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Renal anatomical factors for the lower calyceal stone formation

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Abstract. *Purpose:* The pathogenesis of urolithiasis is mainly explained with metabolic disorders. However metabolic disorders alone are not sufficient to explain this pathology. In the present study the anatomical differences in the lower calyceal stone formers were examined on both the stone forming and contralateral normal side. The objective was to assess the effect of lower pole renal anatomy on the lower calyceal stone formation. *Materials and Methods:* Between July 1999 and July 2004 39 patients with non-obstructed solitary lower pole stones were studied. Mean age was *47.02* years. The anatomic factors were determined on intravenous urograms (IVU). The renal length and width and the number of major and minor calices were noted. Lower pole infundibular calyceal length (ICL) and width (IW), lower infundibular length-to-width ratio were measured. The infundibulo-ureteropelvic angle (IUPA) was measured by two methods using the angle between infundibular and ureteral axes (IUPA-1), and between infundibular and ureteropelvic axes (IUPA-2). We examined a new parameter: Renal longitudinal axis-infundibulum angle (RIA) for renal stone formation. RIA was determined between two axes, including the axis connecting the central point of the pelvis opposite the margins of inferior and superior renal sinus to midpoint of renal axis and the longitudinal renal axis (Figure 2). The data of the stone forming and non-stone forming contralateral side were compared. Statistical analysis was performed by paired-*t*-test. *Results:* The IUPA-1 of the stone forming side was more acute than the non-stone forming side, in 77% of cases. The UIPA-2 of the stone forming side was more acute than the non-stone forming side, in 72% of cases. The differences with both methods between the stone forming and contralateral normal side were statistically significant ($p < 0.05$). Mean ICL of stone forming side was *30.20 mm* whereas it was *25.51 mm* in non-stone forming contralateral side. The difference between mean ICL values was statistically significant ($p < 0.05$). The mean infundibular length-to-width ratio was 8.55 ± 3.25 on the stone forming side and 7.09 ± 2.90 on the non-stone forming contralateral side. The difference between two groups was statistically significant ($p < 0.05$). The differences in RIA, infundibular width (IW), renal length, renal width and the number of major and minor calyces between stone forming and non-stone forming contralateral side were not statistically significant. *Conclusion:* Anatomical disorders of lower pole collecting system may be considered as factors contributing to stone formation. IUPA (1 and 2), ICL and ICL-to-IW ratio are significantly differing factors that might predispose to lower calyceal stone formation.

Key words: Anatomy, Inferior calyx, Kidney, Stone formation

Introduction

Many studies confirm that the radiographic anatomy of the lower calyceal system has a significant role in the stone clearance with extracorporeal shock wave lithotripsy (ESWL). The ESWL is a first choice therapy for the lower pole stones [1]. An acute infundibulopelvic angle, a narrow infundibular neck and long infundibular length of inferior calyx are described as significant unfavourable factors for stone clearance [2–5]. These unfavourable factors might play a role in the stone formation as well.

There are extrinsic and intrinsic etiological factors for stone formation and they are same for both kidneys. But unilateral stone formation occurs more frequently [6]. The crystal density and anatomical structure of the renal collecting system that reduces the rate of urine flow are factors that could influence the stone formation [7]. In a recent publication the anatomy of the renal fornices was studied by microdissection. It was found that, secondary urinary dead spaces were in the fornices of compound papillae only, which were located at the poles of the kidneys. The authors correlated this feature with a higher prevalence of stones in these areas at the time of lithotripsy [8]. So the lower pole collecting system anatomy becomes an important factor in stone formation.

In our study we investigated the anatomical parameters that might affect stone formation frequency in the inferior calyceal system in both the stone forming and non-stone forming contralateral side.

Material and methods

We studied 39 consecutive cases (25 men and 14 women) with non-obstructed unilateral single lower pole stone detected by IVU between July 1999 and September 2004. There are 25 male and 14 female patients 25–72 years old (Median patient age was 47.02 ± 11.90 years). All patients had a medium body habitus and all stones were radiopaque. Stone area (length×width) was measured from a normal plain film of the abdomen. IVU was performed from a distance of 1 m without ureteral compression. Patients were also evaluated with renal ultrasonography (Shimadzu SDU 2200), urine analysis and serum biochemistry. Patients with abnormal renal anatomy (bifid pelvis, pelvic malrotation, duplex or horseshoe kidney), previous renal surgery, pyelonephritic changes, severe hydronephrosis and cases with stent placement were excluded from the study.

