis assessments and is a reliable predictor of the SFR, bleeding and operative time.

Keywords: Renal calculus; S-ReSC; Percutaneous nephrolithotomy; Stone-free rate

J Med Assoc Thai 2021;104(Suppl.5): S10-5
Website: http://www.jmatonline.com

Nephrolithiasis is common, costly, and painful. Stone disease is a global health problem, affecting about 12% of the world's population, although its prevalence varies by age, sex, and race[1]. Thailand is characterized by a high incidence (183.8 per 100,000)[2]. Percutaneous nephrolithotomy (PCNL) is a minimally invasive surgical technique for treating large or complex kidney stones through a small incision[3]. The main aim of this procedure is a completely stone-free status without morbidity and mortality. However, in real-world settings, complete stone clearance is not always achieved, and major complications are still reported[4].

Correspondence to:

Ketsuwan C.

Division of Urology, Department of Surgery, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 270 Rama VI Road, Phyathai, Ratchathewi, Bangkok 10400, Thailand.

Phone: +66-2-2011536, **Fax:** +66-2-2794704

Email: chinnakhet.ket@mahidol.ac.th

How to cite this article:

Sirilarbyot W, Leenanupunth C, Phengsalae Y, Sangkum P, Kochakarn W, Kijvikai K, Ketsuwan C. External Validation of the Seoul National University Renal Stone Complexity Scoring System. J Med Assoc Thai 2021;104 (Suppl.5): S10-5

doi.org/10.35755/jmedassocthai.2021.S05.00062

Several models have been developed to quantitatively and systematically evaluate the complexity of nephrolithiasis to predict PCNL outcomes. The recently developed Seoul National University Renal Stone Complexity (S-ReSC) scoring system is an easy, fast, and reliable system[5,6] based on a single parameter, stone location, which is evaluated by computed tomography (CT). Due to its simplicity, this system is characterized by high reproducibility and replicability. Other scoring systems used for preoperative assessments of the complexity of nephrolithiasis include the stone size, tract length, obstruction, number of involved calices, and essence (STONE) system[7,8], the Clinical Research Office of the Endourological Society (CROES) nomogram[9,10], and Guy's Stone Score[11,12]. In the present study, we aimed to evaluate the S-ReSC system in our tertiary care hospital because it is the most recent. The primary objective was to determine whether the S-ReSC score can predict PCNL outcomes.

Materials and Methods

Ethical approval was obtained from the Institutional Review Board of the Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand (approval number: COA. MURA2019/876). The study was conducted in accordance with the 1964 Helsinki Declaration of the World Medical Association in its current version. Due to the retrospective nature of the study, informed

consent was waived. The patient data were encrypted and remained confidential.

We retrospectively identified 308 consecutive patients scheduled to undergo PCNL between January 2011 and August 2020. Patients with incomplete or unavailable preoperative CT scans or incomplete clinical information and patients under the age of 18 years were excluded. The collected patient characteristics and clinical data included age, gender, body mass index (BMI), American Society of Anesthesiologists physical status classification, laboratory tests (complete blood count, blood chemistry, coagulation panel, and urine culture), and antibiotic susceptibility tests. Non-contrast CT scans were preoperatively characterized for all patients. Operative data included anaesthetic records, operative notes, and need for blood transfusion.

All surgical procedures were performed by experienced endourologists. At the time of anaesthesia administration, each patient received a prophylactic antibiotic (typically second- or third generation cephalosporin) or antibiotics according to their urine culture results. Standard PCNL was performed with the patient in the prone position under general anaesthesia. Adverse events during the intra- and post-operative periods were evaluated according to the Clavien-Dindo classification[13]. Stone-free status was defined as no or clinically insignificant residual fragments with a diameter of less than 4 mm, with no symptoms, infections, or obstruction and no need for further intervention.

