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Predictive value of scoring systems for stone free status and complications before percutaneous nephrolithotomy in children

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PCNL, a minimally invasive surgical technique for kidney stone removal, relies on achieving stone-free status, which various scoring systems aim to predict. This study assesses the predictive accuracy of the Clinical Research Office of the Endourological Society (CROES) and Guy's Stone Score (GSS) systems in determining stone-free rates following percutaneous nephrolithotomy (PCNL) in pediatric patients. A retrospective analysis was conducted on 580 pediatric patients who underwent PCNL at Çukurova University Urology Clinic between January 2007 and March 2024. Patients were categorized into two groups based on postoperative stone status: Group 1 and Group 2. CROES and GSS scores were calculated for each patient. The association between these scores and stone-free status, as well as postoperative complications, was statistically analyzed. Additionally, subgroup analyses were performed based on age groups. The study showed that 83.7% of patients achieved a stone-free condition postoperatively. Significant differences were found between the stone-free and residual stone groups regarding stone burden and operative time ($p < 0.001$). CROES had high accuracy for predicting stone-free outcomes ($p < 0.001$), while GSS was also effective in predicting both stone-free rates and complications. CROES was less effective in predicting complications. Both CROES and GSS are valuable for predicting PCNL outcomes in pediatric patients. While CROES is more reliable for stone-free rates, GSS better predicts complications. However, their limitations highlight the need for pediatric-specific scoring models. Until such models are developed, these systems should be used with caution alongside individualized clinical assessments.

Keywords Pediatrics, Percutaneous nephrolithotomy (PCNL), Stone-free rate (SFR), CROES scoring system, Guy's stone score (GSS)

Percutaneous nephrolithotomy (PCNL) is regarded as a minimal invasive surgical method efficient in the treatment of kidney stones. The success of PCNL is closely related to post-operative stone-free rate which both increases the life quality of the patients and decreases treatment costs[1]. But prediction of stone-free condition rate following PCNL requires the consideration of different patient and stone characteristics. In this regard, different scoring systems were developed to predict stone-free condition rate in clinical applications[2].

Treatment of kidney stones is different in children as they have anatomic and physiological differences from adults. Different factors affect stone formation and treatment response in pediatric patients[3]. Also, surgical treatment leaving minimum stone trace is the best option in pediatric patients due to the high recurrence risk of urinary stones[4]. Thus, the accuracy and reliability of scoring systems developed for pediatric patients have high significance in the prediction of stone-free condition[5].

Although no standardized scoring system exists, Clinical Research Office of the Endourological Society (CROES) nomogram, Guy's Stone Score (GSS), Stone size (S), Tract length (T), Obstruction (O), Number of affected calyces (N), Stone density (E) (S.T.O.N.E.) nephrolithometry and Seul National University Renal Stone Complexity (S-ReSC) are among the most commonly used systems[1,6–8]. The CROES score predicts stone-free rates by assessing factors such as stone burden, case volume, prior treatments, and stone characteristics. Meta-analyses indicate that CROES provides the strongest predictive value for PCNL outcomes in pediatric patients[9]. In contrast, GSS categorizes patients on a scale of 1 to 4 based on stone location and anatomical factors[8]. While

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GSS is simple and easily applicable in clinical practice, CROES requires a more comprehensive data set.Our hypothesis is that the combined use of CROES and GSS may provide a more accurate prediction of PCNL success in pediatric patients.

The objective of this study is to compare the efficiency of CROES and GSS scoring systems in predicting post-PCNL stone-free rate in pediatric patients and to evaluate the accuracy of these systems. Acquired findings may present important information for increasing the success of PCNL applications in children and contribute to clinical decision processes.

Material and methods

Data from 1907 patients prospectively recorded in the Çukurova University Faculty of Medicine Urolithiasis Database between January 2007 and March 2024 were retrospectively analyzed. The study included patients under the age of 18 who had undergone preoperative abdominal tomography and whose postoperative residual stone status was evaluated using peroperative fluoroscopy, postoperative direct urinary system radiography (DUSG), or non-contrast abdominal computed tomography (CT).

A total of 1227 patients older than 18 years, 50 patients with incomplete operative data, and 50 patients with insufficient follow-up data were excluded from the analysis. Based on these criteria, data from 580 patients were included in the statistical analysis (Fig. 1). GSS and CROES scores were calculated for each patient. The associations of age, body mass index (BMI), stone burden, operative time, fluoroscopy time, hospitalization duration, estimated blood loss, and CROES score with stone-free status and complication rates were analyzed.

Postoperative complications were classified according to the Modified Clavien-Dindo scoring system. Residual stone status was assessed using peroperative fluoroscopy or postoperative DUSG, while non-opaque stones were evaluated using non-contrast abdominal CT. Stones smaller than 2 mm were considered clinically insignificant residual fragments (CIRF).