The anatomy of the lower pole collecting system and kidney was analysed using measurements on IVU. The renal length and width and the number of major and minor calices were noted. The renal length was measured between the top and bottom points of the kidney and the renal width between the most lateral point and most medial point opposite the renal pelvis (Figure 1). The infundibular calyceal length (ICL) was measured from the most distal point at the bottom of the infundibulum to the midpoint of the lower lip of the renal pelvis and the infundibular width (IW) was measured at the narrowest point along the lower pole infundibular axis as described by Elbahnasy et al. [2] (Figure 1). The infundibulo-ureteropelvic angle (IUPA) was measured by two methods using the angle between infundibular and ureteral axes (UIPA-1), and between infundibular and ureteropelvic axes (IUPA-2). UIPA-1 is measured between vertical ureteral axis and infundibular axis as described initially by Bagley and Rittenberg [9]. IUPA-2 is measured between infundibular and ureteropelvic axes as described by Elbahnasy et al. [2] (Figure 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 to the central point of ureter at the level of the lower kidney pole. In our study we examined a new parameter, that we think may play a role in the pelvicalyceal drainage. The renal longitudinal axis–infundibulum angle (RIA) was determined between two axes, including the axis connecting the central point of the pelvis opposite the margins of inferior and superior renal sinus to midpoint of longitudinal renal axis and the longitudinal renal axis (Figure 2).

The data of the stone forming and non-stone forming contralateral side were compared. Statistical significance for each anatomical factor was evaluated by paired-*t*-test. Data were analysed using statistical software (SPSS 10.0 version), with $p < 0.05$ considered statistically significant.

Results

Twenty two patients had left side stone (56%) while 17 had right one (44%). In the group with calculous kidney, the mean stone area was $53.64 \pm 36.22\ cm^2$ ($10–156\ cm^2$). The IUPA-1 of the stone forming side ranged from 20 to 74° (mean: $41.43 \pm 13.46°$) and non-stone forming side ranged from 21 to 77° (mean: $49.20 \pm 11.83°$). The difference between the groups was statistically significant ($p < 0.05$). The IUPA-1 of the stone forming side was more acute than the one of the non-stone forming side in 77% of cases and more obtuse in 33% of cases. This angle was less than or equal to 45° in 64% of cases on the stone forming side and

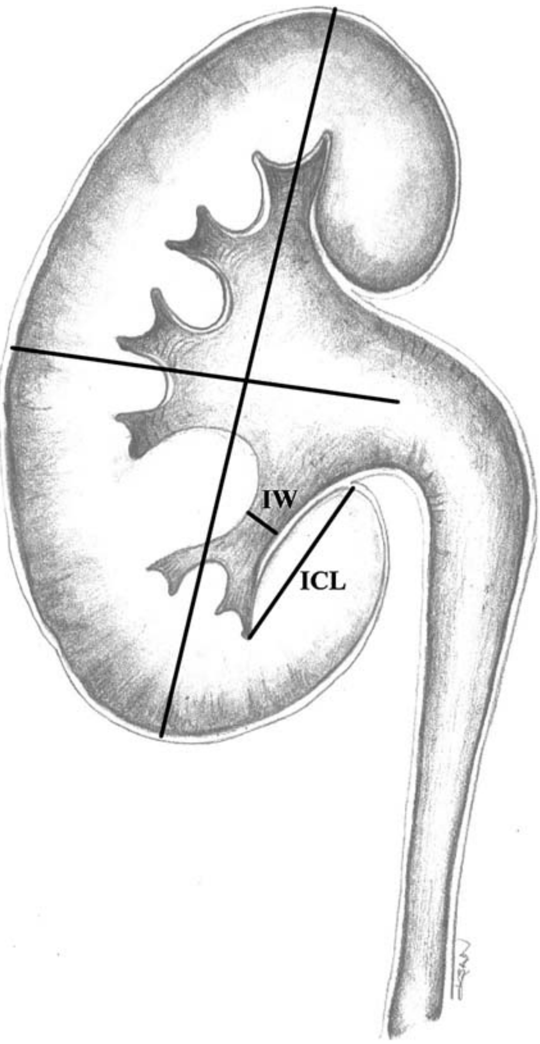

Figure 1. Method of measurıng lower pole infundibular calyceal length (ICL), infundibular width (IW) and renal length and width.