A urology resident assigned an S-ReSC score to each patient based on the location of nephrolithiasis involvement. The S-ReSC score ranges from 1 to 9 according to the number of sites involved in the renal pelvis (#1), superior and inferior major calyceal groups (#2 to 3), and anterior and posterior minor calyceal groups of the superior (#4 to 5), middle (#6 to 7), and inferior calyx (#8 to 9). The S-ReSC scores were divided into three groups: low- (1 to 2 points), intermediate- (3 to 4 points), and high-score (5 to 9 points) groups.

Statistical analysis

Statistical analysis was conducted using the STATA version 14.1 (STATA Corp., TX, USA). Quantitative variables were expressed as means±standard deviations and ranges, and qualitative variables were expressed as numbers and percentages. Univariate and multivariate logistic regression analyses were performed to identify independent predictors of the stone-free status following PCNL. Chi-squared test, independent t-test, and Pearson's correlation coefficient were used. A two-tailed p-value of less than 0.05 was considered statistically significant. The area under the curve (AUC) calculated by receiver operating characteristic (ROC) curve analysis was used to assess the predictive accuracy of the stone size, number of stones, operative time and S-ReSC for the stone-free status.

Results

A total of 270 patients were included in the study (Table 1). Of those, 126 (46.7%) were male and 144 (53.3%) were female. Their mean age was 58.8±11.8 years (range: 18 to 90 years). The mean BMI was 25.9±4.8 kg/m^2 (range: 14.5 to 50.7 kg/m^2). The mean renal stone size was 543.4±433.6 mm^2. The overall complication rate after surgery was 33.3%. The Table 1 also demonstrated the information of the 155 patients in the original development data set[5].

The mean S-ReSC score was 5.4±2.9 (range: 1 to 9). The stone-free rates (SFRs) in the low-, intermediate-, and high-score groups were 100% (37/37), 97.8% (88/90), and 27.3% (39/143), respectively (Table 2). The overall SFR was 60.7%. The S-ReSC score showed a significant inverse correlation with the SFR ($p<0.001$), indicating that the higher the S-ReSC score, the lower the probability of stone-free status. It also significantly correlated with estimated blood loss (EBL; $r=0.15$, $p=0.014$) and operative time (OT; $r=0.14$, $p=0.025$) indicating that the higher the S-ReSC score, the greater the EBL and the longer the OT (Table 3).

Multivariate logistic stepwise regression showed significant inverse associations between the SFR and stone size ($p=0.015$), number of stones ($p=0.004$), OT ($p=0.015$), and S-ReSC score ($p<0.001$) (Table 4). The ROC curves drawn to analyse their accuracies in predicting the stone-free status were shown in Figure 1. All four factors had high predictive accuracy. The S-ReSC score had an AUC of 0.949, the stone size had an AUC of 0.866, the number of stones had an AUC of 0.705, and the OT had an AUC of 0.652.

Discussion

Although nephrolithiasis is often asymptomatic and diagnosed incidentally, treatment is usually required to prevent possible future problems, such as obstructive uropathy, recurrent macroscopic haematuria, and urinary tract infection[14]. Nowadays, the main minimally invasive stone removal strategies are extracorporeal shock wave lithotripsy, retrograde intrarenal surgery (RIRS), laparoscopic surgery, and PCNL[15-18]. Management should achieve both high SFRs and low complication rates. However, life-threatening complications, such as bleeding requiring a blood transfusion, are observed in approximately 9.3% of patients[4]. Hence, preoperative surgical planning is a necessary step to ensure the success of the procedure and minimize post-operative morbidity.

