A Scoring System for Optimal Selection of Endoscopic Treatment for 1-2cm Lower Pole Renal Calculi

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Purpose: To explore the establishment of a scoring system that can provide a reference for clinical decision making regarding the endoscopic treatment of 1-2 cm lower pole stones (LPS).

Materials and Methods: The data of patients with renal calculi who were treated with percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) in three hospitals from January 2013 to December 2017 were analyzed retrospectively. Multivariable logistic analysis was performed to determine the statistically significant indicators and regression coefficients, which were used to construct the scoring system. The stone-free rate (SFR) and postoperative complication rates of PCNL and RIRS within the two fractional segments of the scoring system were compared to select the optimal procedures.

Results: A total of 137 patients in the PCNL group and 152 patients in the RIRS group were included in this study. Five factors were found to be most predictive of endoscopic treatment choice: stone number, stone diameter, infundibulopelvic angle (IPA), infundibular length (IL), and infundibular width (IW), yielding a total score ranging from 0-5. In the 0-2 segments, the RIRS group had better outcomes than the PCNL group in terms of the postoperative complication rates (6.8% versus 18.0%, P = .026). In segments 3-5, the SFR of the PCNL group was significantly higher than that of the RIRS group (88.5% versus 70.6%, *P* = .017).

Conclusion: Our scoring system was based on the patient's preoperative imaging examination to measure the stone number, stone diameter, IPA, IL and IW. RIRS was recommended at 0-2 segments, and PCNL was recommended at 3-5 segments. This new scoring system is expected to provide guidance for urologists to make endoscopic treatment decisions for 1-2 cm LPS.

Keywords: percutaneous nephrolithotomy; retrograde intrarenal surgery; lower pole renal calculi; scoring system

INTRODUCTION

Lower pole stones (LPS) are the most common renal calculi and are the most likely to require treatment because these types of stones are unlikely to be excreted automatically[1]. Endourological procedures, such as percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS), are available treatments for LPS, and several studies have compared the safety and efficacy of PCNL and RIRS for LPS[1-5]. PCNL has a higher stone free rate (SFR) than RIRS, but has higher complication rates, and the complications include bleeding, perinephric hematoma, organ injury, and urinary leakage[6-7]. Due to the development in endoscopic technology, RIRS provides an alternative to PCNL, potentially achieving a comparable SFR and less morbidity than PCNL[1,2,5].

There is still controversy regarding the use of PCNL or RIRS for the treatment of 1-2 cm LPS. In recent years, there have been many scoring systems used to predict SFR and the postoperative complications after calculi surgery, and these scoring systems include the Guy's stone score (GSS), CROES nephrolithometric nomogram, S.T.O.N.E. Score, S-ReSC score and so on. Nevertheless, these scoring systems cannot be used to guide the choice of surgical procedure for 1-2 cm LPS because these scoring systems can only predict a single surgical outcome. Hence, we aimed to construct a new objective scoring system to distinguish the most suitable surgical methods for patients with 1-2 cm LPS. Herein, we derived a scoring system based on the preoperative stone characteristics to provide a basis for the choice between PCNL or RIRS.

MATERIALS AND METHODS

Study population

We performed a retrospective review of patients with 1-2 cm LPS treated with either PCNL or RIRS at Sun Yat-sen Memorial Hospital of Sun Yat-sen University,

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Table 1. Demographics and outcomes compared between PCNL group and RIRS group

Characteristics and outcomes a	PCNL	RIRS	*P*-value
Age (years)	52 (45.5, 60.0)	51.5 (43.0, 61.0)	.654
Male Gender	88 (64.2)	86 (56.6) .184	
Body mass index (Kg/m2)	24.2 (21.4, 26.4)	23.4 (21.3, 26.0)	.611
Laterality			.671
Left	80 (58.4)	85 (55.9)	
Right	57 (41.6)	67 (44.1)	
History of previous ipsilateral surgery	55 (40.1)	65 (42.8)	.652
Stone diameter (mm)	18.0 (13.0, 18.8)	13.0 (11.0, 15.8)	< .001
SFR	122 (89.1)	119 (78.3)	.014
Postoperative complication rates	25 (18.2)	13 (8.6)	< .001
Clavien-Dindo I	19 (13.9)	11 (7.2)	
Clavien-Dindo II	4 (2.9)	2 (1.3)	
Clavien-Dindo IIIa	2 (1.4)	0 (0.0)	
Postoperative hospital stay (days)	7.0 (5.0, 8.0)	3.5 (3.0, 4.0)	< .001
Operative time (min)	55.0 (50.0, 60.0)	60.0 (55.0, 74.0)	< .001
Drop in Hb (g/L)	11.0 (3.0, 19.0)	3.0 (-2.75, 9.0)	<.001
Increase in CREA (μmol/L)	6 (-3.5, 12.0)	5 (-1.0, 11.0)	.934

