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Imaging

Kidney Lower Pole Pelvicaliceal Anatomy: Comparative Analysis Between Intravenous Urogram and Three-Dimensional Helical Computed Tomography

Daibes Rachid Filho, M.D., M.S., Luciano A. Favorito, M.D., Ph.D., Waldemar S. Costa, B.Sc., Ph.D., and Francisco J.B. Sampaio, M.D., Ph.D.

Abstract

Objective: The aim of our study was to evaluate if there is any advantage of three-dimensional helical computed tomography (3D-HCT) over intravenous urogram (IVU) in the morphometric and morphological analysis of lower pole spatial anatomy of the kidney.

Patients and Methods: We analyzed 52 renal collecting systems in 30 patients, ranging in age from 23 to 80 years. The study compared the following features: (1) the angle formed between the lower infundibulum and the renal pelvis (i.e., lower infundibulum–pelvic angle [IPA]), (2) the lower infundibulum diameter (ID), and (3) the spatial distribution and number of lower pole calices (i.e., caliceal distribution [CD]). The study started with the 3D-HCT images obtained for posterior reconstruction and analysis. Afterward, we obtained anteroposterior and oblique IVU images.

Results: For IPA (in degrees) we found a mean $\pm$ standard deviation (SD) value of 75.79 ± 15.3 with 3D-HCT and 77.4 ± 17.17 with IVU, which were not statistically significant. For ID (in mm) we found a mean $\pm$ SD value of 7.5 ± 2.92 with 3D-HCT and 8.15 ± 3.27 with IVU. For CD we found a mean $\pm$ SD value of 2.37 ± 0.75 calices with 3D-HCT and 2.43 ± 0.67 calices with IVU. On analyzing the difference between 3D-HCT and IVU, we found a mean $\pm$ SD value of 0.06 ± 0.51, and we verified that 74.5% of the examinations compared did not present statistically significant difference, with a Wilcoxon p-value of 0.405.

Conclusion: Although 3D-HCT is more precise to study calculus location, tumors, and vessels, IVU was also demonstrated to be as precise as 3D-HCT for studying the lower pole spatial anatomy. We did not observe any statistically significant difference in the measurements of IPA, ID, and CD obtained using 3D-HCT when compared with those obtained using IVU. Therefore, 3D-HCT does not present any advantage over IVU in the evaluation of lower pole caliceal anatomy.

Introduction

For the treatment of urinary lithiasis, many studies have been performed to improve the results of minimally invasive techniques. In some cases of nephrolithiasis, mainly in the lower pole, the choice of extracorporeal shockwave lithotripsy (SWL), percutaneous nephrolithotripsy, or transureterorenoscopic nephrolithotripsy remains a theme of debate.[1–12]

The percentage of complete elimination of fragments from the upper pole, middle calix, renal pelvis, and lower pole are 78%, 76%, 84%, and 58%, respectively.[13] Besides the gravity-dependent factor, which would make difficult the elimination of stone fragments following SWL, Sampaio and Aragão[1] suggested theoretically for the first time that the spatial anatomy of the lower pole collecting system would be important for the retention of fragments after SWL. They proposed that the angle formed between the lower infundibulum and the renal pelvis (i.e., lower infundibulum–pelvic angle [IPA]), the lower infundibulum diameter (ID), and the number of lower pole calices (i.e., caliceal distribution [CD]) would be the most important factors. In 1995 and 1997, respectively, Sampaio et al[2,3] presented and published the results of the first clinical trial and prospective study on the influence of the infundibulopelvic angle in stone clearance after SWL for lower pole calculi in 74 patients. In a mean follow-up period of 9 months, they found that 75% of the patients presenting an angle of greater than 90° formed between the axis of the lower infundibulum, in which the stone was located, and the ureteropelvic axis became stone free within 3 months. On the other hand, only 23% of the patients presenting an angle of less than 90° became stone free during the follow-up. Afterward, many studies were performed which aimed at

Urogenital Research Unit, State University of Rio de Janeiro, UERJ, Rio de Janeiro, Brazil.

improving the results and better selecting of patients for either SWL or more invasive procedures (ureterorenoscopy, percutaneous nephrolithotripsy, or even open surgery).[5,7,8,10] In addition to IPA, ID, and CD, the infundibulum height, the infundibulum length, and the volume of renal collecting system were also studied by some authors as important factors in fragment retention after SWL and were correlated to the success of the procedure, with varied outcomes.[3,6,14–16] The interpretation of such parameters has been mainly based on intravenous urogram (IVU).[7,8,11,17] To our knowledge, to the moment, there are no studies comparing the anatomical measurements of lower pole collecting system obtained using IVU with those obtained using three-dimensional helical computed tomography (3D-HCT), the latter being supposedly more precise.