Ethical standards

Ethics committee approval for the study was obtained from the Non-Invasive Clinical Research Ethics Committee of Çukurova University (Approval Number: June 14, 2024, 145/87). The study was conducted in full compliance with relevant ethical guidelines and regulations. The research methods adhered to the ethical

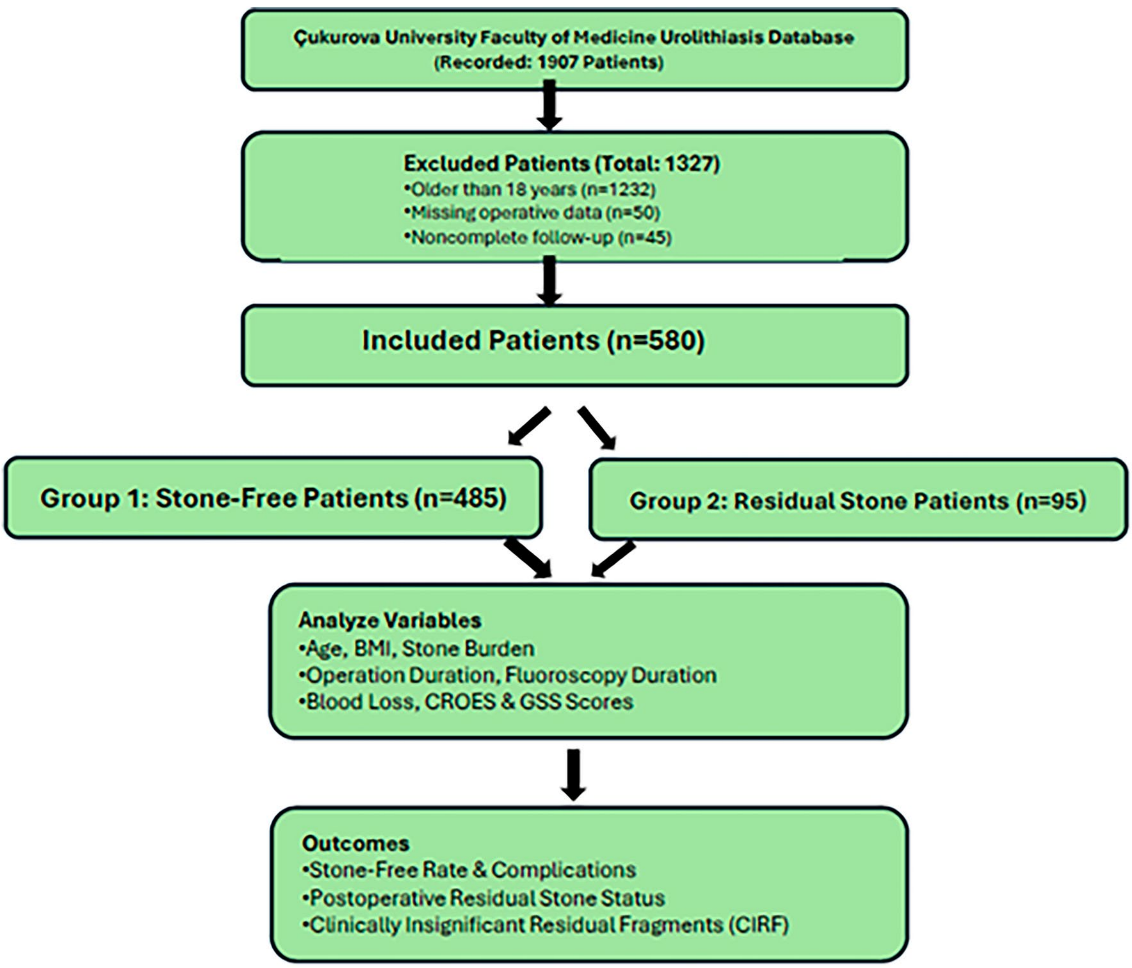

Fig. 1. Flowchart illustrating patient selection and study design.

principles of the Declaration of Helsinki, ensuring the protection of participants' health, privacy, and rights. Due to the retrospective nature of the study, the Non-Interventional Clinical Research Ethics Committee of Çukurova University waived the requirement for informed consent. As a result, no informed consent was obtained from the patients, and there was no direct or indirect contact with them through face-to-face interactions or communication tools.

Surgical technique

In pediatric PCNL procedures, we prefer different techniques based on age groups. For infants (0–2 years) and young children (2–6 years), we primarily use micro-perc (4.8–5 Fr) or mini-PCNL (14–22 Fr), whereas for older children (6–18 years), we generally prefer mini-PCNL (11–18 Fr) or standard PCNL (24–30 Fr).Regarding renal access, we use single-step or serial dilation techniques in younger children, while in older children, we prefer metal or Amplatz dilators due to their larger renal anatomy.For stone fragmentation, we primarily use laser lithotripsy in younger children, whereas pneumatic or ultrasonic lithotripsy may also be employed in older pediatric patients**.**Prior to surgery, all patients underwent general anesthesia. Before initiating the PCNL procedure, a ureteral catheter (3–5 Fr) was placed retrogradely into the kidney via the urethra. Following catheter placement, the PCNL procedure was commenced.

Preoperative microbiological assessment and antibiotic strategy

An evaluation was conducted regarding preoperative urine analysis and antibiotic usage. A complete urinalysis was performed on all patients before the procedure, and in cases with positive findings, urine culture analysis was additionally performed. Patients with positive urine cultures received appropriate antibiotic therapy based on antibiogram results. For patients with negative urine cultures but the presence of pyuria, empirical antibiotic therapy was administered in the preoperative period, and the PCNL procedure was subsequently performed.

Statistical analysis

Categorical measurements were summarized as number and percentage, while numerical measurements were summarized as mean and standard deviation (median and minimum—maximum when required). Chi-square test was used for the comparison of categorical variables between groups. Shapiro–Wilk test was used to assess whether numerical measurements met the assumption of normal distribution. For normally distributed continuous variables, Independent Samples t-test was used for two-group comparisons, whereas Mann–Whitney U test was applied for non-normally distributed continuous variables.For multiple-group comparisons, One-Way Variance Analysis (ANOVA) was used when normality assumptions were met, and Kruskal–Wallis test was applied when assumptions were not met. For post hoc pairwise comparisons of groups with significant results, Bonferroni correction test was used when normality assumptions were satisfied, whereas Bonferroni correction applied Mann–Whitney U test was used when assumptions were not met. SPSS Version 20.0 (IBM Corporation, Armonk, NY, USA) was used for statistical data analysis. The statistical significance level was set at $p < 0.05$ for all tests.

