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ORIGINAL PAPER

The impact of radiological anatomy in clearance of lower caliceal stones after shock wave lithotripsy

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Abstract The goal of this study was to determine the factors affecting stone clearance after extracorporeal shock wave lithotripsy (ESWL) for lower caliceal stones. Lower pole stone clearance was investigated in 128 (80 males, 48 females) patients treated with ESWL during 1998–2003 in our clinic. Renal anatomy was determined on standard intravenous urogram. The lower infundibulopelvic angle (LIPA) was measured as the angle between the vertical pelvis axis and the vertical axis of lower infundibulum (Sampaio's method). The mean age of the patients was 42.8 ± 12.4 (19–77) years. The mean stone diameter and burden were found to be 1.28 ± 0.58 (0.5–3.5) cm and 1.2 ± 1 (0–7) cm^2 respectively. The stone-free rate was 62.5% and ESWL was unsuccessful in 16 (12.5%) patients. Thirty-two (25%) patients had residual fragments $\leq$ 4 mm retained in lower calices after lithotripsy. The stone clearance was found to be unrelated to stone burden and diameter ($P = 0.17$ and $P = 0.14$, respectively). However, there was a significant difference between mean lower pole infundibulum length ($P = 0.001$), infundibulum width ($P = 0.001$) and LIPA ($P = 0.0001$) between stone-free patients and patients with residual fragments. Multivariate logistic regression analysis accepting stone-free as the favourable result also confirmed that LIPA, lower pole infundibulum length and width were factors that significantly affected the outcome. Lower pole anatomy has a significant influence on clearance of fragments after ESWL.

Keywords Extracorporeal shock wave lithotripsy · Lower calyx · Urolithiasis · Residual calculi · Anatomy

Introduction

A low stone-free rate after extracorporeal shock wave lithotripsy (ESWL) is a remarkable problem after treatment of lower pole calculi. This problem has been attributed to low clearance of stone fragments rather than stone disintegration [1–5]. The initial attempts were focused on the lower pole anatomy based on the dedicated work of Sampaio et al. [1–3]. The authors reported the adverse factors for lower pole stone clearance as an acute lower infundibulopelvic angle (LIPA) (<90°), small lower infundibulum diameter, complex caliceal anatomy and a long caliceal length. Although previous reports [1–6] confirmed the findings of Sampaio et al., recent data raised some debate about the impact of renal anatomy on prediction of stone clearance and reproducibility of the parameters [7–10]. Also different methods of measuring the LIPA have been described, further complicating the interpretation of the results [1–6]. Thus ''the debate goes on''. This report also evaluates the effect of lower pole anatomy on post-ESWL clearance of lower pole stone fragments.

Materials and methods

The study group consisted of 128 consecutive patients with lower pole calculi, treated with ESWL during 1998–2003 in our clinic. Eighty patients (62.5%) were male and 48 (37.5%) were female. Before ESWL, all patients were evaluated routinely with renal function tests, urinalysis, urine culture and intravenous urogram (IVU). Patients with

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urinary tract infection were treated before the procedure with appropriate antibiotics. Contraindications for ESWL were coagulation disorders, acute pyelonephritis, obstruction distal to the calculi, non-functioning kidney and hypertension. Antibiotic prophylaxis (starting 24 h before treatment up to 5 days post-ESWL) was given to patients having a stone size of >2 cm to prevent any septic complication.

Extracorporeal shock wave lithotripsy was performed with a Siemens Lithostar plus device, a second-generation lithotriptor, in which shock waves were delivered by an electromagnetic shock head module. All the procedures were carried under fluoroscopic control. The stone burden was defined as the area calculated by multiplying the largest length and the width of the individual stone measured from the abdominal plain X-ray.

The follow-up was performed with plain abdominal X-ray usually taken 1–2 weeks after treatment and continued according to disintegration and clearance. Re-treatments were done not before 3 weeks for the same location. Complete stone clearance was accepted as stone-free and confirmed with IVU or X-ray and ultrasonography in all patients.

After the ESWL treatment, patient registries were analysed for factors affecting stone clearance in patients with successful stone fragmentation, which was defined as fragments ≤ 4 mm. The lower pole anatomy was determined on standard IVU. All measurements were done by the same two doctors for a double-check. Lower pole infundibular length and infundibulum width were measured as described by Elbahnasy et al. [5]. Briefly the infundibulum width was accepted as the narrowest diameter and infundibulum length as the distance from the distant point of the lower calyx to the midpoint of lower lip of renal pelvis (Fig. 1a). The LIPA was determined as described by Sampaio et al. [1–3] based on measuring the angle between the vertical pelvis axis and the vertical axis of the lower infundibulum (Fig. 1b).

For statistical analysis, Statistical Program for Social Sciences (SPSS) was used. Patients who were stone-free and who had retained fragments were compared for each individual parameter using the Mann–Whitney *U* test. Considering the variety of factors that could affect the clearance rates, a multivariate analysis was also done with a logistic regression test. First, each factor was accepted as a continuous variable without any predetermined cut-off value. Secondly, the test was repeated with pre-determined cut-off values. *P* value of <0.05 was accepted as statistically significant. The data were given as mean ± standard deviation.

