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Analysis of the Results of Extracorporeal Lithotripsy (ECL) in the Treatment of Stones of the Inferior Calcific Group (ICG): Does Variability in Calicial Anatomy Influence Them?

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Abstract **Original Research Article**

***Introduction*:** Lower calyceal stones always pose a problem of optimal management: the results of ESWL are insufficient, with the possibility of generating a large quantity of residual fragments and recourse to complementary treatments. The different anatomical varieties of the lower calcific group can vary the results of treatment at this site. The objective of the study is to analyze the influence of the anatomy of the lower calyceal group (LCG) on the results of ESWL. ***Materials*:** A prospective observational study involving 57 patients with LCG stones who were treated by ESWL in our department between January 2021 December 2022 according to the French recommendations of the AFU lithiasis committee. Unfavorable LCG anatomy was defined according to Sampaio's criteria: a length of the inferior stem caliceal lower >10 mm, a width<5 mm and an infundibulo-pelvic angle < 90°. Fragment-free rate was assessed 3 months after ESWL with tomography urography (CTU). Failure was considered as the existence of fragments ≥ 3mm, the need for ancillary procedures after ESWL (ureterscopy, RIRS, PCNL or new ESWL), complications and risk factors associated with the development of perirenal hematoma were analyzed. ***Results*:** The median age was 48,5 years (range: 22-68), with 66,66% of the participants being men (38 men and 19 women). Approximately 14,03 % (n=8) of the patients were taking antiplatelet/anticoagulant drugs, and 8,77 % (n= 5) had High blood pressure. The median size of the lithiasis was 10 mm (range: 5-20 mm), with favorable LCG anatomy observed in 45,61 % (n= 26/57) of patients, including 34,61 % (n= 9/26) who required ancillary procedures after ESWL, compared to 64,51% (n= 20/31) in patients with unfavorable anatomy (54,39 % = 31/57). The stone-free after ESWL for both groups combined was 54,38 % (n= 31/57). Auxiliary procedures included ureteroscopy or RIRS. Two perirenal hematomas were observed in patients on antiplatelet/anticoagulant therapy, with a favorable outcome. ***Conclusion*:** ESWL can be used as an initial treatment for lower calyceal group (LCG) calculations, but it is recommended that the indication should be carefully considered, taking into account factors predictive of success in the treatment of an lower calyceal calculus and, above all, lower calyceal anatomy (recourse to ancillary procedures is high in the case of unfavorable anatomy).

Keywords: Lower calyceal stones, anatomy, Extracorporeal Lithotripsy, RIRS, Extracorporeal shockwave lithotripsy (ESWL).

Introduction

Extracorporeal shockwave lithotripsy (ESWL) is the fragmentation of stone by means of acoustic shockwaves created by an extracorporeal source. ESWL brakes the stone by spallation and squeezing. The optimal frequency for fragmentation is 1 Hz. The initial power must be low, then progressively increased during the session. The contra-indications for ESWL are pregnancy, major deformities, severe obesity, aortic aneurism, uncontrolled coagulation disorders, untreated urinary infection, cardiac pacemaker. A stone density of 1000 UH is a risk factor for fragmentation failure. The success rate for the kidney and the ureter is 60-80% and 80%, respectively. Stone clearance may be facilitated by alpha blockers. Asymptomatic and non-infected residual fragments less than 4 mm must be followed-up annually.

Despite technological advances, extracorporeal lithotripsy remains the first-line treatment for the majority of calculi. However, there are still situations where the choice of which technique to use as first-line treatment may prove difficult. This is the case for stones in a particular anatomical situation, or associated with an anomaly in the excretory tract. Lowe calyceal calculi still pose a problem in terms of optimal management: the results of ESWL are inadequate, with the possibility of generating a large quantity of residual fragments, and recourse to complementary treatments.

Lower calyceal calculi less than 10 mm in size are generally managed by ESWL, while those between 10 and 20 mm are managed by percutaneous nephrolithotomy (PCNL) or flexible ureteroscopy (FUS), with results varying from study to study [1, 2]. These techniques may leave residual fragments, and the particular anatomy of the lower calyx has been blamed for variations in the rate of removal of these fragments [3, 4].

The different anatomical varieties of the LCG can vary treatment results at this site. The aim of our study is to analyze the influence of LCG anatomy on the results of ESWL.

Materials and Methods

We conducted a prospective observational study of 57 patients with Lower Calyceal Group calculation (MONOBLOC calculation) who were treated with ESWL in our department between January 2021 December 2022 according to the French recommendations of the Lithiasis Committee of the French Urological Association.

In the urological history, there were 2 lumbotomies on the same side as the ESWL, one for kidney stones and the other for junction syndrome. At our center, all patients were monitored on an outpatient basis.

