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INFUNDIBULOPELVIC ANATOMY AND CLEARANCE OF INFERIOR CALICEAL CALCULI WITH SHOCK WAVE LITHOTRIPSY

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ABSTRACT

Purpose: We evaluate the significance of inferior caliceal radiographic anatomy and determine its influence on successful fragmentation and clearance of inferior caliceal calculi with extracorporeal shock wave lithotripsy (ESWL*).

Materials and Methods: Between November 1996 and February 1998, 88 patients and 90 renal units with single or multiple inferior caliceal calculi of all sizes and composition were treated with ESWL. The size, number and area of calculi, length and width of the stone bearing inferior calix and infundibulopelvic angle were determined on pretreatment excretory urography. The infundibulopelvic angle was measured by 2 methods using the angle between the inferior caliceal infundibular and ureteral axes (angle 1), and between the infundibular and ureteropelvic axes (angle 2). Cases with residual fragments not clearing within 6 months of satisfactory fragmentation after lithotripsy were considered failures.

Results: Overall stone clearance at 6 months was achieved in about 72% of the renal units. Infundibular length was 30 mm. or less in 77% of successful cases and in 64% of failures. Similarly, the smallest infundibular width of 5 mm. or more was found in 75% of successful cases compared to 41% of failures. Angle 1 of 35 degrees or more was observed in 73% of cases with compared to 18% without clearance. Angle 2 of 45 degrees or more was seen in 71% of successful cases compared to 9% of failures. The chances of a patient becoming stone-free with all favorable criteria of infundibular length 30 mm. or less, infundibular width 5 mm. or greater and infundibular ureteropelvic angle 45 degrees or greater was 100% (23 patients).

Conclusions: Radiographic features of a stone bearing inferior calix and its relation to the renal pelvis can be easily measured on standard excretory urography. An infundibular width of 5 mm. or more and infundibulopelvic angle 1 of 35 degrees or more or angle 2 of 45 degrees or more were statistically significant factors of radiographic anatomy in stone clearance following ESWL. Inferior caliceal length was not statistically significant, although length of 30 mm. or less appeared to be more favorable for stone clearance. The ideal treatment of inferior caliceal calculi in patients with all 3 favorable criteria is ESWL.

KEY WORDS: lithotripsy, calculi

Extracorporeal shock wave lithotripsy (ESWL) is the dominant treatment modality for almost all urinary calculi. The key factor is the satisfactory fragmentation of calculi that can then pass spontaneously. However, the clearance rate of lower pole caliceal calculi has been uniformly low compared to that of calculi elsewhere.[1–9] The dependent position of the inferior calix, and its spatial anatomy and relationship to the renal pelvis appear to be significant factors in retention of residual fragments and, therefore, poor results of ESWL.[10–14] Retention of residual fragments in the lower pole calices was noted to be a major problem with ESWL not only for stones originally in the lower calices, but also when fragments of stones elsewhere migrated there.[4] Caliceal anatomy of the lower pole and its possible impact on stone clearance with ESWL were first described by Sampaio and Aragao,[13, 14] and subsequently others demonstrated its significance.[10, 15] Elbahnasy et al measured radiographic anatomical features in a well defined manner to establish the significance of its influence on the clearance of inferior caliceal calculi following ESWL or ureteroscopy.[10] Stone clearance has been shown to be poorer for an acutely angled than an obtusely angled inferior calix, and better for a shorter calix with a wider than a longer calix with a narrower infundibulum. We determine, verify and define how these factors influence successful fragmentation and clearance of calculi from inferior calices.