Results

The mean age of the patients was 42.8 ± 12.4 (19–77) years. Eleven (8.6%) patients were stented before the treatment because of their high stone burden. The mean stone diameter and burden were found to be 1.28 ± 0.58 (0.5–3.5) cm and 1.2 ± 1 (0–7) cm^2 respectively. The mean shock wave number and power per session were 3,051.17 ± 371 and 18.75 ± 1.8 kV, respectively. Sixty-two (48.4%) patients required only one treatment while 27.3% required more than two sessions. ESWL complications included renal colic in 28 (21.9%), stone-street formation in 14 (10.9%) and necessity for ureteroscopy in 2 (1.6%) patients. The stone-free rate was 62.5% (80 patients). Thirty-two (25%) patients had residual fragments ≤ 4 mm retained in lower calices after the treatment. ESWL was unsuccessful in 16 (12.5%) patients. After a mean follow-up of 9.5 ± 8.9 (0–49) months, 1(8.8%) patient had a recurrence.

Fig. 1 **a** Lower pole infundibular length, **b** The lower infundibulo-pelvic angle (α) measured as described Sampaio et al. [1–3]

Univariate analysis

The stone clearance was found to be unrelated to stone burden and diameter (*P* = 0.17 and *P* = 0.14, respectively). However, there was a significant difference between mean lower pole infundibulum length (*P* = 0.001), infundibulum width (*P* = 0.001) and LIPA (*P* = 0.0001) between stone-free patients and patients with residual fragments. Eighty-four percent of the patients with residual fragments had a LIPA less than 90° while 90% of the stone-free patients had an LIPA higher than 90°.

Multivariate analysis

Logistic regression analysis, accepting stone-free as the favourable result, revealed that LIPA, lower pole

Table 1 Multi-variate logistic regression analysis of factors considered to be related to lower pole stone clearance using stone-free as the favourable result

Variable	OR	*P* value
Stone diameter (cm)	1.013	0.991
Stone diameter (≤ 1 cm, >1 cm)	0.844	0.828
Stone burden (cm^2)	1.624	0.479
Stone burden (≤ 1 cm^2, >1 cm^2)	3.045	0.192
LI-length (cm)	4.263	0.014*
LI-length (<4 cm, ≥4 cm)	4.668	0.122
LI-diameter (cm)	0.000	0.001*
LI-diameter (<0.6 cm, ≥0.6 cm)	6.323	0.004*
LIPA	0.867	0.000*
LIPA (<100°, ≥100°)	29.832	0.000*

First lines represent each factor as continuous variables without any predetermined cut-off values and second lines with cut-off values

LIPA lower infundibulopelvic angle, *LI* lower infundibulum

* $P < 0.05$

infundibulum length and width were factors that significantly affected the outcome (Table 1). When the analysis was repeated by cut-off points, LIPA measurement and lower infundibulum width remained as the factors that had an influence on the clearance rate after ESWL (Table 1). In this series, 30 patients had all 3 unfavourable factors together, namely LIPA <90°, infundibulum length <4 cm and width <0.6 cm and excluding 4 patients with unsuccessful fragmentation the coexistence of these factors resulted in a stone-free rate of 34.6% while 65.6% had retained fragments (≤ 4 mm) in the lower calices.

Discussion

The efficacy of ESWL is considered to be related to stone size, location, composition and type of lithotriptor [1–12]. Decreased clearance for lower pole calculi was confirmed by many studies and could not be attributed solely to the effect of gravity [5, 11, 12]. Our stone-free rate for lower pole calculi is 62.5%, which is similar to other series that usually reported a stone-free rate of 50–60% [5, 6, 11, 13–15].

The impact of LIPA on stone clearance was initially studied by Sampaio et al., who classified the patients as having acute (<90°) or obtuse (>90°) angle [1, 2]. The cut-off point was usually set as 90°–100° (34% stone clearance when LIPA < 100°, Keeley et al. [6]; 23% stone-free when LIPA < 90°, Sampaio et al. [3]). Later Elbahnasy et al. [5] suggested another method based on measuring the angle between the ureteropelvic axis and the vertical axis of the lower infundibulum. Both methods were found to be highly reliable for predicting stone clearance in adults as well as in paediatric patients [1–6, 16].

Some authors have reported infundibulum diameter and length as other important factors for predicting stone clearance [1–5]. The impact of infundibulum diameter is rather controversial [6, 17]. Its importance could be related to stone burden and size of fragments. The dynamic nature of urinary tract affects measurements so that different measurements could be obtained at different minutes of IVU [17]. However, it is also probable that a dilated infundibulum might traverse fragments more easily. In our study, infundibulum diameter was found to be an important factor for stone clearance.