Abbreviations: SFR, Stone free rate; Hb, hemoglobin; CREA, Creatinine.
a Data are presented as mean ± SD, M (Q1, Q3) or number (percent)

The Fifth Affiliated Hospital of Guangzhou Medical University, and Affiliated Hospital of Hebei University from January 2013 to December 2017.

The following inclusion criteria were followed for selecting the patients to be included in the present study population: age between 18 and 75 years old, (2) either sex, and (3) LPS with diameters between 1-2 cm as determined by non-contrast computed tomography (CT). The exclusion criteria were uncontrollable systemic hemorrhagic disease, anatomic abnormalities of the urinary tract, pregnancy, and active urinary tract infection. The demographic, clinical, and operative data were collected.

Surgical technique

PCNL procedure: The patient was placed in the semisupine-lithotomy or prone position. The tract was dilated to F18-22. The calculi were fragmented by Ho:YAG laser. A nephrostomy tube was inserted after surgery. None of these patients required staged procedures.

RIRS procedure: The patient was placed in the lithotomy position. A digital flexible ureteroscope was used to explore the renal calyx, and stones were fragmented by Ho:YAG laser. The stones were pulverized, and a basket was used if needed. None of these patients required staged procedures.

Outcome assessment

The preoperative patient demographic characteristics were assessed. The stone characteristics were measured by using CT and intravenous urography (IVU). The infundibular length (IL), infundibular width (IW) and pelvicalyceal height (PCH) were measured by intravenous urography, as previously described by Elbahnasy et al [8]. The infundibulopelvic angle (IPA) was measured according to Sampaio et al[9]. IL, and it was measured as the distance between the most distal point of the calyx containing the calculus and the midpoint of the lower lip of the renal pelvis (**Supplementary Figure 1**). The IW was measured as the narrowest point in the axis of the lower infundibulum (**Supplementary Figure 2**). The PCH was measured as the distance between the lower lip of the renal pelvis and the bottom of the lower calyx (**Supplementary Figure 3**). The IPA was measured as the angle between the vertical pelvis axis and the vertical axis of the lower infundibulum (Supplementary Figure 4). Stone free was defined as no residual stones or the presence of residual stones that were < 2 mm in diameter on the follow-up KUB for positive stones or CT for negative stones 1 month after the operation. The postoperative complications were assessed according to the modified Clavien–Dindo classification system[10].

Scoring system

We hypothesized that there were differences in the systemic or anatomical factors between patients treated with PCNL and those treated with RIRS and that these factors would affect the choice of surgery.

First, we compared the quantitative data between the PCNL group and the RIRS group, and determined the optimal cutoff points of the statistically significant variables according to Youden's index value. Then, we transformed these significant quantitative data into categorical variables. Multivariable logistic analysis was performed to determine the statistically significant variables. We selected a base category and assigned it

Table 2. Baseline characteristics of the patients

Factors	Area under the Curve	95% confidence interval	Cutoff value	Youden's index	Sensitivity	Specificity
Stone diameter	0.719	0.660-0.778	14.9	0.385	0.628	0.757
Stone density values	0.625	0.561-0.689	1100.4	0.191	0.803	0.388
IL	0.678	0.615-0.741	30.0	0.347	0.584	0.763
IW	0.657	0.594-0.720	5.02	0.296	0.697	0.599
IPA	0.639	0.574-0.703	89.95	0.295	0.638	0.657

Abbreviations: IL, infundibular length, IW, infundibular width, IPA, infundibulopelvic angle.