Results

580 patients were included in the study. Demographic, perioperative and postoperative data of patients are shown in Table 1. Patients were separated into Group 1 and Group 2 based on their post-operative conditions. Group 1 represented stone-free patients while Group 2 represented patients with residual stone. Group 1 included 485 (83.7%) and Group 2 included 95 (16.3%) patients. The median age of the patients was 8 years (0–18). The median age was 8 years (1–18) in Group 1 and 6 years (0–18) in Group 2, showing a statistically significant difference between the two groups ($p = 0.011$). Body mass index (BMI) was measured as 18.11 ± 5.21 in all patients and the average values were 17.95 ± 5.20 in group 1 and 18.92 ± 5.20 in group 2, showing a higher average in group 2 which was not a statistically significant condition ($p = 0.104$). While stone burden was 375 ± 256.236 mm^2 in Group 2, it was 257.351 ± 414.71 mm^2 in Group 1, which showed a statistically significant difference ($p < 0.001$). Group 1 had higher operative, fluoroscopy and hospitalization time, presenting a statistically significant difference between the two groups ($p < 0.001$, $p < 0.001$, $p = 0.006$).

The number of patients without a specific urological clinical condition was 458 (94.1%) in Group 1 and 87 (91.6%) in Group 2, whereas the number of patients with such conditions was 29 (5.9%) in Group 1 and 8 (8.4%) in Group 2. Overall, the number of patients with specific urological clinical conditions was higher in Group 2. In total, 545 patients did not exhibit a specific urological condition, while 35 patients did. Among these patients, Group 1 included 6 patients with a solitary kidney and 2 patients with a history of syndromic disease. In Group 2, there were 13 patients with a solitary kidney, 6 patients with renal anomalies (horseshoe kidney, duplicated collecting system, bifid pelvis, ectopic kidney), 7 patients with a history of syndromic diseases (cerebral palsy, polio, intellectual disability, Lesch-Nyhan syndrome, paraplegia, myelomeningocele), and 3 patients with skeletal deformities (e.g., scoliosis)(Table 1).

The study evaluated surgical data across different pediatric age groups. The Croes score was determined as 220 (114–255) in the 0–2 years group, 200 (94–260) in the 2–6 years group, and 176 (69–260) in the 6–18 years group.In the distribution of Guy's Stone Score (GSS), GSS 1 was the most frequently observed category, with rates of 65.8% in the 0–2 years group, 63.3% in the 2–6 years group, and 59% in the 6–18 years group. GSS 2 was identified at rates of 19.3%, 19.1%, and 14%, respectively. The distribution of GSS 3 was relatively similar across age groups, observed at rates of 13.2%, 13.3%, and 15.8%. The least common category, GSS 4, was recorded in 1.8% of patients in the 0–2 years group, 5.3% in the 2–6 years group, and 11.2% in the 6–18 years group. According to the Clavien-Dindo classification, Grade 1 and Grade 2 complications were the most frequently encountered. Grade 1 complications were observed in 20.2% of patients in the 0–2 years group, 27.7% in the 2–6 years group, and 38.1% in the 6–18 years group. Grade 2 complications were detected in 78%, 67%, and

	Group 1 (Stone-free condition)	Group 2 (Residual stone)	General	*p*
Number of Patients(%)	485(83.7%)	95 (16.3%)	580 (100%)	
Age (Years)[Median(min–max)]	8(1–18)	6(0–18)	6(0–18)	*0.011**
Age Groups,n (%) 0–5 years 6–10 years 11–17 years	114(%23.5) 134(%27.6) 237(%48.9)	23(%24.3) 35(%36.8) 37(%38.9)	274 169 137	*0.003***
BMI (kg/m^2) [mean(SD)]	17.95 ± 5.20	18.92 ± 5.20	18.11 ± 5.21	*0.104****
Stone Burden (mm^2) [mean(SD)]	257.351 ± 414.71	375 ± 256.236	276.7 ± 395.4	*< 0.001****
Operative Time (Minutes) [mean(SD)]	62.84 ± 31.52	92.33 ± 36.72	67.67 ± 34.1	*< 0.001****
Fluoroscopy Time(Minutes) [mean(SD)]	7.55 ± 5.00	10.26 ± 5.6	7.9 ± 5.2	*< 0.001****
Hospitalization Time(Days) [mean(SD)]	4.3 ± 2.2	5.1 ± 2.99	4.4 ± 2.37	*0.006****
Stone surgery story(%) No Yes$^{\alpha}$	451 (92.99%) 34 (7.01%)	95 (94.73%) 5 (5.26%)	39 (0.6%) 546 (99.4%)	*0.079***
Specific urological clinical condition, n (%) No Yes$^{\beta}$	458(%94.1) 29(%5.9)	87(%91.6) 8(%8.4)	545 35	*0.009***
Preoperative urinary tract infection (UTI), n (%) No Yes$^{\mu}$	450(%92.8) 35(%7.2)	80(%84.2) 15(%15.8)	530 50	*0.085***
Post op Blood Replacement(%) No Yes$^{\pi}$	478 (98.6%) 7 (1.4%)	90 (94.7%) 5 (5.3%)	568(97.94%) 12 (2.06%)	*0.014***
Clavien-Dindo classification,n(%) 1 2 3A 3B 4	148 (30.5%) 311 (64.1%) 8 (1.74%) 8 (1.74%) 10 (2.06%)	33 (34.7%) 45 (47.4%) 8 (8.4%) 7 (7.4%) 2 (2.1%)	181 (31.2%) 368(63.44%) 10 (1.72%) 9 (1.58%) 12 (2.06%)	*0.581***
GSS(%) 1 2 3 4	322 (66.39%) 71 (14.6%) 72 (14.84%) 20 (4.17%)	36 (37.89%) 18 (18.94%) 18 (18.94%) 23 (24.21%)	358(61.72%) 89 (15.34%) 90 (15.51%) 43 (7.41%)	*< 0.001***
CROES Score[mean(SD)]	203.58 ± 37.24	151.08 ± 33.3	194.98 ± 41.4	*< 0.001*