As previously stated, recent studies have raised some debate about the impact of renal anatomy on prediction of stone clearance and reproducibility of the parameters [7–10]. In a prospective, randomized trial of ESWL and percutaneous nephrolithotomy, Albala et al. [8] reported poor clearance for lower caliceal calculi greater than 1 cm and found that factors like LIPA, infundibulum width and length had no effect on stone clearance. These findings were also confirmed by Sorensen and Chandhoke [9], who found a significant difference between clearance rates of lower caliceal calculi 11–15 and 6–10 mm (73 vs. 43%). This is not surprising, as previous studies had confirmed that the success rate after ESWL for lower caliceal calculi was adversely affected by increased stone size/burden [9, 11, 12]. Thus, the impact of lower pole anatomy might also depend on stone diameter/burden with a debate on the cut-off value. In the original report by Elbahnasy et al. [5], confirming the affect of anatomical factors such as LIPA, lower infundibulum length and width, the mean stone-burden was 69 mm^2. Similar results were reported by Sabnis et al. [4], who measured the LIPA according to Sampaio's method [1–3] and had a mean stone diameter of 1.5 cm. In the study by Keeley et al. [6], in which the LIPA was found as the most significant factor to predict stone clearance, stone-size varied between 11 and 20 mm. As the mean stone diameter and burden were lower in our series, this might be reflected in our results confirming the importance of anatomical factors for stone clearance. In the present series, an acutely oriented infundibulum (narrow IPA) [1–3] and/or a long lower infundibulum ($P = 0.005$) were unfavourable factors for clearance of lower caliceal stones. However, stone burden and diameter were not found to be significant factors. This result could be attributed to a selection bias as, in our series, most of the patients with lower caliceal calculi had a stone diameter ≤ 2 cm in which the mean stone diameter and burden were 1.28 ± 0.58 cm and 1.2 ± 1 cm^2, respectively. We think that with increasing diameter/burden (>2 cm), clearance might be adversely affected. Recently Ghoneim et al. [18] obtained similar results using Elbahnasy's method [5] for determining LIPA as they have a small (mean stone burden = 69 mm^2) stone burden.

Some authors have proposed caliceal height as a parameter for predicting stone-clearance from the lower calices [19–21] but this parameter was not generally accepted as it might depend on respiration and postural changes of the kidney [18].

The studies concerning stone clearance and lower pole anatomy were criticized by Knoll et al. [10], pointing out a high interobserver variation. We agree with the authors that correct methods should be used for analysis. The IPA determined by Sampaio's method is not simply found by drawing a tangential line (like done by Knoll et al.) over the lower lip of the renal pelvis and measuring the angle between this line and the axis of the lower infundibulum. In this study and reports by Sabnis and Sampaio [1–4] we measured the angle between vertical pelvis axis and vertical axis of lower infundibulum as illustrated in the figure.

Recently the impact of lower pole anatomy in the treatment of lower pole calculi with ESWL was investigated using multivariate analysis [22]. The results were very similar to our study confirming significant correlation between lower infundibulum length, width, LIPA and stone-free status. Repeat analysis using a cut-off point as 30 mm for length did not reach significance while a cut-off point of 5 mm for width and 70° for LIPA seemed appropriate. We used different cut-off points for our final analysis (length 40 mm, width 6 mm, LIPA 100°). These figures were predetermined considering the mean values obtained in stone-free and residual fragment groups. However, as they are higher than expected they might be somehow impractical in the clinical setting. An appropriate cut-off value for length could not be determined in both studies.

The rationale for choosing percutaneous nephrolithotomy as the first-line treatment in the lower pole calculi with unfavourable anatomy might be decreasing the economic burden and avoiding unnecessary treatments. Although percutaneous nephrolithotomy was shown to be a safe procedure in terms of renal function, it is a surgical procedure with potential complications. Chatham et al. [23], in a series of 19 patients that were subjected to percutaneous nephrolithotomy for complex renal calculi, reported that 84% of the patients preserved renal function. However two patients had significant renal function deterioration. In a recent report, Preminger [24] reviewed randomised trials of ESWL versus percutaneous nephrolithotomy and concluded that ESWL is less effective but less invasive. The related study was performed using first, second and third generation lithotriptors, so techniques could not be standard. In patients having adverse anatomical factors, percutaneous nephrolithotomy could be a better way to make patients stone-free. Flexible ureteroscopy and laser lithotripsy are recent alternatives in treatment of lower pole stones. However, it is again a surgical procedure with its own potential complications (ureteral perforation, stricture formation and so on) [5, 24]. In a recent randomized study, Pearle et al. [25] reported that ureteroscopy did not offer any significant advantage over ESWL and might even be hazardous (increased complication rate) for lower pole calculi ≤ 1 cm.

This study has confirmed that the factors affecting stone clearance after ESWL for lower caliceal calculi were lower pole infundibulum length, width and LIPA. Percutaneous nephrolithotomy offers greater stone-free rates than ESWL especially for calculi bigger than 2 cm independent of lower pole anatomy. Accordingly, ESWL might be a good initial option for lower caliceal calculi less than 2 cm in the presence of favourable anatomy, as it is the least invasive treatment method.

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