In this study, we aimed to validate the S-ReSC scoring system based on preoperative CT scan findings and to evaluate its reliability in predicting PCNL outcomes. The system, developed by Jeong et al[5] in 2013, was based on the hypothesis that stone distribution in any location of the kidney is the strongest predictor of the stone-free status after PCNL and can determine the complexity of the procedure. Stone distribution is a complex parameter that combines multiple variables, including stone size, number of stones, and anatomic location. The stone distribution hypothesis was based on the study of Sampaio FJB[19], who showed that the macroscopic pelvicalyceal morphology of the kidney consists of 5 to 14 minor calyces and varies between

Table 1. Comparison of demographic and clinical characteristics between the development and validation groups

Variable	Development group	Validation group	p-value
Number of patients	155	270	-
Age (years): mean±SD	54.9±13.6	58.8±11.8	0.517
BMI (kg/m^2): mean±SD	25.5±3.6	25.9±4.8	0.761
Gender: n (%)			
Male	101 (65.2)	126 (46.7)	0.714
Female	54 (34.8)	144 (53.3)	
Laterality: n (%)			
Right	76 (49.0)	115 (42.6)	0.296
Left	79 (51.0)	155 (57.4)	
Stone density (Hounsfield unit): mean±SD	820.7±336.8	956.7±354.4	0.794
Degree of hydronephrosis, n (%)			0.199
Normal	26 (16.8)	215 (79.6)	
Mild	58 (37.4)	16 (5.9)	
Moderate	42 (27.1)	35 (13.0)	
Severe	29 (18.7)	4 (1.5)	
Operative time (minutes): mean±SD		130.6±82.5	0.001*
Number of stones: mean±SD		2.0±1.4	<0.001*
Length of hospital stay (days): mean±SD		7.0±3.3	0.061
Estimated blood loss (ml): mean±SD		280.8±310.1	0.032*
Stone size (mm^2): mean±SD		543.4±433.6	<0.001*
Skin-to-stone distance (mm), mean±SD		85.7±21.9	0.478
S-ReSC score, mean±SD		5.4±2.9	<0.001*
Complication rate, n (%)			
Clavien-Dindo 1		52 (19.3)	0.163
Clavien-Dindo 2		25 (9.3)	0.610
Clavien-Dindo 3		8 (3.0)	0.528
Clavien-Dindo 4		5 (1.9)	0.060

* Statistically significant
BMI = body mass index; SD = standard deviation; S-ReSC = Seoul National University Renal Stone Complexity

individuals. In most patients, the primary division of the renal pelvis includes two major calyceal groups, and mid-zone drainage depends on these two major groups. Jeong et al[5] proved the predictive accuracy of the S-ReSC scoring system for the stone-free status based on an AUC of 0.860. Choo et al[6] externally validated the S-ReSC system in 327 patients based on kidney, ureter, and bladder (KUB) films or CT scans and reported SFRs of 83.9%, 47.6%, and 21.4% in their low-, intermediate-, and high-score groups, respectively, with statistically significant differences between them, and an AUC of 0.731. These results are in line with our results, as we found a near-perfect accuracy of the S-ReSC score, with an AUC of 0.949.

The surgical regimen for the treatment of nephrolithiasis in a patient depends on three kinds of factors: stone-related, renal anatomic, and clinical factors. These factors also affect the surgical outcomes. Several previous studies[7,16,20] attempting to identify a single basic anatomic predictor of the stone-free status following PCNL have shown that the stone burden, density, location, and number and the morphology of the renal collecting system are crucial predictors of postoperative results. Similarly, our study shows that stone factors such as size and number are important independent predictors of the stone-free status. The integration of multiple variables into a scoring system or the creation of a new nomogram is valuable, as it can achieve higher accuracy than the use of a single factor. In our study, the AUC of the S-ReSC score was higher than those of the stone diameter and stone number. In addition to assessing the reliability of the S-ReSC in predicting the stone-free status, we evaluated its clinical usefulness in predicting postoperative complications. Higher S-ReSC scores were significantly associated with greater EBL and longer OT. Likewise, Jeong et al[5] found significant correlations between

Table 2. Stone-free rates following percutaneous nephrolithotomy by S-ReSC score and low-, intermediate-, and high-score groups

S-ReSC score	Stone-free rate	Score group	Stone-free rate	p-value
1	100% (32/32)	Low (1 to 2)	100% (37/37)	<0.001*
2	100% (5/5)			
3	98.7% (77/78)	Intermediate (3 to 4)	97.8% (88/90)	
4	91.7% (11/12)			
5	100% (3/3)	High (5 to 9)	27.3% (39/143)	
6	91.7% (11/12)			
7	46.2% (6/13)			
8	25.8% (17/66)			
9	4.1% (2/49)			

* Statistically significant.
S-ReSC = Seoul National University Renal Stone Complexity.