	Group 1 (Stone-free condition)	Group 2 (Residual stone)
Solitary Kidney	6	13
Renal Anomaly (Horseshoe Kidney, Duplex Collecting System, Bifid Pelvis, Ectopic Kidney, etc.)	0	6
Syndromic Patient (Cerebral Palsy, Polio Sequelae, Mental Retardation, Lesch-Nyhan Syndrome, Paraplegia, Myelomeningocele, etc.)	2	7
Patients with skeletal deformities (e.g., scoliosis, etc.)	0	3

Table 1. Demographic, pre-operative and post-operation characteristics of patients. *Mann–Whitney U test, **Fisher's exact test, ***Independent Samples t-test. $^{\alpha}$ Patients with a history of at least one ureterorenoscopic stone treatment, pyelolithotomy, percutaneous nephrolithotomy, or extracorporeal shock wave lithotripsy… $^{\beta}$ The specific cases are detailed below. $^{\mu}$Patients with positive growth in preoperative urine culture or pyuria. $^{\pi}$ Patients taking minimum 1 Unit of erythrocyte suspension.

55.7% of patients, respectively. Among the more severe complications, Grade 3A was most commonly observed in the 6–18 years group (10.5%), with lower rates in the 0–2 years (4.3%) and 2–6 years (2.2%) groups. Grade 3B complications were rare, with rates of 1.8%, 2.2%, and 4%, respectively (Table 2).

Average CROES score was measured as 203.58 ± 37.24 in group 1 and as 151.08 ± 33.3 in group 2, showing a statistically significant condition ($p < 0.001$). Residual stone rate was detected to increase with increasing degree in GSS groups, which was regarded to be statistically significant ($p < 0.001$).

In Group 1 (patients who became stone-free), sterile urine was detected in 92.8% of the patients, while 7.2% had positive findings. In Group 2 (patients with residual stones), complete urinalysis was negative in 84.2% of the patients, whereas 15.8% had positive results (Table 1). In Group 1 (stone-free patients), the most common complication was fever (n = 200, 85.1%), for which antibiotic treatment was administered, and in some cases, hospitalization was prolonged. Fever was followed by pain (n = 98, 41.7%), urinary tract infection (n = 75, 31.9%), and bleeding (n = 35, 14.9%). These complications were mostly classified as Grade I and II and were managed with medical treatment and follow-up.In Group 2 (patients with residual stones), fever was also the most common complication (n = 15, 6.4%), followed by urinary tract infection (n = 23, 9.8%) and pain (n = 26, 11.1%). In this group, the incidence of Grade III and IV complications was higher, with severe complications such as prolonged urinary leakage (n = 2), arteriovenous fistula (n = 1), sepsis (n = 2), and colonic perforation

	0–2 years	2–6 years	6–18 years	p
Age(year)	1,5(0,2)	4(2,5–6)	12(6,5–18)	*0.000**
Croes	220(114–255)	200(94–260)	176(69–260)	*0.000**
GSS,n (%) 1 2 3 4	75 (65.8%) 22 (19.3%) 15 (13.2%) 2(1.8%)	119(63.3%) 28 (14.9%) 31 (16.5%) 10 (5.3%)	164 (59%) 39 (14%) 44 (15.8%) 31 (11.2%)	*0.029***
Clavien-Dindo classification,n (%) 1 2 3A 3B 4	23 (20.2%) 83(72.8%) 5(4.3%) 2(1.8%) 1(0.9%)	52(27.7%) 130(69.1%) 4(2.2%) 1(0.5%) 1(0.5%)	106(38.1%) 155(55.8%) 10(3.5%) 6(2.2%) 1(0.4%)	*0.030***
Total (n)	114	188	278	

Table 2. Values related to age distribution and operative data. * Kruskal–Wallis test, ** Fisher's exact test.

Clavien-Dindo classification	Complication	Group 1 (Stone-free condition)	Group 2 (Residual stone)	Intervention performed
Grade I	Pain (n)	98	26	Analgesia—Follow-up
	Oliguria (n)	15	2	Consultation—Follow-up
	Bleeding (n)	35	5	Follow-up
Grade II	Urinary Tract Infection (n)	75	23	Antibiotic Therapy—Prolonged Hospitalization
	Pneumonia (n)	25	5	Antibiotic Therapy—Prolonged Hospitalization
	Fever (n)	200	15	Antibiotic Therapy—Prolonged Hospitalization
	Bleeding (n)	11	2	Blood transfusion-Prolonged Hospitalization
Grade IIIa	İleus (n)	8	8	Resolved with nasogastric decompression
Grade IIIb	Prolonged urinary leakage(n)	3	2	DJ Stent in the Postoperative Period
	Pyuria(n)	1	1	Percutaneous Nephrostomy
	Arteriovenous Fistula(n)	1	1	Angioembolization
	Ureteropelvic Junction Perforation(n)	1	1	DJ Stent
	Colon Perforation(n)	1	1	Surgery
	Urinoma(n)	1	1	Drain
Grade IV	Sepsis(n)	9	2	Intensive Care Admission—Prolonged Hospitalization
	Bleeding(n)	1	0	Nephrectomy
Total		485	95	

Table 3. Postoperative Complications and Interventions According to the Clavien-Dindo Classification.