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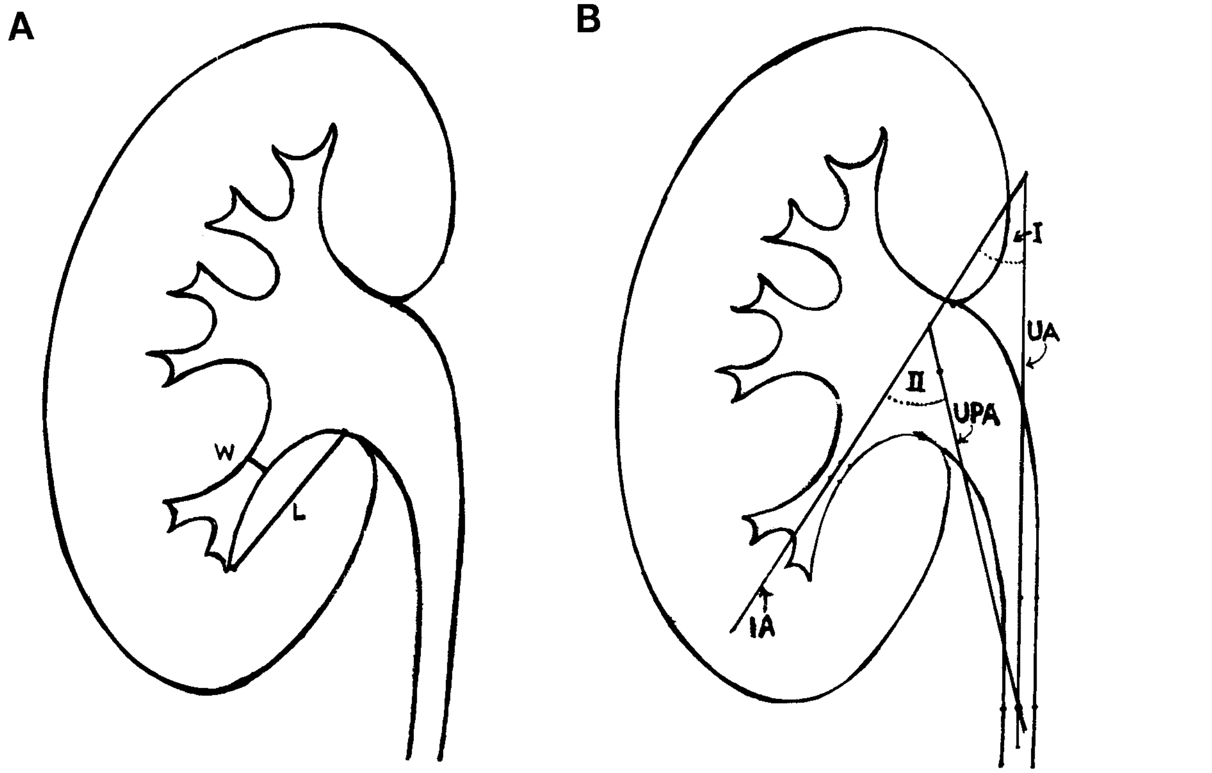
MATERIALS AND METHODS

Between November 1996 and February 1998, 88 patients with inferior caliceal calculi in 90 renal units (2 with bilateral stones) were treated with ESWL using sedation. Stone parameters were determined on plain abdominal x-ray, and radiographic anatomy of the inferior calix, pelvis and ureter was evaluated on pretreatment excretory urography. Patients with inferior caliceal calculi only were included, and those with history of recurrent or residual calculi following surgery were excluded from analysis.

Stone parameters included number, size (maximum diameter) and area of stones. Area was calculated by multiplying the maximum diameter (length) with the next maximum (width) dimension perpendicular to the maximum diameter as seen on plain abdominal x-ray. Inferior caliceal anatomy parameters included length, width and infundibular ureteropelvic angle. The length of the calix was measured from the most distal point to the midpoint of the lower cortical lip at the renal sinus. The width was measured at the narrowest point of the infundibulum (fig. 1). The infundibular ureteropelvic angle was measured by 2 methods using the angles



A, method of measuring caliceal length (*L*) and width (*W*). *B*, method of measuring angles. *IA*, infundibular axis. *UA*, ureteral axis. *UPA*, ureteropelvic axis. *I*, angle 1. *II*, angle 2.

subtended by the infundibular axis on the ureteral axis (angle 1), and between the infundibular and ureteropelvic axes (angle 2). The ureteropelvic axis was drawn by joining the midpoint of the renal pelvis at the renal sinus between the upper and lower cortical lips, and the ureteral axis was drawn at the level of the lower pole of the kidney (fig. 2).

Patients underwent 1 session of 3,000 to 4,000 shocks with a maximum energy level of 3 to 4 to achieve successful fragmentation of stone(s), and some underwent multiple sessions to achieve satisfactory results. In most patients an in situ procedure was performed, while a few required a ureteral stent before the procedure. Inversion therapy was used in 3 cases.[16] Patients were followed and assessed for stone fragmentation and clearance by plain abdominal x-rays on days 1 and 14, and 3 and 6 months after treatment. They were advised to consume 3 to 4 l. per day and to collect fragments by passing urine through a plastic strainer. Patients routinely received antibiotics and analgesics for 3 days after treatment.

The significance of patient age and sex, stone side, size and area, and length, width and angle factors of inferior caliceal anatomy versus stone clearance were evaluated and statistically analyzed. The categorical variables of patient sex and side of the stone versus stone clearance were analyzed using the Pearson chi-square test. The size and area of the stone, and length, width and angle factors of the inferior caliceal anatomy versus stone clearance were analyzed using the Student t or Wilcoxon rank sum test depending on the distribution of data. Logistic regression was applied to determine the predictors of stone clearance. Data were analyzed using statistical software, with $p < 0.05$ considered statistically significant.