Therefore, the objective of our study was to compare the morphometric evaluation of some features of lower pole collecting system spatial anatomy (IPA, ID, and CD) that would be involved in fragment elimination after SWL, using IVU and 3D-HCT.

Patients and Methods

We analyzed 52 renal collecting systems in 30 patients (13 women and 17 men), ranging in age from 23 to 80 years (mean, 56.7).

The Institutional Ethics Committee on Human Research approved the study and all patients signed an informed consent.

The indications for examination included follow-up of bladder, kidney, or prostate cancers, low back pain, hematuria, and prostatism. Among the examination findings, there were alterations such as renal ectopia, forniceal rupture, renal sinus lipomatosis, ureteral and renal lithiasis of the lower pole, prostatic hypertrophy, and renal cysts.

Our study compared the findings obtained using IVU and 3D-HCT, concerning the following lower pole features: IPA, ID, and CD.

The examinations were performed in the same center of reference, through a standardized methodology and with a 3D-HCT Siemens Somaton Plus equipment. The measurements were performed by the same researcher, using a ruler and a square.

The patients who were allergic to the iodinated contrast medium as well as those who presented a doubtful radiological analysis were excluded. All patients were informed that they would undergo two examinations. The screening started with the 3D-HCT images obtained for posterior reconstruction and analysis. Afterward, we obtained anteroposterior and oblique IVU images, with emphasis on the excretory renal phase (calix, pelvis, and upper ureter). The protocol used for imaging aimed at evaluating the equivalence of the data obtained using 3D-HCT and IVU.

A helical reconstruction with 3 mm thickness from the kidney upper pole to the bladder base was performed, which generates approximately 150 images for evaluation. After this initial study, 70% of the usual quantity of the intravenous iodinated contrast medium (Mallinckrodt®, Inc., Hazelwood, MO) was administered, and after 7.5 minutes the remaining 30% was injected and the images were acquired with the same technique, so they contained the renal parenchyma, renal pelvis, ureter, and bladder, enhanced by the contrast medium. The volume of contrast used was 1.5 to 2.0 mL/kg (mean, 100 mL).

The technique used for imaging reconstruction was the maximum intensity projection with images acquired between 5 and 10 minutes. After performing the 3D-HCT examination, the patient received additional 30 mL of contrast medium intravenously and was placed in another room to obtain anteroposterior and oblique urographies with intervals of 5 to 10 minutes.

After imaging, we analyzed the values of IPA and ID, as well as CD. We started the data collection using IVU, and to obtain an unbiased analysis, the measurements on the 3D-HCT images were performed after a randomized evaluation of all IVU images. The anteroposterior images were standardized for evaluation of IPA and ID, and for quantifying the lower pole calices, we also used the oblique images.

The IPA was determined from the intersection of two lines. The first line (y-axis) linked the central axis of the superior ureter (at the level of the lower pole) with the central axis of the ureteropelvic junction. The second line (x-axis) was traced through the central axis of the main inferior infundibulum. Then the IPA was calculated at the intersection of the first and second lines. Figure 1 exemplifies IPA measurement on images obtained using IVU and 3D-HCT in the same renal unit.