	Croes score		Gss score	
	Correlation Coefficient *	p	Correlation Coefficient *	p
Stone burden	− 0.414	< 0.001	+ 0.437	< 0.001*
Residual Stone Condition	− 0.469	< 0.001	+ 0.251	< 0.001*
Operation Duration	− 0.411	< 0.001	+ 0.400	< 0.001*
Scopy Duration	− 0.252	< 0.001	+ 0.233	< 0.001*
Post op Blood Replacement Condition	− 0.125	0.003	+ 0.175	< 0.001*
Days following discharge	− 0.059	0.154	+ 0.237	0.048*
Clavien-Dindo classification	− 0.369	0.045	+ 0.240	0.007*

Table 4. Relationship of CROES and GSS score with operation data. *Pearson or Spearman correlation coefficient.

(n = 1) observed.In conclusion, although fever was the most frequently observed complication in both groups, the incidence of severe complications (Clavien-Dindo Grade IIIb and IV) was higher in Group 2 (Table 3).

Table 4 shows the correlation relationship results of CROES and GSS score with operation data. While a positively significant ($p < 0.001$) correlation was observed between CROES score and stone-free condition, a negatively significant correlation was detected between stone burden ($p < 0.001$), residual stone condition ($p < 0.001$), operation duration ($p < 0.001$), scopy duration ($p < 0.001$), postoperative blood replacement condition

($p = 0.003$) and Clavien-Dindo classification ($p = 0.045$). A positively significant correlation was detected between GSS score and these parameters (Table 4).

Figures 2, 3, 4, and 5 respectively show the ROC curve analyses for the prediction of stone-free condition and post-operative complication rates using the CROES and GSS scoring systems. While CROES score was effective for stone-free condition prediction, it was inadequate for predicting post-operative complications ($p = 0.067$) (Figs. 2 and 3). On the other hand, GSS score was found to be effective for predicting stone-free condition and complication (Figs. 4 and 5).

Discussion

PCNL has been safely applied in pediatric patients for many years. Factors affecting complication and success rates were discussed before in many studies. Many nomograms and scoring systems are available for predicting PCNL success in adults. But a scoring system designed especially for children has not been developed yet. Although PCNL technique does not vary in general, the kidney sizes of the children vary based on their ages. Due to 2 or 3 dimensional kidney measurements, kidney collective systems are generally smaller and malformations are more common in children. Thus, a small stone in adults may cause bigger problems in children[10].

Although designed for adults, studies have shown CROES and GSS scoring systems to be predictive in children either[10,11]. Some studies also investigated the effect of GSS and CROES scores in predicting preoperative stone-free condition in pediatric patients[12].

CROES scoring system emerged as the product of a multi-centered study and evaluated clinical and radiological parameters such as age, gender, body mass index, stone burden, stone localization and kidney anatomy which could affect stone-free result in this system were evaluated. Especially stone burden was marked as the strongest stone-free condition predicting parameter in this scoring system[1].

GSS is another important system which evaluates stone complexity and high scores are related to low stone-free condition rates in this system[8]. But although the efficiency of GSS in predicting PCNL complications is widely accepted, a study in literature showed the incapability of this system to form a significant relationship with complication rates[13].

Our study evaluated 580 PCNL patients and examined the effect of CROES and GSS scoring system in predicting stone-free condition and complication rates. Studies in literature have reported post-PCNL stone-free rates ranging between 72 and 86%[14–17]. Stone-free rate was determined as 75.7% in the first study on CROES nomogram[15] conducted by Smith et al.