Table 3. Postoperative clinical outcomes

Risk factors	Univariable analysis PCNL	RIRS	*P*-value	Multivariable analysis 95% CI (OR)	*P*-value
Stone number			<.001	1.18-3.38 (1.997)	.010
Single	54 (39.4)	96 (63.2)			
Multiple	83 (60.6)	56 (36.8)			
Stone diameter			<.001	1.457-4.197 (2.473)	.001
>15mm	86 (62.8)	57 (37.5)			
≤15mm	51 (37.2)	95 (62.5)			
IPA	<.001	1.448-4.177 (2.459)	.001		
> 90°	62 (45.3)	108 (71.1)			
≤90°	75 (54.7)	44 (28.9)			
IL			<.001	1.585-4.623 (2.707)	.001
> 30mm	73 (53.3)	43 (28.3)			
≤30mm	64 (46.7)	109 (71.7)			
IW			<.001	1.297-3.812 (2.224)	.004
> 5mm	69 (50.4)	109 (71.7)			
≤5mm	68 (49.6)	43 (28.3)			
Stone Density Values			.003	-	-
> 1100HU	78 (56.9)	60 (39.5)			
≤ 1100HU	59 (43.1)	92 (60.5)			
Hydronephrosis			.04	-	-
None or mild	102 (74.5)	128 (84.2)			
Medium or severity	35 (25.5)	24 (15.8)			

Abbreviations: IL, infundibular length, IW, infundibular width, IPA, infundibulopelvic angle.

0 points in the scoring system. We calculated how far every category was from the base category in terms of regression units and set the minimum value as 1 point. We stratified the system into 0-2 segments and 3-5 segments based on the estimated clinical utility, which was achieved through a consensus of all investigators. We then compared the outcomes of PCNL and RIRS within the two fractional segments of the scoring system to screen the optimal selection of endoscopic treatment for 1-2 cm LPS.

Statistical analysis

Statistical analysis was performed by SPSS (IBM Corp, Version 22). Quantitative data with a normal distribution are described by the mean ± SD, and data with a skewed distribution are reported by M (Q1, Q3). Qualitative data were described by the frequency (percentage). A two-sample t test was performed to compare the mean values of the two groups if two independent samples were selected from two normally distributed populations in which the variance was equal; otherwise, the Mann–Whitney U test was performed. Normality was assessed by the Kolmogorov–Smirnov test. Homogeneity of variance was assessed by the F test. A chi-square test was applied to compare the two groups of qualitative data. The Kruskal–Wallis test was used to compare multiple groups of quantitative data and qualitative data. The likelihood ratio test of the conditional parameter estimation was used in a stepwise regression analysis of the multivariable logistic analysis, and the 95% confidence interval was calculated. $P < .05$ was considered statistically significant.

Table 4. Scoring system, factors, and categories

Factors	Categories	Reference value (Wij)	Points
Stone number			
	single	0 = W1REF	0
	multiple	1	1
Stone diameter			
	≤15mm	0 = W2REF	0
	≤ 15mm	1	1
IPA			
	> 90°	0 = W3REF	0
	≤90°	1	1
IL			
	≤30mm	0 = W4REF	0
	≤ 30mm	1	1
IW			
	> 5mm	0 = W5REF	0
	≤ 5mm	1	1

Abbreviations: IL, infundibular length, IW, infundibular width, IPA, infundibulopelvic angle.

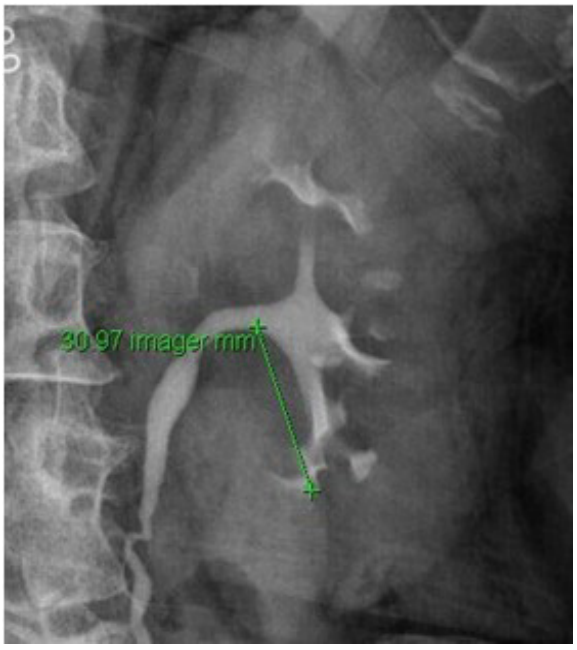

Figure 1. IL measurement.