Prior to a ESWL session, an cytobacteriological examination of urine was mandatory for our entire population, along with a coagulation test and a pregnancy test for women during the genital activity period. Anticoagulants (AVK, antiaggregants) were stopped before ESWL and relayed if necessary. In the case of pacemakers, a check-up of the pacemaker and a cardiological consultation are systematically recommended after ESWL [5].

A tomography urography (CTU) was performed prior to ESWL for all our patients, and stone characteristics were specified ((size, laterality, topography, number of stones and density), anatomy according to Sampaio criteria as well as skin-to-calculus distance and parietal distance.

Other variables analyzed were: age, gender, BMI, previous urinary diversion, number of lithotripsy sessions and technical parameters (number of shocks and mean energy) and complications.

Unfavorable LCG anatomy was defined according to Sampaio's criteria: a length of the inferior calcific stem >10 mm, a width <5 mm and an infundibulo-pylar angle <90º.

Stone free was assessed at 4 weeks after ESWL with tomography urography (CTU). Failure was considered as the existence of fragments ≥ 3mm or the need for ancillary procedures after ESWL (Ureteroscopy, RIRS, PCNL or new ESWL).

Complications and risk factors associated with the development of perirenal hematoma were analyzed. Statistical analysis was performed using SPSS.20 software (significant difference when $p \leq 0.01$).

Treatment was carried out using a "DORNIER COMPACT DELTA" type lithotripter with electromagnetic source and dual radiological and echographic tracking system (Figure 1).

Lithotripsy sessions were performed by a radiology technician under the supervision of a urologist.

Perioperative analgesia consisted of a paracetamol + codeine tablet administered 20 min before the session, and on-demand intramuscular Ketoprofen 50 mg, depending on tolerance. A visual pain scale rated from 0 to 10 was completed by the patient at the end of the session.

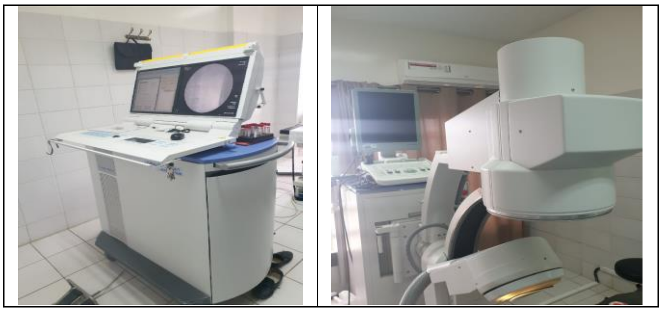

Figure 1: Dornier Compact Delta lithotripter, urology department, Mohammed V military training hospital, Rabat

Throughout the procedure, fragmentation was constantly monitored by fluoroscopic images, which were taken at the beginning, middle and end of ESWL, for a better assessment of calculus fragmentation.

Figure 2: figure showing monitoring of technical parameters-Urology department, Mohammed V military training hospital, Rabat

RESULTS

The mean age of our population was 48,5 ±13,5 years, 66,66% were men (38 men and 19 women) with a male/female sex ratio of 2. 8, 77% (n= 5) of patients were taking antiplatelet / anticoagulant medication and 14,03% (n=8) were hypertensive.

The mean BMI was 27, 2 kg/m2 (73,7% of patients were of normal weight, 25% were overweight and 1,3% were obese). There were no associated urinary tract anomalies. A double-J ureteral catheter was inserted prior to ESWL in 6 patients. The stone manifested itself 82 times as recurrent low back pain and in 18 cases as recurrent urinary tract infections.

Calculus characteristics included a mean calculus size of 12,8 ± 3,4 mm, with extremes ranging from 6,3mm to 20mm; the calculi were straight in 23 cases and left in 34; mean density was 688 ± 135 HU (550-1338); and mean skin-calculus distance was 81 mm.

The characteristics of the cohort are shown in **Table 1**.

Table 1: Description of our population

Patients (n) 57
Age (average) 48,5 ± 13,5
Gender Sex-Ratio à 2
Men (%) 38 (66,66 %)
Female (%) 19 (33,34 %)
Antecedents
Antiplatelet/anticoagulant therapy 5 (8,77 %)
High blood pressure. 8 (14,03%)
Pre-ESWL double J probe 6 (10,52 %)
Laterality
Right side (%) 23 (40,35%)
Left side (%) 34 (59,65 %)
Stone location
Lower calyx (%) 57 (100 %)
stone size (mm) 12,8 ± 3,4 mm (6,3–20,0)
Average skin-stone distance (mm) 81 mm
Urinary stone density (HU) 688 ± 135 HU (500–1338)
500-1000 45 (78,95%)
> 1000 12 (21,05%)
Technical parameters
Average number of shockwaves delivered 2122,2 ± 246,70 (1700-2750)
Average number of sessions/patients 2,3
Average fluoroscopy time 150 secondes
Average ESWL duration 26 min
Energy (average, J) 1,84 ± 0,23 J (1,35 ± 2,74)