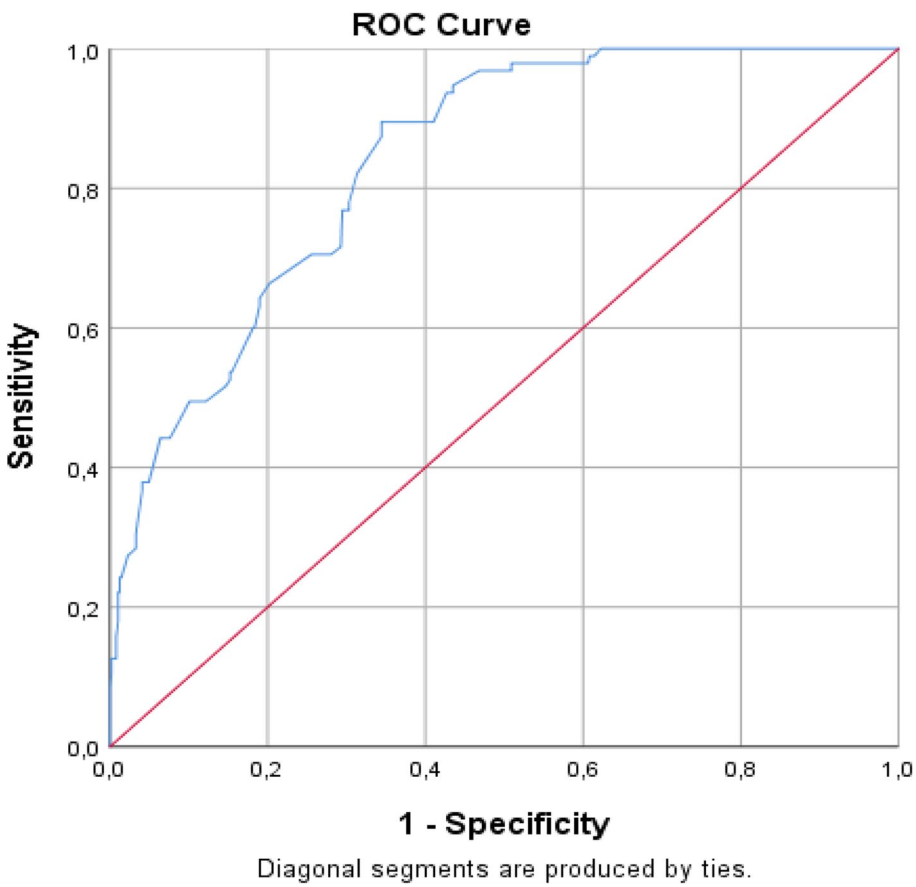

Fig. 2. Stone free condition showing curve of CROES scoring system based on Roc analysis. (AUC:0.839, $p = <0.001$, 95% GA (0.801–0.876) (AUC = Area under the curve).

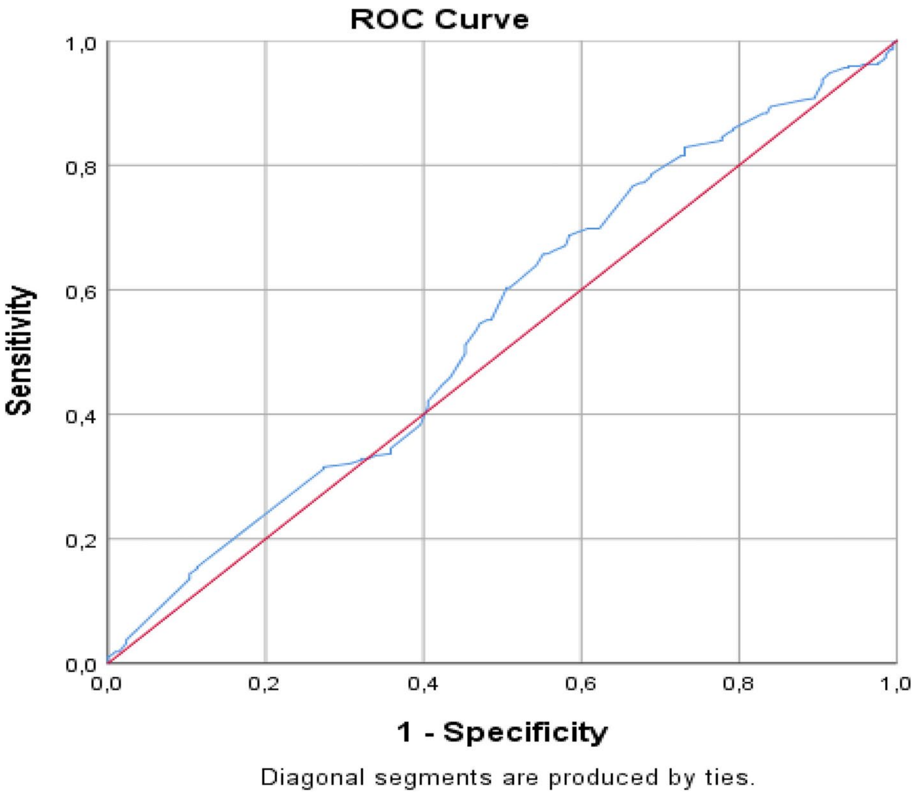

Fig. 3. Curve of CROES scoring system in showing post-operative complication based on Roc analysis (AUC:0.546, $p = 0.067$, 95% GA (0.496–0.595)).

Some studies conducted to validate nephrometry scoring systems in pediatric patients are available in literature. Stone-free rate was determined as[18] 73.6% in a study by Aldaqadossi et al. on 125 patients and as[10] 74.9% in another study by Citamak et al. on 434 patients. This rate was 83% and in line with the literature in our study.

Shahat et al. assessed the result prediction abilities of Guy's stone score (GSS), S.T.O.N.E. nephrolithometry and CROES nomogram in mini-percutaneous nephrolithotomy (MPCNL) applied children. The study presented CROES nomogram as the most effective scoring system in stone-free rate prediction and stated multiple stone, staghorn stone presence, previous stone treatment, affected calyx count and stone burden among other factors which have significant relationships with stone-free rate[19]. The study by Caglayan et al. evaluated the efficiency of different scoring systems in the prediction of post-PCNL surgical results in pediatric patients. Results showed CROES nomogram to be superior in stone-free rate prediction compared to Guy's stone score (GSS). This condition suggests that CROES nomogram can be a more reliable tool for pediatric stone surgery in clinical application. However, the inadequacy of both scoring systems in predicting complication risk reveals the necessity of more advanced and pediatric population specific scoring systems for complication prediction[20].

In the study by Aldaqadossi et al., GSS was efficient in predicting the complication while CROES score was insufficient[18]. In a systematic review of nomograms used for pediatric patients, CROES score was stated as the best nomogram for predicting stone-free condition and postoperative complications[9].

