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Pelvicalyceal stone load: a factor affecting the outcome of extracorporeal shockwave lithotripsy for renal pelvic calculi

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Objectives To determine the effect of variations in pelvicalyceal volume on the results of extracorporeal shock wave lithotripsy (ESWL) and the relationship of stone load to estimated pelvicalyceal volume in patients with renal pelvic stones.

Patients and methods In all, 204 patients with renal pelvic stones were treated primarily by ESWL. Exclusion criteria were radiolucent stones, dilatation of the renal collecting system, JJ stent insertion before ESWL and an inadequate follow-up. The surface area of the stones and the renal collecting system were measured using a grid of 1 mm^2 divisions. The pelvicalyceal volume was calculated as 0.6 $(area)^{1.27}$. To evaluate the treatment results a pelvicalyceal stone load (PSL) index, describing the relationship of stone load to total estimated pelvicalyceal volume, was defined as stone volume/renal collecting system volume.

Results The mean (range) pelvicalyceal volume of the patients was 13.24 (4.12–28.47) mm^3 and the mean PSL index was 26.2%. The cumulative success rates according to the PSL decreased from 97% to 90% with increasing PSL, but remained at $>95\%$ in patients with a PSL index of $<50\%$. In all, 184 sessions were applied and the session/patient ratio increased from 1.41 to 3.0 with increasing PSL. Complications were acute pyelonephritis in three and steinstrasse in five patients.

Conclusion The PSL index appears to be a more accurate and reproducible method for predicting the outcome of ESWL, and has the advantage of considering the effect of pelvicalyceal anatomy.

Keywords extracorporeal shock wave lithotripsy, renal stones, pelvicalyceal volume

Introduction

After its clinical introduction by Chaussy *et al.* [1] in 1980, ESWL has become the treatment of choice for most symptomatic urinary tract calculi [2–4]. The success of ESWL therapy depends on many factors, including stone location, stone composition, the shock wave generator and the presence of obstruction or infection. However, stone size seems to be the most important factor affecting treatment outcome. Although there is no consensus about a threshold size to distinguish whether the stone is appropriate for ESWL or not, the general opinion favours the treatment of renal stones that are $\leqslant 2$ cm in diameter [5]. A review of the published results of ESWL for kidney stones of $\leqslant 2$ cm shows stone-free rates of 48–99% [3–7]. However, stone surface area is another option by which to evaluate treatment success, and recent reports suggest that the success rate can be up to 92% if the stone surface area is $<500\ mm^2$, even if they are staghorn stones [8]. However, estimating stone load with these methods is of limited value, as patients have different intrarenal anatomy and pelvicalyceal volume. Stones in a small or narrow pelvis may have an inadequate water-stone interface or 'expansion chamber', while a relatively larger stone can float in a large intrarenal collecting system. Although collecting system dilatation been confirmed to affect success rates [8] there is insufficient information about the role of normal variations in pelvicalyceal volume in patients with unobstructive renal pelvic stones.

In the present study, we analysed the success rates of ESWL considering the pelvicalyceal stone load (PSL) in patients with kidney stones in an undilated renal pelvis. The PSL was defined as the total volume of stones in the pelvis and calyces of the affected kidney, and a PSL index was devised to express the total stone volume to pelvicalyceal volume measured from IVU and calculated as described previously [9], to address the effectiveness of ESWL. Higher values of the PSL index reflect either a large stone burden in a small pelvis or a relatively small stone burden in a large pelvicalyceal volume. The aim was to determine the relationship of these two entities and its role in the outcome of ESWL.

Patients and method

Between July 1996 and September 1998, 204 patients with renal pelvic stones were treated primarily by *in situ*

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ESWL (Lithostar Plus, Siemens, Germany); 109 patients (79 men and 30 women) were included in the study after excluding 10 patients with radiolucent stones, 56 with mild to severe dilatation of the renal collecting system, 11 with an inadequate follow-up and 18 who had a JJ stent placed before ESWL. The mean (range) age of the patients included was 41.7 (22–69) years. All patients were evaluated with a plain and lateral abdominal film, IVU, urine culture and sensitivity testing, with renal ultrasonography and retrograde pyelography or CT if needed.

All patients were treated as outpatients and received no anaesthesia. The stones were located fluoroscopically; the maximum and mean (range) shock wave energy and number of shock waves delivered per session were 19 (17.4–19, 18.4) kV and 4000 (2200–4000, 3345), respectively. Patients in whom the stones were insufficiently disintegrated underwent repeated sessions of ESWL; a total of 184 ESWL sessions were delivered. Patients were evaluated with a plain abdominal film or ultrasonography immediately after ESWL, and IVU in the third month. Treatment was considered successful if the IVU showed complete stone clearance or sufficient stone disintegration (residual fragments of $\leqslant 3$ mm).