≤ 2 n (%) 38 (66,67%)
> 2. n (%) 19 (33,33%)
Results (stone free) n (%) 54.38 %

The population was divided into two groups according to the anatomy of the lower calyceal group described according to Sampaio's criteria; the group with favorable anatomy comprised 45, 61 % of patients (n= 26/57) and the group with unfavorable anatomy comprised 54,39 % (n= 31/57). (Tables 2 and 3 show the characteristics of intrarenal anatomy)

Table 2: Description of population anatomy according to Sampaio's criteria

	Average value
Stone size (mm) ≤ 10 > 10	12,8 ± 3,4 n=32 n=25
Angle infundibulo-pelvic (degrees °) ≤ 90° >90°	88,25 ± 19,15 n=30 n=27
Length of the stem caliceal lower (mm) ≤ 25 > 25	32,05 ± 10,75 n =25 n =32
Diameter of the stem caliceal lower (mm) ≤ 5 > 5	4,71 ± 1,45 n=28 n=29

Table 3: Anatomy appreciation

Total number of patients: 57	
Favourable anatomy % (n)	Unfavorable anatomy % (n)
45,61% (n=26/57)	54,39 % (n= 31/57)

For technical parameters: the average number of sessions per patient was 2,3 (the majority of patients underwent between one and three ESWL sessions), the average number of shockwaves (delivered) was 2122,2 ± 246,70 with extremes from 1700 to 2750 shockwaves and the average energy was 1,84 ± 0,23 J with extremes from 1,35 J to 2,74 J.

The stone-free after ESWL for both groups combined was 54,38 % (n= 31/57), the rate of use of auxiliary procedures after ESWL for the group with favorable anatomy was 34,61 % (9/26) versus 64,51 % (n=20/31) for the group with unfavorable anatomy. Auxiliary procedures were: ureteroscopy or RIRS. The success rate is 65,23 % for stones smaller than 1 cm and 35,28% for stones greater than or equal to 1 cm (p <0,01).

The success rate is 79,12% when the angle infundibulo-pelvic is greater than or equal to 90°, and 33,13% when the angle is less than 90° (p< 0,001).

The stone-free was 54,26 % and 59,86% respectively for stem diameters of less than 5 mm and greater than or equal to 5 mm. This difference was not significant (p > 0,3).

The stone-free is 73,54% if the length of the calyceal stem is less than 3 cm and 36,47% if the stem is greater than or equal to 3 cm (p<0,001).

Multivariate analysis found that the anatomical factors determining the efficacy of ESWL for lower calyceal calculus were infundibulo-pelvic angle, the most important determinant (p< 0,001), followed by calyceal rod length (p<0,001). The results for stem diameter were not significant.

Table 4: Univariate statistical analysis of ESWL success factors for the treatment of lower stone

	ESWL success story	**ESWL failure**	**P**
Stone size (mm)	8,6 ± 1,7	17 ± 5,1	< 0,0001
Angle infundibulo-pelvic (degrees °)	114,8 ± 18,5	61,7 ± 19,8	< 0,0001
Length of the stem caliceal lower (mm)	21,9 ± 8,9	42,21 ± 12,6	< 0,001
Diameter of the stem caliceal lower (mm)	5,12 ± 1,2	4,3 ± 1,7	0,59

Table 5: Multivariate analysis of LEC success factors for the treatment of lower calyceal stone

	Odds Ratio (OR)	**IC 95%**	**P**

Angle infundibulo-pelvic (degrees °)	3,15	[1,6-5,9]	0,0008
Length of the stem caliceal lower (mm)	2,1	[1,65-4,2]	0,42 (not significant)
Diameter of the stem caliceal lower (mm)	4,5	[3,2-12,9]	0,78 (not significant)

There was no correlation between patient BMI and ESWL results (p = 0.47).

To record complications, we used the Clavien-Dindo reference classification: Two perirenal hematomas (in patients on antiplatelet/anticoagulant therapy) were observed, with a favorable outcome.