Citamak et al. showed the efficiency of CROES score and the inefficiency of GSS in complication prediction[10]. A 2024 study comparing the STONE Score, GSS, CROES Nomogram, and RSCS for predicting stone-free status after multiple-tract mini-PCNL found all four systems to be reliable. GSS and CROES showed similar accuracy in predicting post-PCNL stone-free rates[21]. Our study showed the inefficiency of CROES score and the efficiency of GSS score in predicting postoperative complications.

Complications of PCNL operations performed using adult equipment in children and the factors affecting these complications were analyzed in the study by Goyal et al. The results of the study showed stone size, GSS, tract size, number of interventions and operation duration to be related to the complications. A more detailed analysis also showed the operation duration to be an independent factor by itself for predicting the complication risk. This shows that the controlling of surgery duration may be important for decreasing the complication risk[11]. Our study provided a significant result for operation duration between the groups and while a positively significant correlation was detected between operation duration and CROES, a negatively significant correlation was detected between them.

A 2024 study demonstrated the high efficacy of mini-percutaneous nephrolithotomy (mini-PCNL) in pediatric kidney stone treatment. With a 90% stone-free rate, it was highlighted as a successful option, and no major complications were reported. Although fluoroscopy and hospital stay were longer, its superior stone-free

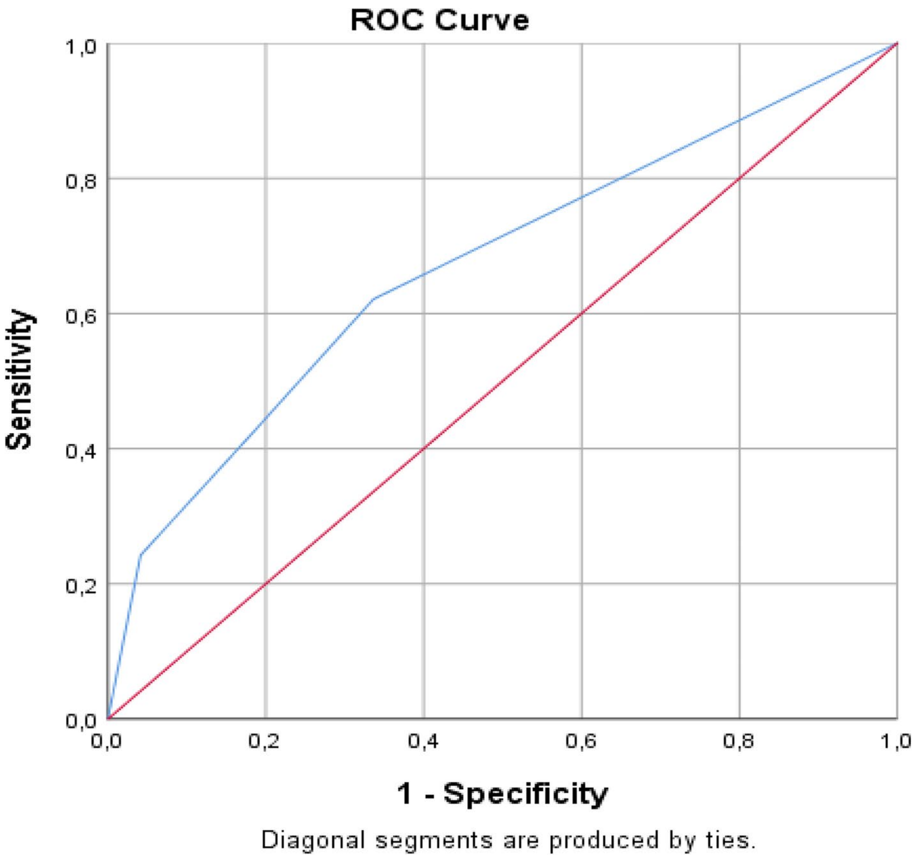

Fig. 4. Effect of GSS Score in Showing Stone-Free Condition in Roc Curve Analysis. (AUC:0.670, $P = < 0.001$, 95% Ga (0.606-0.734)).

rate confirms mini-PCNL as a safe and effective method[22]. The 83% stone-free rate and an average hospital stay of 4.4 days in our study are consistent with these findings.

A 2024 study compared mini-percutaneous nephrolithotomy (mini-PCNL) and standard PCNL in the treatment of pediatric kidney stones. The results indicated that mini-PCNL was associated with a shorter hospital stay and less postoperative hemoglobin decrease compared to standard PCNL. No significant differences were found between the two methods in terms of stone-free rates and complications. These findings support mini-PCNL as a safe and effective treatment option for pediatric patients[23].

The study by Mahmood et al. evaluating the efficiency and safety of mini PCNL method in kidney stone treatment in children at different age groups provided high stone-free rates at all age groups and age was not a restricting factor on its success and safety[24].

Although our study showed a significant difference between age and scoring systems in our study ($p = 0.011$), age factor was not considered to be a predictive factor since these scoring systems were developed for adults. But sub-grouping of pediatric patients based on their ages may reveal a significant difference in the performance of scoring systems between different pediatric age groups[19].

Limitations of the study

Due to its retrospective design, there is a risk of missing data and selection bias. Additionally, the CROES and Guy's Stone Score systems have not yet been fully validated in the pediatric population, posing limitations regarding their reliability and generalizability in this patient group. The fact that the study was conducted at a single center also restricts the generalizability of the findings. Furthermore, the absence of preoperative urine culture data, stone composition analysis, and long-term clinical follow-up information are significant factors that hinder a more comprehensive evaluation of surgical outcomes.