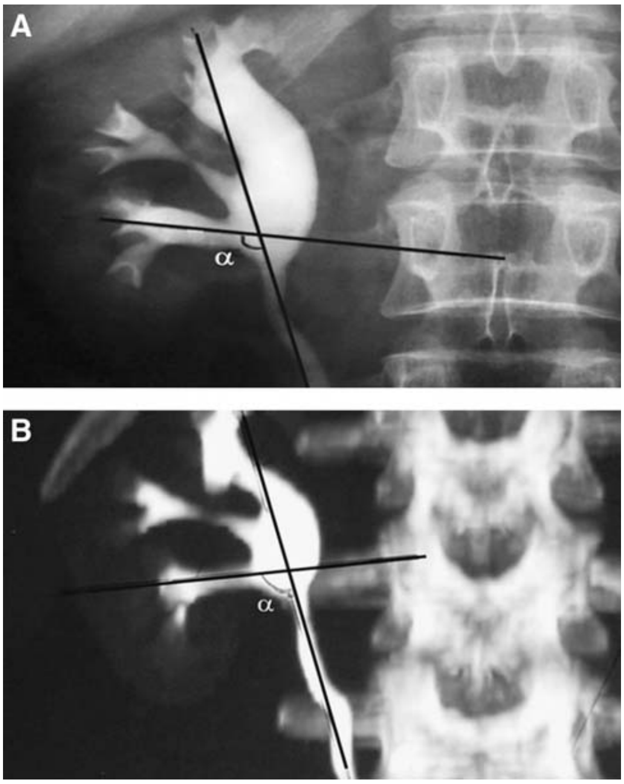

FIG. 1. Pelvicaliceal and ureteral excretory phase demonstrating the infundibulum–pelvic angle (IPA) measurement (α) in the same renal unit. (**A**) Image obtained with intravenous urogram (IVU). (**B**) Image obtained with three-dimensional helical computed tomography (3D-HCT). The IPA was determined from the intersection of two lines. The first line (y-axis) linked the central axis of the superior ureter (at the level of the lower pole) with the central axis of the ureteropelvic junction. The second line (x-axis) was traced through the central axis of the main inferior infundibulum. The IPA (α) was obtained at the intersection of first and second lines.

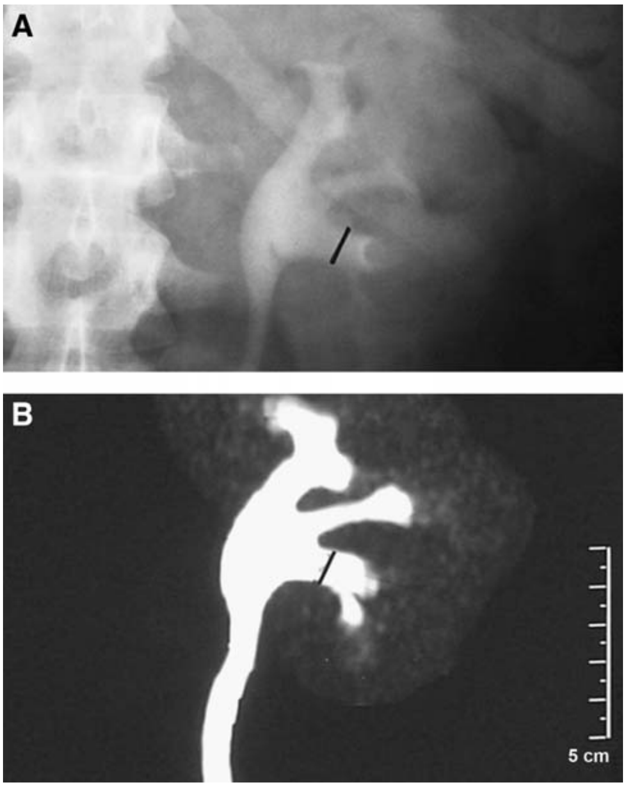

FIG. 2. Pelvicaliceal and ureteral excretory phase demonstrating the lower infundibulum diameter measurement in the same renal unit (straight line). (**A**) Image obtained with IVU. (**B**) Image obtained with 3D-HCT. The infundibulum diameter was always analyzed in the narrowest point of the main lower infundibulum.