Table 5. Outcomes compared between PCNL group and RIRS group in 0-2 scores and 3-5 scores.

0-2 scores	**PCNL**	**RIRS**	***P*-value**
SFR a	45 (90.0)	95 (80.5)	.131
Postoperative complication rates	9 (18.0)	8 (6.8)	.026
Clavien-Dindo I	7 (14.0)	7 (5.9)	
Clavien-Dindo II	1 (2.0)	1 (0.8)	
Clavien-Dindo IIIa	1 (2.0)	0 (0.0)	
3-5 scores	**PCNL**	**RIRS**	***P*-value**
SFR	77 (88.5)	24 (70.6)	.017
Postoperative complication rates	16 (18.4)	5 (14.7)	.618
Clavien-Dindo I	12 (13.8)	4 (11.8)	
Clavien-Dindo II	3 (3.4)	1 (2.9)	
Clavien-Dindo IIIa	1 (1.1)	0 (0.0)	

Abbreviations: SFR, stone free rate.
a Data are presented as number (percent)

RESULTS

The present study included 289 patients, including 137 patients who underwent PCNL and 152 patients who underwent RIRS. Comparisons of the demographics and outcomes between the PCNL group and RIRS group are listed in **Table 1**. The SFR of the PCNL group was higher than that of the RIRS group (89.1% versus 78.3%, $P = .014$), but the postoperative complication rates were also higher than those of the RIRS group (18.2% versus 8.6%, $P = .014$). **Supplementary Table 1 and Table 2** list the characteristics and outcomes of the patients treated by PCNL or RIRS among the three hospitals, and these characteristics were not significantly different. Supplementary **Table 3** and **Table 4** show the quantitative and quantitative factors that were compared between the PCNL group and the RIRS group. The ROC curve was drawn according to the previous significant quantitative data (**Supplementary Figure 5**).

Table 2 shows the Youden's index used to determine the cutoff points of the stone diameter, stone density values, IL, IW, and IPA. The calculated cutoff points of the stone diameter, stone density values, IL, IW, IPA were 14.9 mm, 1100.4 HU, 30.0 mm, 5.02 mm, 89.95°, respectively. To facilitate calculation and memory, we decided to set the optimal cutoff points to their nearest integer: the stone diameter cutoff was 15 mm, the stone density value cutoff was 1100 HU, the IL cutoff was 30 mm, the IW cutoff was 5 mm, and the IPA cutoff was 90°.

Figure 2. IW measurement.

Figure 3. PCH measurement.

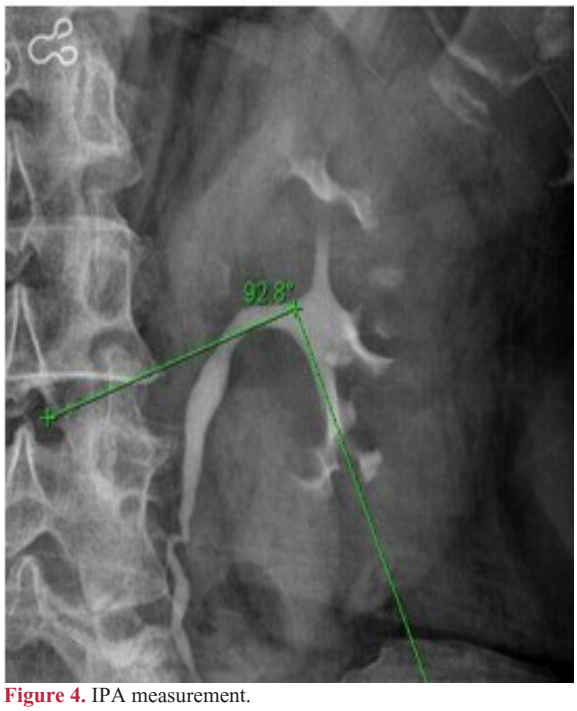

Figure 4. IPA measurement.