Table 3. Correlations between the S-ReSC score and post-operative outcomes

Variable	S-ReSC score	
	r	p-value
Stone-free status	-0.78	<0.001*
Estimated blood loss	0.15	0.014*
Length of stay	0.04	0.466
Operative time	0.14	0.025*
Complications	0.004	0.953
Haemoglobin level decrease	0.05	0.445

* Statistically significant.
S-ReSC = Seoul National University Renal Stone Complexity

the S-ReSC score and OT and low haemoglobin levels (p=0.013 and p=0.003, respectively).

Breakthroughs in flexible ureteroscopy and intracorporeal lithotripsy, especially thanks to thulium fibre and holmium lasers, have revolutionized RIRS, leading to higher success rates and lower complication rates. Jung et at[21] modified the S-ReSC scoring system for application to RIRS by adding one additional point per site to the original score for lower pole stones, which were difficult to eliminate with a flexible ureteroscope, thus increasing the maximum score from 9 to 12. The overall SFR in their study was 85.2%, with statistically significant differences between the low- (94.2%), medium- (84.0%), and high-score (45.5%) groups. The AUC of the modified S-ReSC score was 0.806. Park et al[22] confirmed the predictive value of the modified S-ReSC scoring system for the stone-free status following RIRS, with an AUC of 0.731. Thus, this scoring system is also useful for the initial evaluation of nephrolithiasis patients scheduled for RIRS. Moreover, it does not require software and is easy to use. A drawback is that it cannot differentiate between stones of different sizes in the same location.

This study has several limitations. Firstly, due to its retrospective nature, selection bias cannot be excluded. Secondly, the analysis of data from multiple surgeons may impact the reliability and validity of the results. Finally, stone analysis was not investigated for the influence on outcomes. The strength of our study is that it is the first to validate the S-ReSC scoring system with complete postoperative outcome assessments, including the SFR, LOS, EBL, and complication rates.

Conclusion

The S-ReSC scoring system is simple, accurate, and easily reproducible in urological clinics. Our external validation shows that it is useful in nephrolithiasis assessments and is a reliable predictor of the stone-free status, bleeding, and OT.

What is already known on this topic?

The S-ReSC scoring system was developed to evaluate the complexity of nephrolithiasis and to predict PCNL outcomes. However, no previous validation study has conducted a complete post-operative outcome assessment, including the SFR, hospitalization, and complication rates.

What this study adds?

The present study validated the S-ReSC system in an external cohort and demonstrated its value in predicting not only the stone-free status but also several other surgical outcomes.

Acknowledgements

We would like to thank all participants and other health personnel and acknowledge the assistance of the

Table 4. Multivariate regression analysis of stone-free status predictors

Variable	Odds ratio	95% confidence interval	p-value
S-ReSC score	-1.13	-1.50 to -0.76	<0.001*
Stone size (mm^2)	-0.002	-0.005 to -0.0005	0.015*
Number of stones	-0.636	-1.07 to -0.20	0.004*
Operative time (minutes)	-0.009	-0.02 to -0.002	0.015*

* Statistically significant
S-ReSC = Seoul National University Renal Stone Complexity