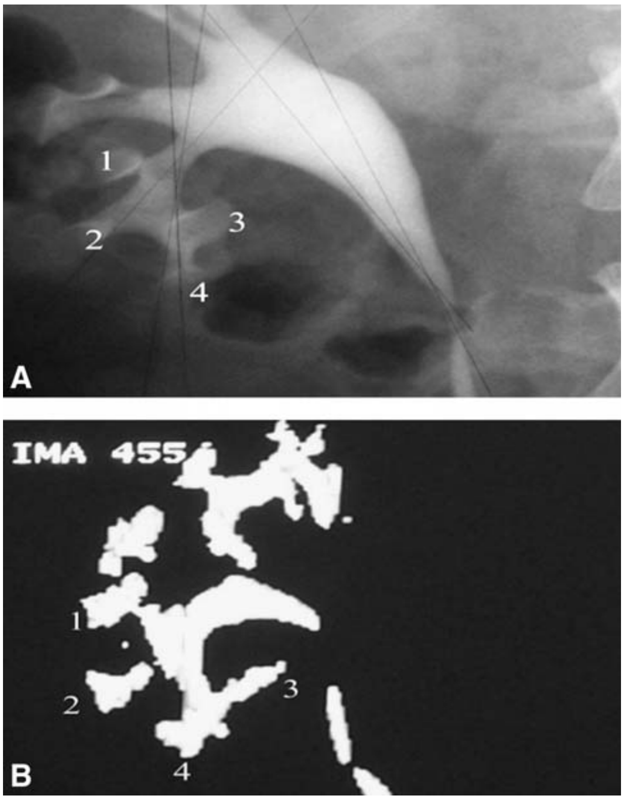

FIG. 3. Pelvicaliceal and ureteral excretory phase demonstrating the lower calices quantification in the same renal unit (1 to 4). (**A**) Image obtained with IVU. (**B**) Image obtained with 3D-HCT.

The lower ID was always analyzed at the narrowest point of the main lower infundibulum, as shown in Figure 2. The lower calices quantification (CD) is shown in Figure 3.

Statistical analysis was conducted comparing the IPA, ID, and CD obtained using 3D-HCT versus IVU. For the statistical analysis and comparison of the values obtained using the two examination methods, we used the Wilcoxon test (for ordinal or numeric variable, nonparametric and paired test) and McNemar λ^2 (for categorical variable, paired). The values were considered significant for $p < 0.05$. It is important to remember that these two statistical methods do not evaluate agreement among the groups, but the equivalence among the examinations. For similarity evaluation, the concordance analysis was performed by statistical concordance using the methods of general concordance, the kappa coefficient of concordance, the weighted kappa coefficient of concordance, and intraclass correlation coefficient, which analyze only the values without clinical interference and finally the clinical coefficient of concordance.

Results

The patients' age and the measurements performed are presented in Table 1.

For the lower IPA, we found the following values: mean $\pm$ standard deviation (SD) value of $75.79° \pm 15.3°$ obtained with 3D-HCT and $77.4° \pm 17.17°$ with IVU. The median was 76.5° with 3D-HCT and 79.50° with IVU. The Wilcoxon test showed a p-value of 0.209. The detailed results are shown in Table 2.

For ID, we found the following values: mean $\pm$ SD of 7.5 ± 2.92 mm with 3D-HCT and 8.15 ± 3.27 mm with IVU. The median was 7 mm with 3D-HCT and 8 mm with IVU. The Wilcoxon test showed a p-value of 0.03. The detailed results are shown in Table 3.

For CD, we found the following values: 2.37 ± 0.75 with 3D-HCT and 2.43 ± 0.67 with IVU. The detailed results are shown in Table 4.

When analyzing the difference between 3D-HCT and IVU we found a mean $\pm$ SD value of 0.06 ± 0.51, and we found that 74.5% of the examinations compared did not present statistically significant difference, $p = 0.405$ with the Wilcoxon test.

Analysis of concordance

In the evaluation of lower IPA we observed that the McNemar λ^2 test did not present a statistically significant difference ($p = 0.375$). The general concordance was 90.4% (69.2% + 21.2%), and the kappa coefficient of concordance was 75.1% ($p < 0.001$).

Also, for lower ID the McNemar λ^2 test did not present a statistically significant difference ($p = 0.500$). The general concordance was 96.15% (1.92% + 94.23%). Despite the low value of kappa coefficient (48.5%), the sample presented concordance ($p < 0.001$).

Table 1. Morphometric Values Found for Lower Pole Anatomy Features with Intravenous Urogram and Three-Dimensional Helical Computed Tomography