Strengths of the study

Despite these limitations, the study has several strengths. The inclusion of a large pediatric patient cohort provides high statistical power. The comparative analysis of two different scoring systems offers valuable insights into predicting percutaneous nephrolithotomy (PCNL) outcomes in children. Furthermore, the detailed assessment of age-based subgroups and the in-depth analysis of CROES and GSS results enhance the study's contribution to clinical practice. The rigorous statistical analyses and the consistency of the findings with existing literature further support the reliability and scientific value of the results.

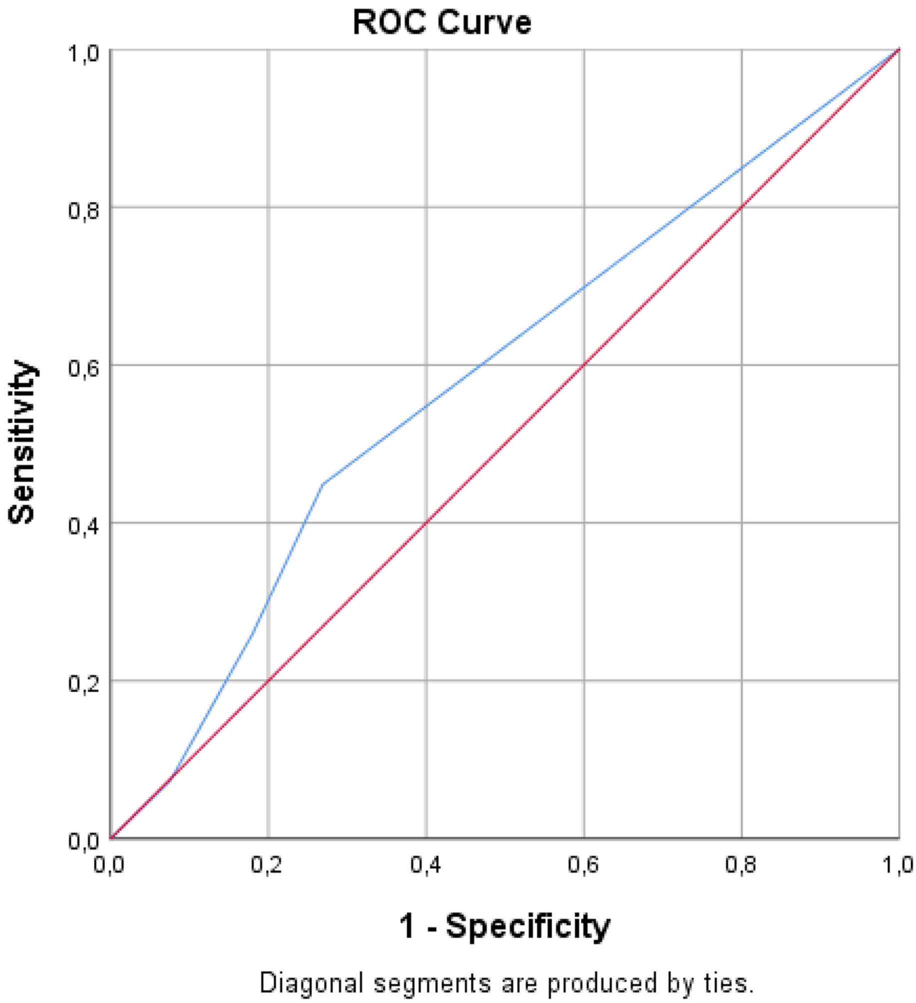

Fig. 5. Effect of GSS Score in showing Post-operative Complication in Roc Curve Analysis (AUC:0.581, $p = 0.001$, 95% GA (0.533–0.629)).

Conclusion

This study compared the effectiveness of the CROES and Guy's Stone Score (GSS) scoring systems in predicting percutaneous nephrolithotomy (PCNL) outcomes in pediatric patients. The findings indicate that while the CROES scoring system demonstrates high accuracy in predicting stone-free rates, it is less effective in forecasting postoperative complications. In contrast, the GSS score was found to be a reliable predictor of both stone-free rates and complication risks. These results suggest that although the CROES score is a valuable tool for predicting postoperative stone clearance, its utility in assessing potential complications is more limited. On the other hand, the GSS score exhibits strong predictive capability for both stone-free status and postoperative complications.

The results of this study provide valuable insights into the applicability of the CROES and GSS scoring systems in optimizing PCNL outcomes in pediatric patients. However, the limitations of these scoring systems in the pediatric population should be acknowledged. Future research incorporating larger patient cohorts and considering age-specific factors may contribute to the refinement of these predictive models. Additionally, the development of pediatric-specific scoring systems could enhance the accuracy of complication prediction. Until such models are established, existing scoring systems should be applied cautiously in conjunction with comprehensive clinical evaluations.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author contributions

N.A.—Abstract writing and translation M.D.—Patient data collection and data recording M.Z.—Literature re-viewand SPSS analysis I. O. Y.—Abstract writing and text editing M. G.A.—Table formatting and writing the resultssection N.S.—Literature review and writing the introduction section I.A.A.—Article review.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Ethics Committee of Çukurova University Faculty of Medicine and conducted in full compliance with relevant guidelines and regulations. The research methods adhered to the ethical principles of the Declaration of Helsinki, with all necessary measures taken to protect the health, privacy, and rights of participants. Due to the retrospective nature of the study, the Non-Interventional Clinical Research Ethics Committee of Çukurova University waived the requirement for informed consent. Accordingly, no informed consent was obtained from the patients, and there was no direct or indirect contact with them through face-to-face interactions or communication tools.

Additional information

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