The surface area of the stones and the renal collecting system were measured using a 1 mm^2 grid, on which the borders and diameters of the stones and pelvicalyceal system were marked from the IVU. The surface area and the diameters of the stone and renal collecting system were then calculated by counting the enclosed grid squares, with estimates obtained by three of the study members; the mean of these three measurements was calculated, with the variability for the same area being $<5\%$.

The pelvicalyceal volume was calculated as $0.6\,(\text{area})^{1.27}$ [9], and the stone volume calculated as $4/3\pi \times r1 \times r2 \times r3$, where the three radii of the stones were measured from the plain abdominal and lateral films. A PSL index describing the relationship of stone load to total estimated pelvicalyceal volume was defined as (total pelvicalyceal stone volume/total pelvicalyceal volume) $\times 100$.

Results

The overall stone-free and success rates were 62% and 90%, respectively. Patients were divided into subgroups according to the PSL index and stone surface area (Table 1). The cumulative success rates with PSL decreased from 97% to 90% with increasing PSL index (Fig. 1). The mean (range) pelvicalyceal volume was 13.24 (4.12–28.47) mm^3; only three patients had a volume of <5 mm^3 (30 had 5.1–10, 42 had 10.1–15, 21 had 15.1–20, nine had 20.1–25 and four had >25 mm^3). The mean PSL and stone surface area were 26.2% and 223.3 mm^3, respectively. Of the 109 patients included in the study, 56 (51%) required one ESWL session, 30 (28%) required two and 23 (21%) required three (Table 2). The session/patient ratio increased from 1.41 to 3 with increasing PSL.

Table 1 Treatment results according to PSL and stone surface area

PSL or area	*No. of patients*	*Stone-free, n (%)*	*Fragmentation, n (%)*	
			successful	*unsuccessful*
PSL, %				
⩽10	39	25 (64)	38 (97)	1 (3)
10.1–20	23	15 (65)	22 (96)	1 (4)
20.1–30	11	7	11	0
30.1–40	8	6	7	1
40.1–50	10	7	9	1
50.1–60	5	3	3	2
60.1–70	6	3	4	2
70.1–80	4	1	3	1
>80	3	1	1	2
Stone surface area, mm^2				
0–99	15	10	15	0
100–199	42	28 (67)	40 (95)	2 (5)
200–299	18	10 (56)	16 (89)	2 (11)
300–399	17	11 (65)	14 (82)	3 (18)
400–499	12	6	9	3
>500	5	2	4	1
Total	109	68 (62)	98 (90)	11 (10)

There were no major complications but acute pyelonephritis occurred in three (3%) of the patients and steinstrasse in five (4.5%); the latter complication was managed conservatively in two patients while two underwent additional ESWL sessions to the steinstrasse and one underwent ureteroscopy.

Discussion

For success with ESWL, stone diameter is one of the most important criteria and success rates in urological practice are usually compared by considering stone size. However, there is no consensus about how to determine stone size or on a threshold size to distinguish whether the stone is appropriate for ESWL or percutaneous nephrolithotomy (PCNL). For renal calculi of >3 cm (greatest diameter) PCNL has more chance of success and a lower rate of auxiliary procedures [7]; stones of 2–3 cm are also candidates for PCNL, with higher stone-free rates than ESWL (90% vs 43%) [7]. Therefore PCNL is generally preferred in patients with stones of >2 cm. Stones of <2 cm can best be managed by ESWL primarily, with stone-free rates of 48–99% [3–7]. However, evaluating success rates by stone size alone can cause problems, as the intrarenal anatomy can vary widely [10,11]. Although stone surface area correlates closely with stone burden, the