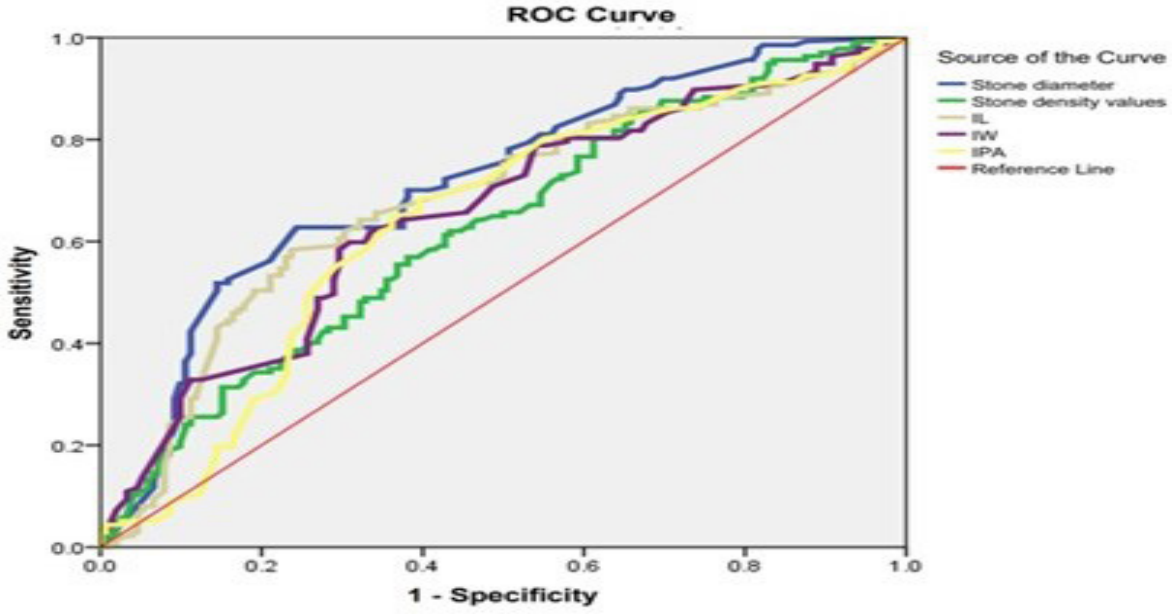

Figure 5. ROC curve.

Table 3 shows the variables that were significant according to the univariate and multivariable analysis between the PCNL group and RIRS group. The multivariable analysis indicated five factors that were most significantly associated with the optimal selection of endoscopic treatment for 1-2 cm LPS: stone diameter, stone number, IPA, IL, and IW. They were incorporated into the scoring system with the associated integer point values (Table 4). In our study, we chose single stone number, stone diameter ≤ 15 mm, IPA > 90°, IL ≤ 30 mm, and IW > 5 mm as the base categories.

The surgical results were compared, as shown in Table 5. In the 0-2 segments, the RIRS group had better postoperative complication rates than the PCNL group (6.8% versus 18.0%, P = .026). In segments 3-5, the SFR of the PCNL group was significantly higher than that of the RIRS group (88.5% versus 70.6%, P =.017).

DISCUSSION

To the best of our knowledge, the new clinical scoring system that is described by this study is the first scoring system to be derived that can predict the optimal treatment procedure for 1-2 cm LPS. Our data show that the quantitative effect of the five factors included in the scoring system can accurately predict the choice of surgical methods: RIRS should be performed for 0-2 fractional segments, and PCNL should be performed for 3-5 fractional segments.