more than or equal to 45° in 56% of cases on the non-stone forming side (Table 1). The IUPA-2 of the stone forming side ranged from 29° to 115° (mean: 55.33 ± 21.06°) and non-stone forming side ranged from 32° to 120° (mean: 62.51 ± 20.65°). The difference between the groups was statistically significant ($p < 0.05$) and UIPA-2 was more acute on the stone forming side than non-stone forming side in 72% of cases and more obtuse in 28% of cases. The IUPA angle-2 was more than or equal to 45° in 77% of cases on the non-stone forming side and less than or equal to 45° in 46% of cases on the stone forming side (Table 1).

The mean RIA was 78.30 ± 17.12° (36–112°) on the stone forming side and 82.05 ± 16.20° (44–119°) on the non-stone forming side. The difference between two groups was not statistically significant ($p > 0.05$). The mean ICL of the stone forming side was 30.20 ± 10.02 mm. (22–43 mm.) and of the non-stone forming side was 25.51 ± 5.31 mm (18–37 mm). The difference between two groups was statistically significant ($p < 0.05$). The median ICL-to-IW ratio was 8.55 ± 3.25 on the stone forming side and 7.09 ± 2.90 on the non-stone forming contra lateral side. The difference between two groups was statistically significant ($p < 0.05$). There was no statistically significant difference between both groups with respect of the IW, renal length, renal width, number of major and minor calices (Table 2).

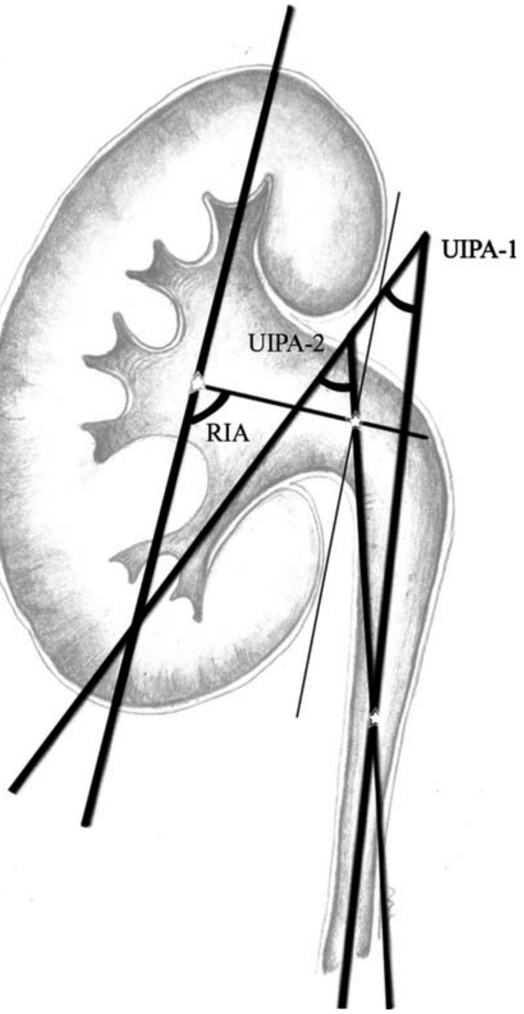

Figure 2. Method of measurıng angles UIPA-1,UIPA-2 and RIA.

