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Factors affecting lower calyceal stone clearance after Extracorporeal shock wave lithotripsy

S. Azab [a,*], A. Osama [b]

[a] *Urology Department, Faculty of Medicine, October 6 University, Cairo, Egypt*
[b] *Radiology Department, October 6 University, Cairo, Egypt*

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Abstract
Objective: Extracorporeal shock wave lithotripsy (ESWL) is one of the most commonly used procedures to remove renal calculi from the lower calyces. The aim of this work is to study the impact of radiological, anatomical and demographic factors on stone clearance after ESWL of lower calyceal calculi.
Patients and methods: This retrospective study included 150 patients aged between 16 and 70 years who were subjected to ESWL at October 6 University Hospital, Egypt, between June 2008 and October 2011. All the patients had solitary radio-opaque lower calyceal renal stones sized 2 cm or less. Intravenous urography (IVU) was performed to determine the patients' lower-pole calyceal anatomy (infundibulum width, infundibulum length and the lower-pole infundibulopelvic angle). The patients who were divided into two groups according to the treatment results (Group 1: stone-free patients; Group 2: patients with residual fragments) were followed up for 3 months and re-assessed by plain X-ray.
Results: A total of 126 patients (84%) were stone-free (Group 1), while 24 patients (16%) had residual fragments (Group 2). The stone size was 0.5–1 cm in 76 patients (60.3%) and 1–2 cm in 50 patients (39.7%) of Group 1, respectively, with no statistically significant difference. In patients with a lower-pole infundibulopelvic angle $\geq$45°, stone clearance was 52% compared to a stone clearance of 32% in patients with a lower-pole infundibulopelvic angle <45° with no statistically significant difference. Regarding the infundibulum length (<35 mm vs. $\geq$35 mm) and width (<4 mm vs. $\geq$4 mm), no statistically significant difference was observed between Group 1 and Group 2. Ninety out of 106 patients (84.9%) with a body-mass index (BMI) $\leq$30 kg/m^2 were stone-free, compared to 36 out of 44 patients (81.8%) with a BMI > 30 kg/m^2.

* Corresponding author.
E-mail address: ssazab@yahoo.com (S. Azab).

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Conclusions: There is no statistically significant effect of stone size, anatomy of the lower calyx and BMI on stone clearance after ESWL of lower calyceal stones. However, small stone size ($\leq$2 cm), a shorter and wider infundibulum and a larger lower-pole infundibulopelvic angle seem to promote a more rapid and more complete stone clearance.

Introduction

Extracorporeal shock wave lithotripsy (ESWL) is one of the most commonly used procedures to re-move renal calculi from the upper urinary tract [1]. Since the introduction of ESWL in the early 1980s, stones in the lower pole calyx (LPC) have been an interesting point of discussion. Observations in a meta-analysis carried out by Lingeman et al. [2] which were later supported by other reports [3], showed a reduced success in the treatment of lower-pole stones when compared to the treatment results of stones in the upper and middle calyces, this reduced success being related to the poor clearance of fragments rather than to a reduced fragmentation.

ESWL offers several advantages over other modalities of stone treatment: it is a minimally invasive procedure often not requiring deep anesthesia, it is an outpatient treatment, and most of the patients can resume their work within two days after the procedure. The outcome of stone clearance after ESWL is strongly related to stone disintegration and clearance of the fragments [4]. Stone disintegration is affected by several factors, such as stone size and composition, the number of stones, patient-related factors (age, obesity), the operator's experience and the type of lithotripter and its properties (shock wave number, shock wave energy) [5]. In addition, the clearance rate of stone fragments is influenced by the anatomy of the intrarenal collecting system and lower-pole spatial anatomic measures, such as infundibular width (IW), infundibular length (IL), and lower pole infundibulopelvic (LPIP) angle drainage [5]. Many studies have assessed the success of ESWL on stone clearance with contradictory results. This may be due to different inclusion criteria, the use of different methods of measuring the angle, the use of different types of lithotripters, or different follow-up criteria [6].

In the present study, besides LPC anatomy and stone size, various factors such as the number of shock waves used and the number of sessions, the patients' age and a possible influence of the body mass index (BMI) on the treatment results have been studied.

