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Lower-Caliceal Stone Clearance Index to Predict Clearance of Stone after SWL

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ABSTRACT

***Background and Purpose*: There is no uniform consensus regarding the anatomic factors that influence the clearance rate of caliceal stones after SWL, as different authors have studied various independent factors separately. We correlated both favorable and unfavorable factors into a formula to predict the clearance rate.**

***Patients and Methods*: A series of 56 consecutive patients (37 male, 19 female) with isolated lower-caliceal single stones (right 29, left 27) treated with SWL using the Dornier Compact Delta lithotripter were analyzed retrospectively. Of these, 40 patients had soft stones, and 16 patients had hard stones. The first stone-free rate (SFR) according to plain films and ultrasonography was analyzed by stone size, and a stone clearance index (SCI) formula was applied to see if there was any change in the SFR, especially for stones >2 cm.**

***Results*: The formula, which correlated well with the clearance, is SCI = [(IVA × IW × stone type)/IH] − (stone size in mm^2/10). Nearly all (90%) of the patients with an SCI of >0 cleared their stones within 3 months, and 87% of the patients with an SCI <0 cleared their stones after 3 months. Positive and negative predictive values were 93.33% and 76.9%, respectively. The accuracy of the correlation is 85.71%.**

***Conclusions*: The success of SWL for lower-caliceal stones can be predicted easily using the SCI. Stones of >200 mm^2 (>2 cm) surface area may still be suitable for SWL if the SCI is positive, whereas alternative treatment modalities should be considered if the SCI is a low negative value (<−7).**

INTRODUCTION

MANAGEMENT OF LOWER-POLE STONES BY SWL remains one of the most debated topics in endourology because of the limited clearance rate and higher retreatment rate.[1] It is important to determine which patients would benefit from SWL and which might fare better with percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS). To predict the clearance of residual lower-caliceal calculus after SWL, a few favorable and unfavorable factors (infundibulopelvic angle, infundibulovertical angle, infundibular width, inferior caliceal anatomy, infundibular height, infundibular length, and composition of stone) have been discussed.[1–6] There is no uniform consensus regarding the relative importance of these factors, as different authors have studied various independent factors separately. In a patient with a combination of favorable and unfavorable factors, therefore, it is very difficult to predict the clearance, as the contribution of each factor to stone clearance is not known.

In this era of evidence-based and cost-effective medicine, it is vital to select the most appropriate treatment for patients with lower-pole stones for which guidelines need to be established. In this retrospective study, we correlated both favorable and unfavorable factors into a formula to predict clearance.

PATIENTS AND METHODS

Between December 2001 and February 2003, 56 consecutive patients (37 male, 19 female) with isolated lower-caliceal single stones (right 29, left 27) were treated with SWL using the Dornier Compact Delta lithotripter. Their data were analyzed retrospectively. First stone-free rates (SFRs) were analyzed according to the stone size, and an SCI formula was applied to identify any change in the SFR, especially for the stones >2 cm. The average BMI of these patients was 24.22 (range 21–32).

Various anatomic and stone factors such as the infundibulopelvic angle, infundibulovertical angle (formed by lines

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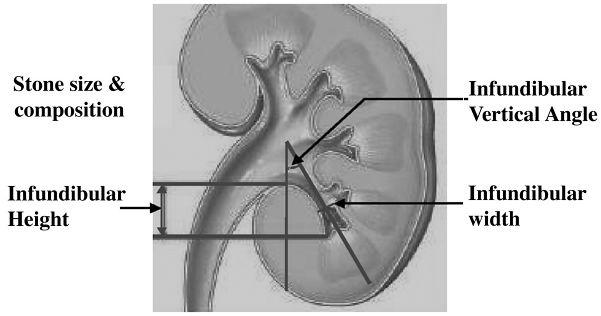

FIG. 1. Factors correlating well with clearance.