Patient number	*Sex*	*Age (years)*	*Kidney side*	*IPA (degrees)*		*ID (mm)*		*CD*	
				IVU	*3D-HCT*	*IVU*	*3D-HCT*	*IVU*	*3D-HCT*
1	M	50	Left	100	97	8	8	4	4
2	M	45	Right	58	77	4	5	2	1
			Left	95	74	10	10	2	2
3	M	68	Right	55	59	4	5	3	3
4	M	64	Right	79	79	8	5	2	2
			Left	95	85	9	6	3	2
5	M	44	Right	60	78	7	10	4	4
			Left	88	78	10	10	3	3
6	F	72	Right	68	68	15	10	2	2
			Left	94	96	10	7.5	4	4
7	F	70	Right	60	74	10	7	3	2
8	F	60	Right	64	64	9	6	2	2
			Left	88	76	5	4	2	2
9	F	57	Right	57	60	10	12	2	2
			Left	66	78	4	5	2	3
10	F	43	Right	67	71	7	8	2	3
			Left	76	67	8	8	2	2
11	F	64	Right	95	103	2	2	1	1
			Left	85	95	8	10	2	2
12	M	73	Right	105	78	3	5	2	2
			Left	80	70	3	4	2	2
13	F	32	Right	85	80	8	5	3	2
			Left	82	78	10	6.5	2	2
14	M	41	Right	102	102	8	6	2	2
			Left	100	102	4	5	3	2
15	M	68	Right	75	77	8	9	2	2
			Left	40	45	6	6	2	2
16	M	72	Right	70	60	15	11	2	2
			Left	63	50	6	5	2	2
17	M	68	Right	103	94	10	10	3	3
			Left	95	91	10	5	2	3
18	F	23	Right	80	66	5	5	2	2
			Left	72	63	5	5	2	2
19	F	46	Right	68	65	8	6	2	2
			Left	48	58	5	5	3	2
20	M	64	Right	70	75	9	9	2	2
21	M	66	Left	90	105	6	4	2	1
22	M	59	Right	60	65	9	10	2	2
			Left	80	80	10	7	2	3
23	F	80	Right	96	90	7	6	3	3
			Left	54	58	4	5	3	3
24	M	58	Right	80	75	12	16	3	3
25	M	61	Left	88	83	10	7	2	2
26	F	42	Right	70	78	10	10	3	3
			Left	90	85	15	15	4	4
27	F	67	Right	79	65	17	12	3	3
			Left	100	90	14	11	2	2
28	M	72	Right	85	76	8	10	3	4
			Left	108	100	9	11		
29	F	38	Left	53	65	7	7	2	2
30	M	62	Right	58	40	7	6	3	2
			Left	49	53	8	7	2	2

IPA = infundibulum–pelvic angle; ID = infundibulum diameter; CD = caliceal distribution—number of lower pole calices; IVU = intravenous urogram; 3D-HCT = three-dimensional helical computed tomography.

For lower CD the general concordance was 74.5%. The weighted kappa coefficient of concordance was 63.3% ($p < 0.001$).

Continuing the statistical concordance analysis, we also used the intraclass correlation method for IPA, ID, and CD. The concordance values found by this method were 81.4%, 76.5%, and 74.6%, respectively, for IPA, ID, and CD.

Aiming at transferring the pure statistical data to the clinical setting, and also for minimizing possible inaccuracies of this analysis, we subjected these values to clinical concor-

Table 2. Statistical Analysis of the Lower Infundibulum–Pelvic Angle, in Degrees, Obtained with Intravenous Urogram and Three-Dimensional Helical Computed Tomography ($N = 52$)

	Examination		*Difference*
Descriptive statistics	*IVU*	*3D-HCT*	*(IVU–3D-HCT)*
Mean	77.46	75.79	1.67
Standard deviation	17.17	15.30	9.91
Maximum	108.00	105.00	27.00
Third quartile	93.00	85.00	9.00
Median	79.50	76.50	1.50
First quartile	63.25	65.00	−4.75
Minimum	40.00	40.00	−19.00
p-Value, Wilcoxon test			0.209

Table 4. Distribution of the Number of Lower Pole Calices Obtained with Intravenous Urogram and Three-Dimensional Helical Computed Tomography ($N = 51$)

	IVU		*3D-HCT*	
CD	n	%	n	%
1	1	2.0	3	5.9
2	31	60.8	31	60.8
3	15	29.4	12	23.5
4	4	7.8	5	9.8
Total	51	100.0	51	100.0
Mean ± SD	2.43 ± 0.67		2.37 ± 0.75	

CD = caliceal distribution (i.e., number of lower calices); SD = standard deviation.

dance evaluation. The clinical limits of concordance studied for the analysis were the following: IPA with a difference among the examinations $\leq 5°$ or $>5°$, ID with a difference ≤ 1 or >1 mm, and CD with a difference ≥ 0; the confidence interval was 95%. The clinical concordance for IPA was 46.2% for a difference among examinations $\leq 5°$, 53.8% for ID for a difference among examinations ≤ 1 mm, and 74.5% for CD with difference equal to zero.