Discussion

There are extrinsic and intrinsic etiological factors for stone formation and they are same for both kidneys. But the unilateral renal stones are more frequent than bilateral ones [6]. The anatomical structure of the renal collecting system that reduces the rate of urine flow and crystal density may be the factor that influences the stone formation [7]. Stagnation and retention of crystals in the inferior calyceal system due to gravity is accused for lower pole calculi. Cass et al. reported that 25–35% of calyceal calculi are localized in the inferior calyceal system [10]. ESWL is the first choice therapy for the problematic lower pole stones and the same anatomical area is evaluated in many studies that examines the effects of anatomical factors on the stone clearance after ESWL. The influence of the anatomical factors such as IUPA, IW, ICL, number of minor calices in predicting the clearance of fragments after ESWL are determined. An acute infundibulopelvic angle, a narrow infundibular neck and a long infundibular length of inferior calyx are described as significant negative factors for stone clearance [2, 3, 4, 5, 11]. In a similar way, these unfavourable factors might affect the formation of stone in the same localization. Nabi et al. studied in 100 consecutive cases with inferior calyceal calculus the IUPA and infundibular width (as described by Elbahnasy et al. [2]) to define the significance of this anatomical factors for stone formation and compared the results of stone forming and non-stone forming side. They found the IUPA (IUPA-2 in our study) more acute on the stone forming side in 74% of cases and concluded that IUPA was a significant factor for stone formation [4]. We measured in our study the IUPA with two methods and examined with each one similar findings with Nabi et al. IUPA-1 was more acute in 77% of cases and IUPA-2 in 72% of cases on the stone forming side and both of these differences between stone forming and contralateral non-stone forming side were statistically significant ($p < 0.05$). Our findings are in line with Nabi et al. and we suggest that IUPA (as UIPA-1 and UIPA-2) may be a significant parameter in the formation of lower

Table 1. Angle characteristics of IUPA-1 and UIPA-2 on the stone forming and contralateral non-stone forming side

	More acute angle on the stone forming side than the non-stone forming side	More obtuse angle on the stone forming side than the non-stone forming side	≤45° on the stone forming side	≥45° on the non-stone forming side
IUPA-1° in % of cases	77%	33%	64%	56%
IUPA-2° in % of cases	72%	28%	77%	46%

Table 2. Analysis of anatomical factors predicting stone formation. $p < 0.05$ considered statistically significant (bold variables)

Variables	Stone forming side	Non-stone forming contralateral side	p Value
Mean IUPA (Angle-1)° ± SD	41.43 ± 13.46°	49.20 ± 11.83°	0.000
Mean IUPA (Angle-2)° ± SD	55.33 ± 21.06°	62.51 ± 20.65°	0.004
Mean RIA° ± SD	78.30 ± 17.12°	82.05 ± 16.20°	0.056
Mean ICL (mm) ± SD	30.20 ± 10.02 mm	25.51 ± 5.31 mm	0.000
Mean IW (mm) ± SD	4.02 ± 1.98 mm	4.28 ± 1.95 mm	0.372
Mean ICL to IW ratio ± SD	8.55 ± 3.25	7.09 ± 2.90	0.023
Mean no. minor calices ± SD	8.69 ± 1.65	8.20 ± 1.52	0.055
Mean no. major calices ± SD	3.71 ± 0.79	3.48 ± 0.75	0.071
Mean renal length (mm) ± SD	117.51 ± 11.47 mm	119.97 ± 11.08 mm	0.101
Mean renal width (mm) ± SD	55.64 ± 9.78 mm	53.84 ± 9.32 mm	0.112

pole calculi. The IUPA was more acute on the stone forming side. We believe that this condition can cause stagnation and retention of crystals in the inferior calyceal system which may result in the formation and growth of inferior calyceal calculi. The RIA, that we think as a possible factor for renal stone formation was slightly acute on the stone forming side compared with non-stone forming side, but the difference was not statistically significant (Table 1).