RESULTS

A total of 88 patients and 90 renal units, including 2 patients with bilateral renal stones, were treated for inferior caliceal calculi with ESWL. The 62 men and 26 women were 22 to 67 and 22 to 60 years old, respectively. Of the patients 2 who had undergone open surgery previously and had residual or recurrent calculi, and 2 with poor stone fragmentation were excluded from study. After lithotripsy 1 patient with a solitary kidney died of acute infection and septicemia. There were 7 patients lost to followup. Thus, 12 renal units of 90 were excluded from analysis of stone clearance. Ureteral stenting was done as an auxiliary procedure before ESWL in 11 cases and between treatments in 1. The number of stones in each renal unit varied from 1 to 4, and 15 units had 2 or more. Stones ranged from 5 to 30 mm., and the area per calix ranged from 20 to 450 mm.^{2}. Of the 78 renal units analyzed 56 (about 72%) had stone clearance 6 months after treatment. Statistical analyses of parameters of stones and inferior caliceal anatomy versus clearance are shown in the table.

The calix was 30 mm. or less in 77% of renal units with stone clearance compared to 64% of failures, and the caliceal width was 5 mm. or more in 75% and 41%, respectively. Angle 1 was more than 45 degrees in 73% of treatment successes compared to 18.2% of failures. Similarly, angle 2 was 45 degrees or more in 71% of treatment successes compared to only 9% of failures. The infundibulopelvic angle was the most significant factor ($p < 0.00001$), followed by infundibular width ($p < 0.0048$). The length of the calix, and stone size and area were not statistically significant for stone clearance. However, 77% of patients with clearance had a caliceal length of 30 mm. or less compared to 64% of failures. The chances of a patient becoming stone-free with all 3 favorable criteria of infundibular length 30 mm. or less, infundibular width 5 mm. or greater and infundibular ureteropelvic angle 45 degrees or greater was 100% (23 patients). Only 1 of 4 cases with all unfavorable criteria had stone clearance. The chance of becoming stone-free was 100% (33 cases) with angle 2 of 45 degrees or greater and width 5 mm. or greater, and 96.8% (30 of 31) with angle 2 of 45 degrees or greater and length 30 mm. or less. The predominant stone composition

Statistical analysis of variables in clearance of inferior caliceal calculi following ESWL

Variables	Clearance		Failure		p Value	Unadjusted Odds Ratio (95% CI)
No. men (%)	39	(70)	17	(30)	0.5	1.48 (0.47–4.67)
No. women (%)	17	(78)	5	(22)		
No. stone side (%):						
Rt.	31	(78)	9	(22)	0.25	0.56 (0.20–1.52)
Lt.	25	(66)	13	(34)		
Mean mm. stone size (SD)	13.88	(5.66)	14.36	(3.71)	0.34	0.98 (0.89–1.07)
Mean mm.^{2} stone area (SD)	131.5	(91.0)	156.86	(79.22)	0.09	0.996 (0.99–1.00)
Mean mm. calix length (SD)	27.02	(6.34)	29.00	(4.92)	0.19	0.95 (0.87–1.03)
Mean mm. calix width (SD)	6.75	(2.71)	4.82	(2.58)	0.0048	1.34 (1.08–1.66)*
Mean degrees angle 1 (SD)	43.41	(14.21)	26.36	(12.07)	0.00001	1.14 (1.07–1.22)
Mean degrees angle 2 (SD)	51.68	(13.15)	31.82	(11.17)	0.00001	1.19 (1.09–1.29)†

* Adjusted odds ratio was 1.16 (0.86 to 1.56).
† Adjusted odds ratio was 1.19 (1.09 to 1.29).

was calcium oxalate monohydrate as determined on x-ray diffraction crystallography.

DISCUSSION

Inferior caliceal calculi have a low clearance rate following ESWL compared to calculi elsewhere in the pelvicaliceal system. Others have reported a stone clearance rate from 41% to 79%.[1–9] We noted an overall stone clearance rate of 72% in 56 of 78 units. A total of 15 units (19%) had 2 to 4 calculi. Stone size varied from 5 to 30 mm., with 24 (31%) up to 10, 45 (58%) 11 to 20 and 9 (11%) 20 to 30 mm. The stone-free rate was 72.1% for calculi up to 10, 51.3% for those 11 to 20 and 38.7% for those more than 20 mm.[9] Others have reported a stone clearance rate of only 54% for stones 1 cm. or less in largest diameter.[10] In our study stone clearance was 88%, 62% and 78% for stones up to 10, 11 to 20 and 20 to 30 mm., respectively. Similarly the area of the stones ranged from 20 to 450 mm.^{2}, with 31 (40%) up to 100, 34 (44%) 101 to 200, 9 (11%) 201 to 300 and 4 (5%) more than 300 mm.^{2}. The respective stone clearance rates for these categories were approximately 84%, 62%, 66% and 75%. In our cases size and areas of stone were not statistically significant (p = 0.34 and 0.09, respectively).