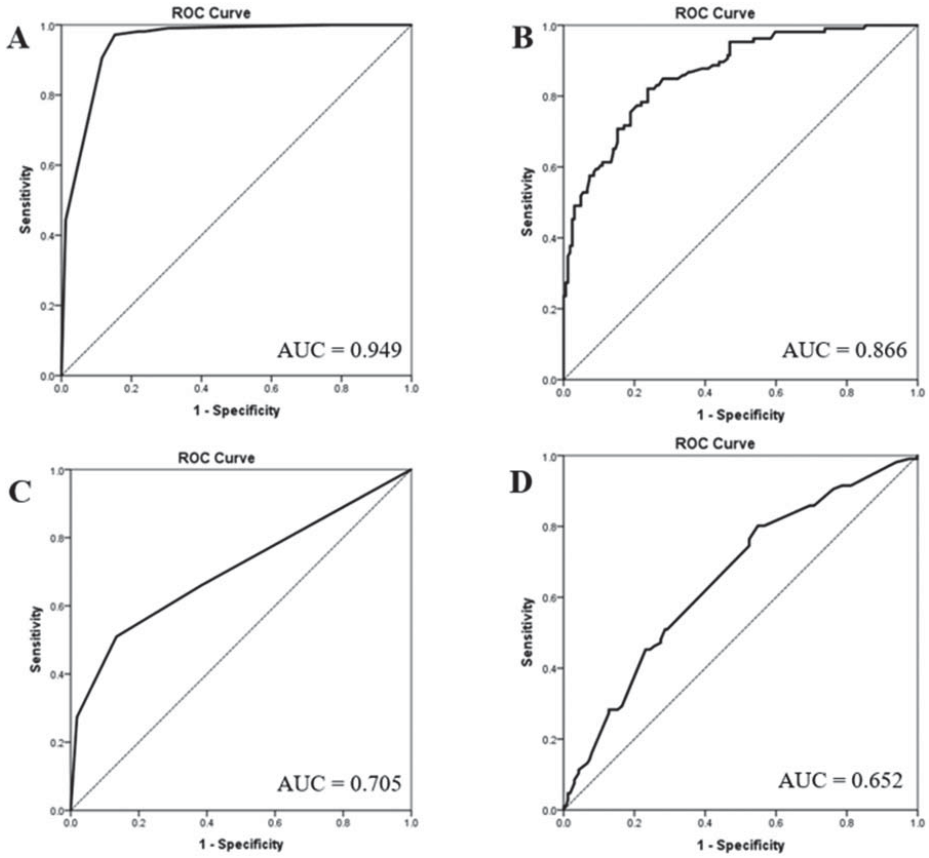

Figure 1. ROC curve analysis: A) S-ReSC, B) stone size, C) number of stones, D) operative time.

Department of Clinical Epidemiology and Biostatistics, Faculty of Medicine Ramathibodi Hospital.

Potential conflicts of interest

The authors declare no conflicts of interest.

References

1. Alelign T, Petros B. Kidney stone disease: an update on current concepts. Adv Urol 2018;2018:3068365.
2. Tanthanuch M, Apiwatgaroon A, Pripatnanont C. Urinary tract calculi in southern Thailand. J Med Assoc Thai 2005;88:80-5.
3. Turk C, Neisius A, Petrik A, Seitz C, Tepeler A, Thomas K. EAU Guidelines on Urolithiasis [Internet]. European Association of Urology; 2018 [cited 2021 Jan 7]. Available from: https://uroweb.org/wp-content/uploads/