Ozturk et al retrospectively analyzed 144 cases of PCNL and 38 cases of RIRS[11]. The SFR of the PCNL group was 93.8%, and the postoperative complication rate was 13.2%. The SFR of the RIRS group was 73.7%, and the postoperative complication rate was 5.3%. A clinical trial reported by Bozzini et al included patients diagnosed with 1-2 cm single lower calyceal calculi on a plain CT scan and was the largest prospective multicenter randomized controlled trial to date[5]. A total of 181 patients underwent PCNL with an SFR of 87.3% and a postoperative complication rate of 19.1%. A total of 207 patients underwent RIRS with an SFR of 82.1% and a postoperative complication rate of 14.5%. The study showed that there was no significant difference in the SFR between the PCNL and RIRS groups, but the difference in the postoperative complication rates between the two groups was close to a significant difference (P = .053). In our study, the safety and efficacy of PCNL and RIRS are consistent with previous literature reports. The one-month SFR of PCNL was 89.1%, which was significantly higher than the 78.3% of RIRS. The postoperative complication rate of PCNL was 18.2%, which was significantly higher than that of RIRS (8.6%).

Five factors were included to construct the scoring system: stone diameter, stone number, IPA, IL, and IW. The stone diameter and stone number represent the stone load, which may be the most important indicator affecting the outcome of endoscopic surgery. There was a decrease in the SFR, as well as an increase in the complication rates with increasing stone diameter and stone number when using PCNL or RIRS. Atalay's study showed that the stone burden variables were influential predictors of SFR after PCNL (stone surface area, stone burden volume, and maximum stone size, P < .05)[12]. In a prospective study, Olbert et al found evidence from patients treated with PCNL that a large stone burden is a prognostic factor that predicts longer surgery and prolonged hospitalization[13]. In Li's study, a high stone burden was found to significantly affect the occurrence of SIRS after the RIRS procedure[14].

The pelvicalyceal anatomy, such as the IPA, IL, and IW, was associated with SFR after RIRS according to Inoue's univariate analysis[15]. However, the IPA was the only negative risk factor found by the multivariable analysis. Moreover, the pelvicalyceal anatomy does not have any effect on the outcome after PCNL[16].

There are many indicators, such as hydronephrosis and urinary culture results, that were not incorporated into this scoring system. We speculate that there are two possible reasons: one is that these indicators themselves will not affect the outcomes of PCNL or RIRS; the oth-

er is that these indicators have the same degree of influence on PCNL or RIRS, that is, they do not need to be included on the basis that they can equally affect the postoperative outcomes.

All currently available PCNL or RIRS outcome clinical scoring systems have advantages and disadvantages. In external validation and comparative studies, no system has proven to be superior, as compared to other systems. These scoring systems include different indicators and can only predict one surgical outcome. The S.T.O.N.E. score is based on factors determined through CT imaging, including the stone size, tract length, degree of obstruction, number of involved calyces, and stone essence[17]. Guy's stone score is based on the stone location and renal anatomy[18]. In daily clinical work, there are often a variety of surgical methods to choose from, so it is necessary to compare the strengths and weaknesses of these surgical methods.

The ideal scoring system should be able to be applied when evaluating between the two surgical methods, and the ideal scoring system should have a high ability to predict SFR and complications. It also should be easy to apply in daily clinical practice and produce the greatest repeatable results with minimal subjectivity.

We analyzed the factors that differed between the patients in the PCNL group and the RIRS group through univariate and multivariable logistic analyses. The scoring system was divided into two intervals: RIRS was recommended at 0-2, and PCNL was recommended at 3-5. The five indicators included in our scoring system are all easily accessible from imaging studies. The scoring process is simple and convenient. According to the scoring results, we can directly draw conclusions about the optimal endoscopic surgical method to perform.

There are still some limitations in this study. This scoring system may not be applicable to any situation, such as patients with IPA values that are too small, IL values that are too long, and IW values that are too narrow to perform RIRS. Urologists may be concerned about performing PCNL in solitary kidneys. Due to this study's retrospective research, sample size, research time and other reasons, more prospective studies need to be performed in the future to verify the role of the scoring system for guiding clinical work.

CONCLUSIONS

We derived a scoring system, which includes the stone diameter, stone number, IPA, IL, and IW, to facilitate scoring based on the preoperative imaging examination. When it is verified by further multicenter prospective studies, this scoring system is expected to provide guidance for urologists to make optimal endoscopic treatment decisions for 1-2 cm LPS.

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CONFLICT OF INTEREST

The authors report no conflict of interest.

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