Patients and methods

This retrospective study included 150 patients aged between 16 and 70 years who were subjected to ESWL at October 6 University Hospital, Egypt, between June 2008 and October 2011. All patients had solitary radio-opaque lower calyceal renal stones sized 2 cm or less. Preoperative assessment included laboratory work-up (serum creatinine, urine analysis), intravenous urography (IVU), medical history, physical examination and ultrasonography of the urinary tract. The stone size and location were reviewed and determined based on the anteroposterior abdominal plain X-ray images of the IVU series. Patient-related data, such as demographics and BMI, stone characteristics (site and size) and treatment-related data (number of sessions, total number of shock waves used) were recorded. The patients were sub-divided according to their BMI ($\leq$30 kg/m^2 or >30 kg/m^2). Exclusion criteria were multiple or branched stones, a stone size > 2 cm, patients with a distorted pelvi-calyceal anatomy, acquired congenitally or in the course of previous surgery, horseshoe kidney, severe hydronephrosis, a history of previous procedures performed for the treatment of LPC stones, acute urinary tract infection, coagulopathy and pregnancy.

The patients were followed up for 3 months. The intervals between different ESWL sessions were 2 weeks. Plain radiography was used to determine the details of the lower-pole calyceal anatomy (infundibular width – IW, infundibular length – IL and the lower-pole infundibulopelvic angle – LPIPA). Infundibular length was defined as the length between the most distal point of the lower calyx, where the targeted stone was located, and the midpoint of the opening of the lower calyx into the renal pelvis (Fig. 1). Infundibular width was measured at the narrowest point of the lower calyx. The infundibulopelvic angle was determined in two axes, the ureteropelvic axis and the infundibulo-pelvic axis. The first axis extends from the central point of the pelvis opposite the margins of the superior and inferior renal sinuses to the central point of the ureter opposite the lower pole of the kidney. The second axis is the central axis of the lower-pole infundibulum [7,8].

Technique

All the patients underwent ESWL using a mobile electrohydraulic (spark gap) lithotripter (BMA For Design and Industry Corp., Giza, Egypt). After being placed in the supine position, the patients received sedoanalgesia in the form of meperidine hydrochloride (1 mg/kg) and/or fentanyl (1.5 g/kg). Therapy was usually started at a low power of 14 kV which was then gradually increased to 24 kV based on patient tolerance. The number of shock waves used depended on how fast complete fragmentation of the stone could be achieved; however, the maximum number of shock waves delivered was 3200 per session.

Follow-up

All the patients with radio-opaque stones were followed up with plain radiography. After 3 months follow-up, the patients were divided into two groups, depending on whether they were stone-free (Group 1) or whether they had residual fragments (Group 2). The patients were considered stone-free when there was no radiological evidence of stone fragments or, as far as asymptomatic patients with sterile urine were concerned, when they had $\leq$3 mm fragments. The study end points were a stone-free status, the number of shock waves used and the number of sessions required.

Statistical analysis

Statistical analysis was performed using SPSS version 12.0.1 (SPSS Inc., Chicago, IL, USA) for Windows. The independent sample *t* test