<table>
<tr><td colspan="4">57 patients with a lower calciceal group calculation.
38 men and 19 women (22- 68 years)
The median age: 48.5 years,
Antecedents: 14,03 % (n=8) of the patients were taking antiplatelet/anticoagulant drugs, and 8,77% (n= 5) had High blood pressure.
The median size of stone 12,8 ± 3,4 mm (6,3–20,0)</td></tr>
<tr><td colspan="2">Favorable LCG anatomy: 45,61 %</td><td colspan="2">Unfavorable LCG anatomy: 54,39%</td></tr>
<tr><td colspan="4">Stone free after ESWL</td></tr>
<tr><td colspan="2">For favorable anatomy: 62,5%</td><td colspan="2">For unfavorable anatomy:43,56%</td></tr>
<tr><td colspan="4">Auxiliary procedures after ESWL: ureteroscopy or RIRS</td></tr>
<tr><td>No: 65,39%</td><td>Yes: 34,61%</td><td>No: 35,49%</td><td>Yes: 64,53%</td></tr>
</table>

Figure 3: The design of our study

DISCUSSION

The type of lithotriptor, patient characteristics, intrarenal anatomy, size, composition, and, above all, localization of the stones are essential factors in the success of ESWL. Medium and large calculi, measuring less than 15 mm, are preferably and commonly treated by ESWL. However, this is not the case for lower calculi [6]. In instances of lower calcific calculi, it is the elimination, rather than the fragmentation, of the stones after ESWL that is called into question. Generally speaking, the stone-free (SF) for the treatment of lower calyceal calculi by ESWL is estimated at 63%, whereas it is 73%, 69%, 80%, and 88%, respectively, for the upper calyx, middle calyx, pelvis, and pyeloureteral junction.

In a meta-analysis of 2927 patients treated with ESWL, Lingeman *et al*., showed that the stone-free (SF) rate was directly related to stone location and size [7]. The SF was 74% for stones smaller than 10 mm and 56,3% for stones between 10 and 20 mm. These results were validated in a multicenter, prospective, randomized study comparing ESWL and PCNL for the treatment of lower calyceal calculi. Among the 63 patients treated with ESWL, an overall stone free of 37% was achieved, with a retreatment rate of 15,6% and the need for an ancillary procedure in 13,7% of cases. However, the Stone free for stones smaller than 10 mm was 66,7%, compared with 23% for stones between 10 and 20 mm [7].

Consequently, ESWL is strongly recommended as a primary treatment for symptomatic calyceal stones measuring less than 10 mm in diameter. However, the situation becomes less straightforward for lower calyceal calculi ranging from 10 to 20 mm in diameter.

Several authors have demonstrated that intrarenal anatomy can influence the removal of lithiasis fragments following ESWL. Specifically, it is the anatomy of the lower calyx that has often been implicated in ESWL failures.

Sampaio *et al*., reported a stone-free (SF) of 75% after ESWL for inferior calcific calculi with a diameter ranging from 7 to 25 mm when the infundibulopyelic angle exceeded 90 degrees. Conversely, in cases with a more acute angle, less than 90 degrees, the FS dropped to only 23% [3].

Gupta *et al*., also observed a correlation between the infundibulopyelic angle and the stone-free following ESWL, affirming the findings of Sampaio *et al*., They further demonstrated that the SF increased when the length of the lower calyceal rod measured less than 3 cm [4]. Finally, Elbahnasy *et al*., assessed the anatomy of the lower calyx in 15 patients and its impact on the SF after ESWL for calculi smaller than 15 mm. They identified three adverse factors-infundibulopelvic angle (< 90 degrees), width (< 5 mm), and length (> 3 cm) of the lower calyceal stalk-that independently affected the SF rate [8].

Conversely, Moody *et al*., found no correlation between the stone-free after ESWL and the anatomy of lower calyceal calculi [9]. A prospective multicenter study is, therefore, still needed to validate these anatomical criteria.

The efficacy of ESWL is also influenced by the composition of the stones. Graff *et al*., reported stone-free of 81% and 83%, respectively, for uric acid and calcium oxalate dihydrate stones [10, 11]. However, the same cannot be said for cystine, brushite, or calcium oxalate monohydrate stones. Several authors do not recommend ESWL as the first-line treatment for these types of calculi if their size exceeds 10 mm, particularly in lower calyceal situations [10-13].

Finally, the safety profile of ESWL supports its use as a first-line procedure. Complications associated with ESWL for calculi smaller than 15 mm are rare, estimated at less than 5% [14]. Kim *et al*., reported a ureteral impaction rate of less than 0.3% after treating calculi less than 10 mm with LT01 lithotripters, and 6.2% in the case of calculi between 10 and 20 mm [15]. Hemorrhagic complications after ESWL are exceptionally rare, with the rate of perirenal hematoma estimated between 0.1 and 0.66% [14-17].

Conclusion

ESWL can serve as an initial treatment for LCG calculi, but careful consideration of the indication is recommended, taking into account factors predictive of success in treating an lower calyceal calculus, especially considering the lower calyceal anatomy (the use of ancillary procedures is high in cases of unfavorable anatomy).

Despite the relative simplicity of ESWL and its low morbidity, the indication for the treatment of an inferior calcific calculus must be carefully considered, taking into account predictive factors for success. A highly dense calculus, reaching or exceeding 1 cm in diameter, with unfavorable anatomical factors, could be promptly treated by percutaneous nephrolithotomy.

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