EAU-Guidelines-on-Urolithiasis-2018-large-text.pdf
4. Ketsuwan C, Pimpanit N, Phengsalae Y, Leenanupunth C, Kongchareonsombat W, Sangkum P. Peri-operative factors affecting blood transfusion requirements during PCNL: A retrospective non-randomized study. Res Rep Urol 2020;12:279-85.
5. Jeong CW, Jung JW, Cha WH, Lee BK, Lee S, Jeong SJ, et al. Seoul National University Renal Stone Complexity score for predicting stone-free rate after percutaneous nephrolithotomy. PLoS One 2013;8:e65888.
6. Choo MS, Jeong CW, Jung JH, Lee SB, Jeong H, Son H, et al. External validation and evaluation of reliability and validity of the S-ReSC scoring system to predict stone-free status after percutaneous nephrolithotomy. PLoS One 2014;9:e83628.
7. Okhunov Z, Friedlander JI, George AK, Duty BD, Moreira DM, Srinivasan AK, et al. S.T.O.N.E. nephrolithometry: novel surgical classification system for kidney calculi. Urology 2013;81:1154-9.
8. Sirirak N, Sangkum P, Phengsalae Y, Kongchareonsombat W, Leenanupunth C, Ratanapornsompong W, et al. External validation of the S.T.O.N.E. score in predicting stone-free status after rigid ureteroscopic lithotripsy. Res Rep Urol 2021;13:147-54.
9. Smith A, Averch TD, Shahrour K, Opondo D, Daels FP, Labate G, et al. A nephrolithometric nomogram to predict treatment success of percutaneous nephrolithotomy. J Urol 2013;190:149-56.
10. Ketsuwan C, Kijvikai K, Kongchareonsombat W, Sangkum P, Rongthong S, Leenanupunth C. 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. J Med Assoc Thai 2020;103:762-6.
11. Thomas K, Smith NC, Hegarty N, Glass JM. The Guy's stone score—grading the complexity of percutaneous nephrolithotomy procedures. Urology 2011;78:277-81.
12. Lojanapiwat B, Rod-Ong P, Kitirattrakarn P, Chongruksut W. Guy's Stone Score (GSS) based on intravenous pyelogram (IVP) findings predicting upper pole access percutaneous nephrolithotomy (PCNL) outcomes. Adv Urol 2016;2016:5157930.
13. de la Rosette JJ, Opondo D, Daels FP, Giusti G, Serrano A, Kandasami SV, et al. Categorisation of complications and validation of the Clavien score for percutaneous nephrolithotomy. Eur Urol 2012;62:246-55.
14. Rule AD, Krambeck AE, Lieske JC. Chronic kidney disease in kidney stone formers. Clin J Am Soc Nephrol 2011;6:2069-75.
15. Kijvikai K. The role of laparoscopic surgery for renal calculi management. Ther Adv Urol 2011;3:13-8.
16. Ketsuwan C, Kongchareonsombat W, Sangkum P, Kijvikai K, Sananmuang T, Leenanupunth C. Perioperative renal calculus factors affecting percutaneous nephrolithotomy outcomes. Thai J Urol 2019;40:1-8.
17. Ketsuwan C, Leenanupunth C, Phengsalae Y, Sangkum P, Kongchareonsombat W, Kaewjai N, et al. Prospective randomized controlled trial to evaluate the effectiveness of watching movies to decrease anxiety during extracorporeal shock wave lithotripsy. Res Rep Urol 2021;13:97-104.
18. Lee HY, Yang YH, Shen JT, Jang MY, Shih PM, Wu WJ, et al. Risk factors survey for extracorporeal shockwave lithotripsy-induced renal hematoma. J Endourol 2013;27:763-7.
19. Sampaio FJ. Renal anatomy. Endourologic considerations. Urol Clin North Am 2000;27:585-607.
20. Binbay M, Akman T, Ozgor F, Yazici O, Sari E, Erbin A, et al. Does pelvicaliceal system anatomy affect success of percutaneous nephrolithotomy? Urology 2011;78:733-7.
21. Jung JW, Lee BK, Park YH, Lee S, Jeong SJ, Lee SE, et al. Modified Seoul National University Renal Stone Complexity score for retrograde intrarenal surgery. Urolithiasis 2014;42:335-40.
22. Park J, Kang M, Jeong CW, Oh S, Lee JW, Lee SB, et al. External validation and evaluation of reliability and validity of the Modified Seoul National University Renal Stone Complexity scoring system to predict stone-free status after retrograde intrarenal surgery. J Endourol 2015;29:888-93.