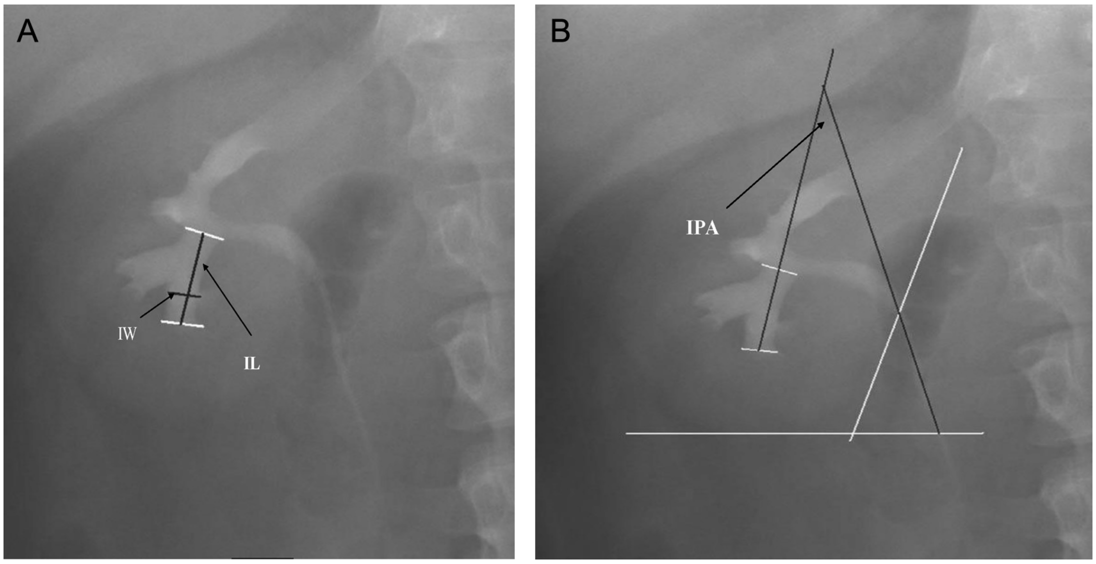

Figure 1 Measurement of the lower-pole calyceal anatomy. (A) Infundibular width (IW): the narrowest point of the lower calyx; infundibular length (IL): the length between the most distal point of the lower calyx and the midpoint of the opening of the lower calyx into the renal pelvis. (B) Infundibulopelvic angle (IPA). The ureteropelvic axis (black line on the right) is derived from the 2 white lines. The black line on the left is the central axis of the lower-pole infundibulum.

was used for the comparison of Group 1 and Group 2 with regard to the statistical significance of stone size and anatomical factors, such as infundibular length and width and infundibulopelvic angle. A univariate analysis of the correlation between the success rate of stone clearance and all influencing factors was carried out with χ^2 test. A P-value <0.05 was considered statistically significant.

Results

Out of 150 patients with solitary radio-opaque lower calyceal renal stones treated with ESWL, 126 (84%) were stone-free (Group 1) and 24 (16%) had residual fragments (Group 2) after a follow-up of 3 months. Group 1 consisted of 96 male and 30 female patients with a mean age of 45.02 ± 13.02 (range 16–70) years. The mean stone size was 0.87 ± 0.22 (range 0.5–2) cm (Tables 1 and 2). In 76 patients (60.3%) of this group the stone size ranged from 0.5 to 1 cm, whereas in 50 patients it ranged from 1 to 2 cm, but there was no significant difference as far as the stone-free status was concerned.

In patients with an infundibulopelvic angle ≥45°, stone clearance was 52%, whereas it was 32% in patients with an infundibulopelvic angle <45° with no significant difference (Table 3).

Regarding infundibular length and width, no statistically significant difference was observed between the two groups (Table 3). The average number of sessions was 1.91, while the average number of shock waves used per session was 2154. The number of sessions ranged from 1 to 5 sessions with 68 patients (45.3%) requiring one session, 48 patients (32%) two, 18 patients (12%) three, 12 patients (8%) four and 4 patients (2.6%) five sessions.

As for the effect of BMI on stone clearance, 90/106 patients (84.9%) with a BMI $\leq 30\,kg/m^2$ were stone-free, compared to 36/44 patients (81.8%) with a BMI $> 30\,kg/m^2$. The correlation between the number of shock waves used and the infundibulopelvic angle (≥45° and <45°) showed no statistically significant difference. In patients with an infundibular width <4 mm, an increased number of shock

Table 1 Significance of patients' characteristics on stone clearance.

Variable	Group 1	Group 2	*P* value
Gender	$N = 126$	$N = 24$	0.643
Male (Total n) = 110	96	14	
Female (Total n) = 40	30	10	
Stone side			0.544
Right side (Total n) = 70	60	10	
Left side (Total n) = 80	66	14	
BMI			0.461
$\leq 30\,kg/m^2$ (Total n) = 106	90	16	
$> 30\,kg/m^2$ (Total n) = 44	36	8	

Body mass index, BMI.

Table 2 Impact of lower calyceal anatomy on stone clearance after ESWL.

Factor	Group 1	Group 2	*P* value
Infundibular length (mm)	$N = 126$	$N = 24$	0.369
<35	80 (53.3%)	10	
≥35	46 (30.7%)	14	
Infundibular width (mm)			0.213
<4	60 (40%)	16	
≥4	66 (44%)	8	
LPIPA (°)			0.633
<45	48 (32%)	14	
≥45	78 (52%)	10	
Stone size			
<1 cm	76 (50.6%)	6	0.432
1–2 cm	50 (39.6%)	18	

Lower pole infundibular pelvic angle, LPIPA.