Table 2. Stone and Anatomic Features

Average stone bulk (mm^2) (range)	128 (36–230)
Average stone size (mm) (range)	13 (8–23)
Percent <10 mm (N)	14.8 (8)
Percent 10–20 mm (N)	57.14 (32)
Percent >20 mm (N)	28.57 (16)
Stone composition (% [N])	
Soft	71.42 (40)
Hard	28.57 (16)
Infundibular height (mm) (mean)	12–36 (21.6)
Infundibular width (mm) (mean)	3–10 (5.8)
Infundibulovertical angle (°) (mean)	20–60 (39.6)

drawn in the direction of the infundibulum of the lower calix and the imaginary vertical line drawn parallel to the long axis of the spine), infundibular width (narrowest part of infundibulum among all intravenous urogram [IVU] films), inferior caliceal anatomy, infundibular height (the distance between a horizontal line from the lower point of the lower calix to the highest point of the lower lip of renal pelvis), infundibular length, and stone composition were assessed on the basis of the plain film and IVU of all patients (Fig. 1). The infundibulovertical angle, formed by lines drawn in the direction of the infundibulum of lower-pole stones and the imaginary vertical line along the direction of gravity, is a fixed landmark and is easy to measure. Infundibular height is the distance the stone has to traverse; it correlates better than infundibular length with the clearance. Infundibular width measurement from a single film is imprecise; hence, the maximum diameter taken after reviewing all IVU films was used.

To determine the effect of stone composition and its application to the SCI, these stones were divided into hard, with a factor of 0.85, and soft, with a factor of 1.0. If the stone density is greater than that of bone with a clear margin and no evidence of porosity under magnification, it was considered a hard stone. Those stones with speculated and irregular margins having porosity throughout and with a density less than that of bone were considered soft. Any stones with a combination of these characteristics were considered hard.

Stone clearance was assessed by plain films and ultrasonography. The time to clearance of the stone was evaluated in all. Patients were advised to use mechanical percussion and inversion therapy to enhance clearance.[7,8]

Patients having prior SWL, prior stenting, complex lower-pole anatomy, and stone treated with more than one session of SWL were excluded from the analysis. Complex lower-pole anatomy was defined as crowding of the calices with gross dysmorphism on IVU. Favorable and unfavorable factors were correlated in the form of a formula, which is obtained purely by using these factors in various permutations and combination and correlating them with the clearance, keeping to the principle that favorable factors are directly related and unfavorable factors are related inversely to clearance.

Table 1. Stone Clearance According to Size

	Cleared/total	*SFR (%)*
<1 cm	7/8	87.5
1–2 cm	21/32	65.62
>2 cm	9/16	56.25

RESULTS

Stone-free rates

Those stones <10 mm showed an 88% clearance rate after one session, irrespective of the composition and unfavorable factors. Somewhat fewer (69%) of the stones between 10 and 20 mm were cleared at 3 months. Stones >2 cm had a clearance rate of 57% (Table 1).

Stone parameters required for the SCI were analyzed as follows (Table 2). Forty patients had soft stones and 16 had hard stones (inclusive of mixed stones). The formula, which correlated well with the clearance, is:

$$\text{SCI} = [(\text{IVA} \times \text{IW} \times \text{stone type*})/\text{IH}] - (\text{stone size in mm}^2/10)$$

*Multiplied by 1 for soft stone and 0.85 for hard stones.

where IVA = infundibulovertical angle, IW = infundibular width, and IH = infundibular height. All favorable factors (IVA, IW, and type of stone) are multiplied, and the total is divided by the unfavorable factor (IH). This value is subtracted from 1/10th of another unfavorable factor (stone size). For example, in a patient with all unfavorable factors and a stone size of 10 × 9 mm, IVA 20°, IW 3 mm, IH 35 mm, and a soft stone (calcium oxalate dihydrate), $\text{SCI} = (20 \times 3 \times 1)/35 - 9 = 1.71 - 9 = -7.29$. Because −7.29 is a low negative value, the stone will not clear despite being <1 cm.

Table 3. Stone Clearance in Relation to SCI

SCI	*Complete clearance <3 months*	*Complete clearance >3 months*
>0	28	2
≤0	6	20

Odds ratio 46.67 calculated by 2 × 2 table; $P = <0.0001$ (chi-square test).