We found the mean ICL 30.20 mm on the stone forming side and 25.51 mm on the non-stone forming contralateral side with the methodology as described by Elbahnasy et al. [2]. By 56% of the cases the ICL was greater or equal to 30 mm. The difference between two sides was statistically significant ($p < 0.05$). We suggest that, the infundibular length is another possible risk factor for stone formation that may cause an impairment of the calyceal drainage and therefore stasis. Gökalp et al. studied the effect of anatomical factors, such as lower infundibulopelvic angle (LIPA), lower infundibulum diameter (LID) and inferior calyceal length (ICL) in renal stone formation. They concluded that LID and ICL were significant parameters in stone formation and the increase of them could cause stasis in lower calyceal system. The parameters were measured from 119 calculous kidneys and the control group was consisted of 40 healthy kidney donors (80 kidneys). They reported a mean ICL of 32.54 mm for calculous kidneys and 20.99 mm for the noncalculous control group. The difference between these two values was statistically significant [12]. The measurement method was as described by Sampaio and Arago [13]. The weak point of this study was that the non-stone forming and the stone forming kidneys were not assessed in same patient with the same etiological factors for stone formation. Elbahnasy et al. reported an average infundibular length of 38 cm in 34 patients with solitary lower pole stones with the same methodology as ours. This study was conducted to assess the effect of ESWL and ureteroscopy on the inferior calyceal calculi [2]. Our finding are similar to that of the Elbahnasy et al. and in accordance with the ones of Gokalp et al. Our hypothesis is supported by poor clearance of inferior calyceal calculi following ESWL in kidneys with ICL greater than 30 mm [2].

We found the mean IW to be 4.02 mm on the stone forming side and 4.28 mm on the non-stone forming contra lateral side. The difference between two sides was not statistically significant ($p > 0.05$). Gökalp et al founded the LID (to be) higher in the stone formers (mean 9.98 mm) and they claimed that the LID was a possible risk factor for stone formation [12]. The difference between our results and those of Gökalp et al. can be due to the difference in the method of measurements. Nabi et al. reported a mean IW of 5.6 mm on the stone forming side and 4.8 mm on the non-stone forming side. The methodology was same with ours and they concluded that there was no statistically significant difference between both sides [4]. It was clearly seen that the narrow IW can preclude efficient stone passage and cause stagnation in the inferior calyceal system [2, 11]. Elbahnasy et al. reported good results with ESWL on the solitary lower pole stone patients with IW greater than 4 mm [2]. Sumino et al. reported that an IW greater than 5 mm was a favourable factor for an improved stone-free rate after ESWL [11]. In the case of primary calculi the neck of the calyx is narrow [14, 15]. In addition the IW measurements vary significantly in the same patient depending on hydration status and the method used to perform IVU [16].

We found in our series the median ICL-to-IW ratio 8.55 ± 3.25 on the stone forming side and 7.09 ± 2.90 on the non-stone forming contra lateral side. The difference between two groups was statistically significant ($p > 0.05$). Sumino et al. examined the lower infundibular length-to-diameter ratio for predicting of the lower pole stone clearance after ESWL on 63 patients. They concluded that, ICL-to-IW ratio was less than 7 in 53.4% of patients and 7 or greater in 47.6% of patients. After ESWL two-thirds of the patients with a ratio smaller than 7 became stone free and Sumino et al. considered this parameter as a good predictive factor for stone clearance [11]. On comparison, the ICL-to-IW ratio in our series was more than 7 in 69% of cases on the stone forming side and less than 7 in 59% of the cases on the non-stone forming side. Our findings are similar to that in the series of Sumino et al. and there was a statistically significant difference between two sides in our study .We believe that ICL-to-IW ratio may be a mark able factor that could influence the stone formation in inferior calyceal system.

The mean number of totally minor calyces on the stone forming and on the non-stone forming contra lateral side was 8.69 ± 1.65 and 8.20 ± 1.52. The difference between two sides was not statistically significant ($p > 0.05$). Ishikawa studied morphologic and urodynamic differences between stone forming and stone-free sides on 35 cases with unilateral recurrent and/or multiple stone formation and marked the high number of minor calyces on the stone forming side as a significant parameter for stone formation [17]. We assessed the number of major calyces on both sides, but did not find any significant difference between them ($p > 0.05$).

Moreover, in a recent study, it has been marked that the stone clearance after ESWL can be predicted with artificial neural network analysis including the digitally recorded IVU results of urinary transport [18]. We believe that, this methodology can be adapted to investigate the inferior calyceal stone formation. The limitations of our study are the absence of urodynamic studies and histological investigation of the calyceal anatomy.

Conclusion

There are many factors that contribute to the renal stone formation. Renal morphology is an important one among these factors. Our study revealed that inferior calyceal infundibulopelvic anatomy had a significant role in inferior calyceal stone formation. We concluded that, IUPA (1 and 2), ICL and ICL-to-IW ratio were significant risk factors, which could predispose to lower calyceal stone formation.

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