Comments

Current treatments for lower pole lithiasis include SWL, percutaneous nephrolithotripsy, and retrograde ureterorenoscopy. The anatomical variations of caliceal infundibula and lower pole angles, as well as the complexity of the lower pole drainage system affect the success rates for each treatment chosen.[3,7,11–13] Nevertheless, the negative effects of lower IPA, infundibular length, and width are critical for SWL.[6] Besides gravity-dependent position of lower pole calices, these anatomical features might influence fragment clearance after SWL for lower pole lithiasis.[12]

Despite the indication of the method for treating lower pole nephrolithiasis, it is important to know if the method used for studying the lower pole caliceal anatomy is precise. This knowledge is important for planning the percutaneous access, for flexible ureterorenoscopy inside the lower pole calices, and also for indicating and predicting the success of SWL for treating lower pole lithiasis. Here, we were interested to evaluate if IVU is enough to study the lower pole anatomy or if 3D-HCT would give additional and more precise information. 3D-HCT is a commonly used examination in the investigation of many renal pathologies such as lithiasis, tumors, vascular anomalies and also in the study of vascular anatomy in renal donors;[14–19] however, there are few reports on the analysis of 3D anatomy of the kidney lower pole with 3D-HCT.[20–25]

In our study, we observed that the morphological analysis and the morphometric values of lower pole anatomy found with IVU and 3D-HCT did not present statistically significant difference. The agreement analysis was highly significant; nevertheless, when we used clinical agreement we faced an important decrease, even though the agreement still existed.

A previous work[3] confirmed the trend of an average increase in values for lower ID (5.8 mm, varying from 1 to 19) when obtained with pyelograms. In IVU an image enlargement occurred, which varied according to the distance from the focus to the object. This kind of image distortion is not observed in CT, and it could explain why the median of the lower ID obtained with IVU was a little bit higher than the median obtained with 3D-HCT; nevertheless, the difference was not statistically significant.

The factors that could influence the results can rarely be excluded from clinical practice. Of course, we would doubt whether the static radiological examinations could represent precisely a dynamic system, that is, urine elimination by the collecting system. Some works proposed that the ID would vary according to abdominal compression performed during IVU.[11] Also, the hydration state of the patient, or even small movements at the moment of acquiring the images, could alter the results.

Besides the fact that the values studied do not present a statistically significant difference but agree with each other, it is important to point out that in developing countries the cost of IVU is much lower than 3D-HCT. Although 3D-HCT is much more precise to study calculus location, tumors, and vessels, the IVU was also demonstrated to be as precise as 3D-HCT for studying the lower pole spatial anatomy.

Table 3. Statistical Analysis of Lower Infundibulum Diameter, in Millimeters, Obtained with Intravenous Urogram and Three-Dimensional Helical Computed Tomography ($N = 52$)

	Examination		*Difference*
Descriptive statistics	*IVU*	*3D-HCT*	*(IVU–3D-HCT)*
Mean	8.15	7.50	0.65
Standard deviation	3.27	2.92	2.12
Maximum	17.00	16.00	5.00
Third quartile	10.00	10.00	2.88
Median	8.00	7.00	0.00
First quartile	6.00	5.00	−1.00
Minimum	2.00	2.00	−4.00
p-Value, Wilcoxon test			0.030

Conclusions

There was no statistically significant difference in the measurements of lower IPA, lower ID, and lower CD obtained with 3D-HCT when compared with those values obtained with IVU. Therefore, in our study, 3D-HCT did not present advantages over IVU when analyzing the morphometric and the morphological features of kidney lower pole spatial anatomy.

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Disclosure Statement

No conflict of interest exists.

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Address correspondence to:
Francisco J.B. Sampaio, M.D., Ph.D.
Urogenital Research Unit
State University of Rio de Janeiro
Av 28 de Setembro, 87, fundos, FCM
Rio de Janeiro, RJ 20562-030
Brazil

E-mail: sampaio@urogenitalresearch.org

Abbreviations Used

CD = caliceal distribution (i.e., number of lower calices)
CT = computed tomography
3D-HCT = three-dimensional helical computed tomography
ID = infundibulum diameter
IPA = infundibulum–pelvic angle
IVU = intravenous urogram
SD = standard deviation
SWL = extracorporeal shockwave lithotripsy