Table 4. Utility of SCI in Predicting Stone Clearance

Sensitivity	*Specificity*	*Positive predictive value*	*Negative predictive value*	*Accuracy*
82.4	90.9	93.33	76.92	85.71
28/34	20/22	28/30	20/26	48/56

The values obtained by the formula were compared with the clearance rates of the stones. The average SCI values in patients who cleared their stones within 3 months and after 3 months were +5.68 and −4.31, respectively (Tables 3 and 4). Nearly all (90%) of the patients with an SCI of >0 cleared their stones within 3 months, and 87% of the patients with an SCI <0 cleared their stones after 3 months. Five patients (9%) with an SCI <−7 did not clear by 6 months, of whom 2 (3.5%) had small stones (<100 mm^2). All three patients with stones of >200 mm^2 surface area with a positive SCI (>2) cleared their stones within 3 months. The positive and negative predictive values were 93.33% and 76.9%, respectively. The accuracy of the correlation was 85.71% (see Table 3).

The factors that correlated well with clearance are shown in Figure 1. The SCI is plotted against clearance in months in Figure 2, which shows the intersection of the slope at 3.5 months.

DISCUSSION

There are no studies correlating different anatomic factors with stone size and composition. This is the first study to our knowledge to correlate all the favorable and unfavorable anatomic and stone factors to predict clearance after SWL. The formula incorporates all the factors with different permutations and combinations to get the maximum sensitivity and specificity.

It is known that gravity plays a major role in clearing stone fragments. Thus, patients with lower-pole stones have residual fragments significantly more often than in those with stones in other sites.[9–11]

Stone size and composition are also important factors in predicting clearance. The clearance is enhanced when the stone burden is minimal.[1,12] Uric acid and calcium oxalate dihydrate have better coefficients of fragmentation, and the success rate differs between calcium oxalate dihydrate and calcium oxalate monohydrate.[13] Hence, multiplying the stone type by 0.85 for hard stones and 1 for soft stones and subtracting 1/10th of the stone surface area correlated well with the clearance of the stone

In our study, we excluded patients with complex lower-caliceal anatomy, which itself is an independent unfavorable factor that might hamper clearance, and patients who required more than two sessions of SWL, to avoid errors in calculating the size of the stone fragments between sessions.

Patients with a negative SCI should be warned about the possibility of residual stones, and in patients with an SCI <−7, residual fragments are almost inevitable, even with small stones. Hence, alternative treatment modalities such as PCNS or RIRS may be advised.

The aim of SWL therapy is complete clearance of all fragments within 3 months. Persistence of residual stones for more than 3 months is considered treatment failure because regrowth of such fragments may mandate new treatment during follow-up.[14]

CONCLUSIONS

The success of SWL for lower-caliceal stones can be predicted easily using the SCI formula. Stones of >200 mm^2 (>2 cm) surface area may still be suitable for SWL if the SCI is positive, but alternative treatment modalities should be considered if SCI is low or negative (<−7).

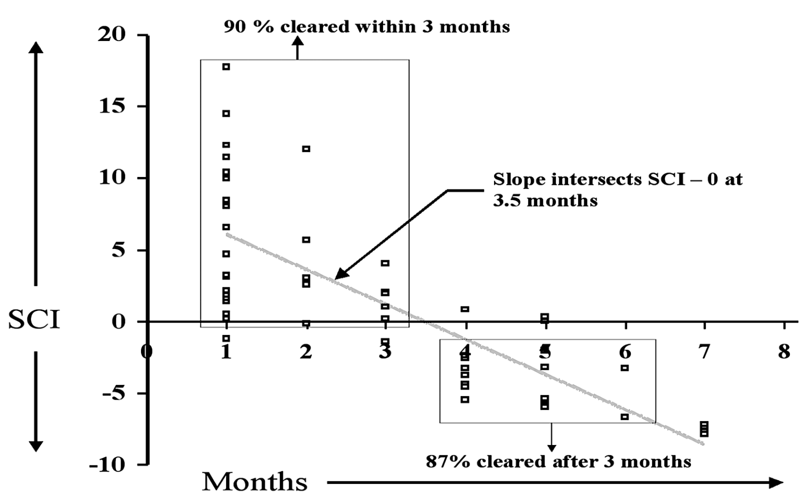

FIG. 2. SCI plotted against clearance (in months).

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