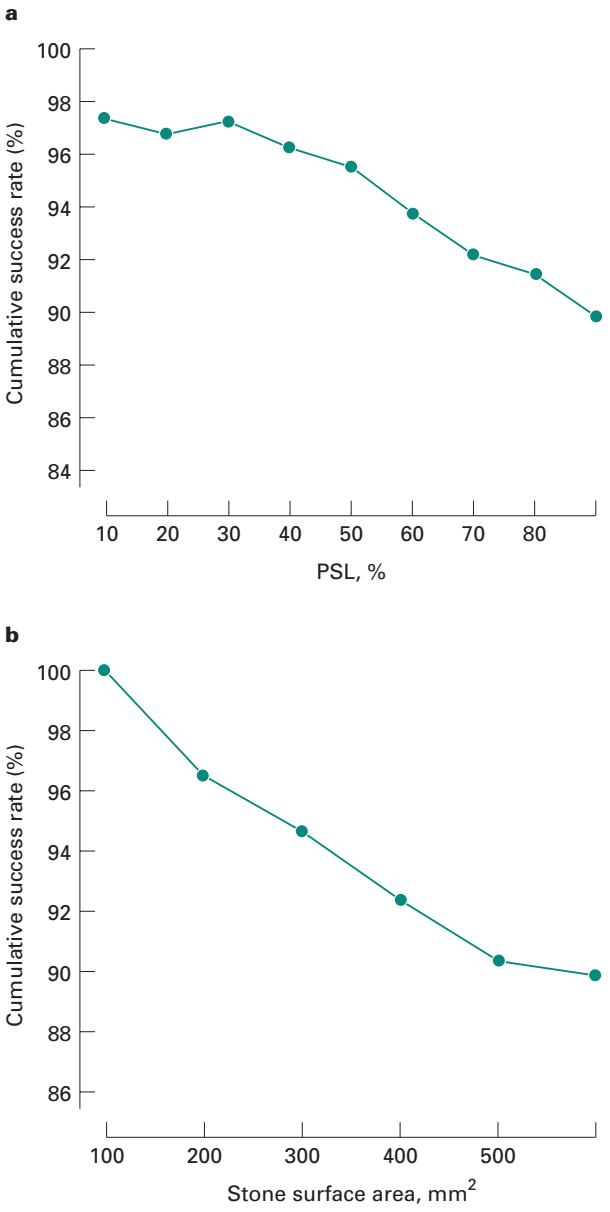


Fig. 1. The cumulative success rates according to **a,** the PSL index and **b,** the stone surface area.

volume of the pelvis and calyces may be important for success, necessitating a definition including both stone and pelvicalyceal volumes. Thus in the present study we devised the PSL index and compared this index with conventional methods of assessing the outcome of ESWL.

In assessing stone surface area, stone volume and pelvicalyceal volume accurate measurements are important; there are three methods available for measuring stone surface area, of which computer image analysis was the most accurate [12]. However, the grid method used in the present study is the cheapest and easiest, giving reasonable results with a variability on multiple

Table 2 Re-treatments and session/patient ratio according to PSL

	No. of ESWL sessions				
PSL, %	*1*	*2*	*3*	*Total*	*Sessions/patient*
⩽10	28	6	5	55	1.41
10–20	15	5	3	34	1.48
20–30	7	2	2	17	1.55
30–40	2	6	–	14	1.75
40–50	2	6	2	20	2
50–60	1	1	3	12	2.4
60–70	1	2	3	14	2.33
70–80	–	2	2	10	2.5
>80	–	–	3	8	3
Total	56	30	23	184	1.69

measurements of the same area of <5%. However, the pelvicalyceal volume was calculated by computer using the total area of the renal pelves and calyces measured from IVU. This method was used previously to assess renal function and the success of endopyelotomy for PUJ obstruction [9,13]. The present results showed that there was a wide variation in pelvicalyceal volume; however, pelvicalyceal volume depends on both renal pelvic and calyceal volume. A kidney may have a large extrarenal pelvis with small calyceal volumes, whereas another may have a very narrow pelvis with large calyceal volumes. Thus although the pelvicalyceal volume apparently has an effect on ESWL results, the separate evaluation of pelvic and calyceal volumes may provide more accurate results. Unfortunately this approach causes measurement and calculation problems and is the subject of another study. Residual fragments migrating into the calyces after ESWL may be affected by these volume variations; large or dilated calyces can act as a trap for small fragments. However, there were no detectable differences in residual fragments in patients with large or small calyceal volumes; thus, although fragments can move into large calyces after ESWL, they can easily migrate to the renal pelvis after the passage is cleared.

For ESWL, the cumulative success rate declined with increasing conventional stone surface area and PSL, as expected (Fig. 1). However, while the success rates were >95% in patients with a PSL index of <50%, there was a steady decrease when evaluated only with stone surface area. This trend cannot be confirmed statistically, because there were too few patients in each category to calculate a meaningful percentage. However, PSL index appears to be of more practical value. While a stone in a large collecting system may have an adequate water-stone interface, the same stone in a relatively small or narrow pelvis may not.

A higher PSL index reflects either a large stone burden in a small pelvis or a relatively small stone burden in a large pelvicalyceal volume. Thus lower success rates in patients with a high PSL index may depend on either a large stone burden or a small pelvicalyceal volume, or both. However, from the re-treatment rates and session/patient ratio, the PSL index is more reliable; an increasing index results in a higher session/patient ratio, with a PSL index of $< 50\%$ giving a session/patient ratio of $\leqslant 2$, but reaching a ratio of 3 at the highest PSL.

In conclusion, the PSL index appears to be a more accurate and reproducible method for predicting the outcome of ESWL, with the advantage of considering the effect of pelvicalyceal anatomy and volume on success rates. Although there are limitations and difficulties in calculating this index, especially in patients with radiolucent stones and severe hydronephrosis, it may help to decide on treatment options for larger renal pelvic calculi which could be candidates for both ESWL or PCNL. However, a longer follow-up with more patients is essential to confirm the utility of this method.

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Abbreviations: **PSL**, pelvicalyceal stone load; **PCNL**, percutaneous nephrolithotomy.