The anatomy of the calices and its role in the treatment of inferior caliceal calculi with ESWL or endoscopy have been reported by others.[11–14] The length of the calix ranged from 15 to 55 mm. in our patients with stone clearance, compared to 20 to 40 mm. in those with treatment failure. Of the patients 77% with caliceal lengths up to 30 mm. were stone-free compared to 64% with a length of more than 30 mm. However, the length of the calix was not a significant factor for clearance (p = 0.19). Mean width of the inferior calix was 6.75 mm. in patients with stone clearance compared to 4.82 mm. in those with treatment failure (see table). Statistical analysis revealed that width was a significant factor for stone clearance (p = 0.0048). Caliceal width was 5 mm. or more in 75% of stone-free cases compared to 41% of failures. Of the patients with a caliceal width of 5 mm. or more 82% had clearance compared to 52% with a width of 4 mm. or less.

An angle of more than 90 degrees between the lower infundibulum and renal pelvis has been reported in 74% of cases with assessment of resin casts of the pelvicaliceal system.[13] In 1 study a pelvicaliceal angle of more than 90 degrees was found in 36% of cases.[15] In another study an infundibular ureteropelvic angle of 90 degrees or more was found in only 12% of cases.[10] We measured the angle in 2 ways, and infundibulopelvic angle 1 ranged from 15 to 95 and angle 2 ranged from 10 to 95 degrees. Only 1 of our cases had an angle of more than 90 degrees. Our infundibular ureteropelvic angle findings are noticeably different from others. The reason for this discrepancy in some reports was due to the difference in the methodology of measurement of the angle.[10,15] In those studies the infundibulopelvic angle was the angle subtended by the infundibular and renal pelvic axes, and not the ureteropelvic axis as in our study. Others have found the angle to be obtuse in a larger percentage of cases. Means of angles 1 and 2 were approximately 39 and 46 degrees overall, respectively, 43 and 52, respectively, in patients who became stone-free, and 26 and 36, respectively, in those with treatment failure. Infundibulopelvic angle 1 was 35 degrees or more in 73% of treatment successes compared to only 18% of failures. There was a strong association (p = 0.00001) between the angle and rate of stone clearance. Angle 2 was 45 degrees or more in 71% of cases with compared to only 9% of those without clearance, which was also statistically significant (p = 0.00001). Logistic regression analysis of factors that were significant with univariate analysis revealed angle 2 to be the most significant with a higher adjusted odds ratio of 1.17 (table 1). While others noted poorer stone clearance with an acutely angled compared to an obtusely angled inferior calix, almost all of our cases had acute angle, angle 1 of 35 degrees or less and angle 2 of 45 degrees or less associated with poor stone clearance.

The unfavorable factors of inferior caliceal anatomy inherent in its position and angulation are responsible for a poorer stone-free rate following ESWL. Different adjunctive treatment modalities to achieve better clearance of stone fragments have been suggested.[4] Forced diuresis, inversion therapy, a cobra catheter for direct irrigation of the stone containing inferior calix and percutaneous irrigation have been used to enhance clearance.[16–18] In 1 study inversion therapy was a safe and beneficial adjunctive treatment for inferior caliceal fragments after ESWL, while others did not find it useful to improve the results of ESWL for these calculi.[16,19] In our 3 cases inversion therapy appeared to be beneficial. However, its usefulness cannot be categorically stated as we did not perform a controlled trial of this procedure. Our cases with all favorable criteria of infundibular length 30 mm. or less, infundibular width 5 mm. or greater and an angle 2 of 45 degrees or greater had 100% stone clearance.

CONCLUSIONS

Our study revealed that inferior caliceal infundibulopelvic anatomy has a significant role in determining the stone-free rate following satisfactory fragmentation of stone with ESWL. Various factors of renal anatomy can be easily measured on standard excretory urography. Infundibulopelvic angle 1 of more than 35 or angle 2 of more than 45 degrees, and an infundibular width of more than 5 mm. are statistically significant factors associated with stone clearance. Our infundibulopelvic angle findings are different from those of others. Although the length of the calix was not statistically significant, it appeared to be associated with a more favorable outcome when it was 30 mm. or less. Thus, using these radiographic parameters ESWL can be selected as a treatment modality for a predictably favorable outcome in individual cases.

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