Table 3 Comparison between the Group 1 (stone-free) and Group 2 (residual fragments).

	Group 1 patient stone free	Group 2 patient residual fragments	*P* value
Age (years)	45.02 ± 13.02	47.02 ± 11.01	0.341
Stone size (cm)	0.87 ± 0.22	1.16 ± 0.37	0.327
IL (mm)	29.2 ± 4.0	31.5 ± 6.4	0.154
IW (mm)	4.1 ± 1.0	3.8 ± 0.5	0.185
LPIPA (°)	42.2 ± 6.0	40.38 ± 2.5	0.218
No. of shock °wave	2054 ± 489	2039 ± 513	0.831

waves was necessary (3200 as compared to 2300 in patients with an infundibular width ≥4 mm), however, there was no significant difference ($P = 0.860$). Similarly, the infundibular length did not have a statistically significant effect on the number of shock waves ($P = 0.926$), nor had the BMI ($P = 0.461$). The overall complication rate was 11% in the form of steinstrasse (5%), renal colics (4%) and urinary tract infection (2%).

Discussion

Various treatment options for lower-pole kidney stones have evolved in recent decades, with ESWL being considered one of the best and least invasive procedures [8]. The outcome depends on different factors. The question as to whether there is a relationship between stone size and stone clearance is controversial in the literature. The present study showed no significant relationship between stone size and stone clearance, which is in accordance with a number of reports [9,10], especially as far as stones <2 cm are concerned, while other studies reported an adverse effect of a larger stone size on the treatment results [8]. Our findings may be attributed to the fact that we performed the study only on stones sized 2 cm or less.

According to our results, anatomic factors do not have a statistically significant effect on stone clearance, which is matching with the findings of Sahinkanat et al. [11]. Other authors, however, found that infundibular width and length, as well as the pelvicalyceal angle were significant factors for stone clearance [11–13]. Elbahnasy et al. stated that a lower-pole infudibulopelvic angle ≥90° or an infundibular length ≤3 mm and an infundibular width ≥5 mm, regardless of the lower-pole infudibulopelvic angle, were significant factors influencing stone clearance after ESWL [12]. On the other hand we could not find any significant effect of LPIP angle ≥45°and <45° on stone clearance and that discrepancy with the other reports might be due to using fixed measuring points which enable more clear landmarks for measurements.

Brownlee et al. reported that multiple sessions of ESWL resulted in an increased stone-free rate compared with a single-session therapy (88% vs. 23%) [14]. In the present study, the number of sessions did not have a significant effect on stone clearance. The contribution of ESWL therapy to the stone-free rate and retention of passable stone fragments ≤4 mm in the lower pole might be an effect of the gravity-dependent position of the lower calyces. In patients with an infundibular width <4 mm, an increased number of shock waves was necessary (3200 as compared to 2300 in patients with an infundibular width ≥4 mm), however, there was no significant difference ($P = 0.860$).

Regarding BMI and stone clearance, we found no statistically significant difference, which is comparable to the results obtained by Hammad Ather et al. [15].

Nowadays, ESWL is the treatment of choice for most symptomatic lower-pole calyceal calculi due to its non-invasive nature, minimal anesthesia requirements and cost-effectiveness [16]. However, several recent reports have indicated a variable clearance rate using ESWL [4,17,18]. A number of factors influencing stone clearance have been identified [1,3]. These include stone characteristics, the type of lithotripter used, LPC anatomy and body habitus. For isolated LPC stones, the pelvicalyceal angle, infundibulum length and width are considered important determinants for stone clearance. The impact of body habitus on stone clearance has so far been little discussed by other investigators.

Conclusions

In our study, ESWL was the procedure of choice for the treatment of lower-pole renal stones. The findings show that there is no statistically significant effect of stone size, anatomy of the lower calyx and BMI on stone clearance. However, a small stone size (≤2 cm), a shorter and wider infundibulum and a larger lower-pole infundibulo-pelvic angle seem to promote a more rapid and more complete stone clearance. Limitations of the study were its retrospective nature and the fact that the number of cases in the second group was too small for an appropriate assessment. We, therefore, recommend a larger study focussing on the impact of various factors influencing stone clearance after ESWL.

References

[1] Drach GW, Dretler S, Fair W, Finlayson B, Gillenwater J, Griffith D, et al. Report of the United States cooperative study of extracorporeal shock wave lithotripsy. Journal of Urology 1986;135:1127–33.
[2] Lingeman JE, Siegel YI, Steele B, Nyhius AW, Woods JR. Management of lower pole nephrolithiasis: a critical analysis. Journal of Urology 1994;151:663–7.
[3] Andreassen KH, Dahl C, Andersen JT. Extracorporeal shock wave lithotripsy as first line monotherapy of solitary calyceal calculi. Scandinavian Journal of Urology and Nephrology 1997;31:245–8.
[4] Sabnis SR, Naik K, Patel SH. Extracorporeal lithotripsy for lower calyceal stone: can clearance be predicted. British Journal of Urology 1997;80:853–7.
[5] Gerber R, Studer UE, Danuser H. Is newer always better? A comparative study of 3 lithotriptor generations. Journal of Urology 2005;173:2013–6.
[6] Fong YK, Peh SOH, Ho SH. Lower pole ratio: a new and accurate predictor of lower pole stone clearance after shockwave lithotripsy? International Journal of Urology 2004;11:700–3.
[7] Elbahnasy AM, Shalhav AL, Hoeing DM, Elashry OM, Smith DM, Mc-Dougal EM, et al. Lower calyceal stone clearance aftershock wave lithotripsy or ureteroscopy: the impact of lower pole radiographic anatomy. Journal of Urology 1998;159(3):676–82.
[8] Lin C-C, Hsu Y-S, Chen K-K. Predictive factors of lower calyceal stone clearance after extracorporeal shockwave lithotripsy (ESWL):

the impact of radiological anatomy. Journal of the Chinese Medical Association 2008;71(10):496–501.

[9] Sorenson CM, Chandhoke PS. Is lower pole caliceal anatomy predictive of extracorporeal shock wave lithotripsy success for primary lower pole kidney stones? Journal of Urology 2002;168:2377–82.

[10] Fong YK, Peh SOH, Ho SH. Lower pole ratio: a new andaccurate predictor of lower pole stone clearance after shockwave lithotripsy? International Journal of Urology 2004;11:700–3.

[11] Sahinkanat T, Ekerbicer H, Onal B, Tansu N, Resim S, Citgez S, et al. Evaluation of effects of relationships between main spatial lower pole calyceal anatomic factors on the success of shock-wave lithotripsy in patients with lower pole kidney stones. Urology 2008;71:801–5.

[12] Elbahnasy AM, Shalhav AL, Hoenig DM. Lower caliceal stone clearance after shock wave lithotripsy or ureteroscopy: the impact of lower pole radiographic anatomy. Journal of Urology 1998;159:676–82.

[13] Knoll T, Musial A, Trojan L. Measurements of renal anatomy for prediction of lower pole caliceal stone clearance: reproducibility of different parameters. Journal of Endourology 2003;17:447–51.

[14] Brownlee N, Foster M, Griffith DP. Controlled inversion therapy: an adjunct to the elimination of gravity-dependent fragments following extracorporeal shock wave lithotripsy. Journal of Urology 1990;143:1096–8.

[15] Hammad Ather M, Abid F, Akhtar S, Khawaja K. Stone clearance in lower pole nephrolithiasis after extra corporeal shock wave lithotripsy – the controversy continues. BMC Urology 2003;3:1.

[16] Madbouly K, Sheir KZ, Elsobky E. Impact of lower pole renalanatomy on stone clearance after shock wave lithotripsy: fact or fiction? Journal of Urology 2001;165(5):1415–8.

[17] Tan MÖ, İrkilata L, Şen İ, Onaran M, Küpeli B, Karaoğlan U, et al. The impact of radiological anatomy in clearance ofl ower caliceal stones after shock wave lithotripsy. Urological Research 2007;35: 143–7.

[18] Elbahnasy AM, Clayman RV, Shalhav A. Lower-pole caliceal stone clearance after shock wave lithotripsy: percutaneous nephrostolithotomy, and flexible ureteroscopy: impact of radiographicspatial anatomy. Journal of Endourology 1998;12:113–9.