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ORIGINAL ARTICLE

Lower pole anatomy and mid-renal-zone classification applied to flexible ureteroscopy: experimental study using human three-dimensional endocasts

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Abstract

Purpuse The aim of this study was to analyze the anatomy of the inferior pole collecting system and the mid-renal-zone classification in human endocasts applied to flexible ureteroscopy.

Methods 170 three-dimensional polyester resin endocasts of the kidney collecting system were obtained from 85 adult cadavers. We divided the endocasts into four groups: A1—kidney midzone (KM), drained by minor calices (mc) that are dependent on the superior or the inferior caliceal groups; A2—KM drained by crossed calices; B1—KM drained by a major caliceal group independent of both the superior and inferior groups; and B2—KM drained by mc entering directly into the renal pelvis. We studied the number of calices, the angle between the lower infundibulum and renal pelvis and the angle between the lower infundibulum and the inferior mc (LIICA). Means were statistically compared using ANOVA and the unpaired *T* test ($p < 0.05$).

Results We found 57 (33.53 %) endocasts of group A1; 23 (13.53 %) of group A2; 59 (34.71 %) of group B1; and 31 (18.23 %) of group B2. The inferior pole was drained by four or more calices in 84 cases (49.41 %), distributed into groups as follows: A1 = 35 cases (41.67 %); A2 = 18 (21.43 %); B1 = 22 (26.19 %); and B2 = 9 (10.71 %). Perpendicular mc were observed in 15 cases (8.82 %). We did not observe statistical differences between the LIICA in the groups studied.

Conclusions Collector systems with kidney midzone drained by minor calices that are dependent on the superior or on the inferior caliceal groups presented at least two restrictive anatomical features. The mid-renal-zone classification was predictive of anatomical risk factors for lower pole ureteroscopy difficulties.

Keywords Flexible ureteroscopy · Kidney anatomy · Lower pole anatomy · Endocasts

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Introduction

The use of flexible ureteroscopy (FUR) in treatment of intrarenal stones has increased, especially for those located in the inferior renal pole [8, 10]. The stone-free rate, regardless the chosen treatment method, is directly related to anatomic parameters [4, 9, 22]. The size of calculi is one of most important factors for decision on the best treatment method [5]. Stones wider than 20 mm are better treated with percutaneous surgery, while stones smaller than 10 mm show good results when treated by flexible ureteroscopy (FUR) or extracorporeal shockwave lithotripsy (ESWL), and stones between 10 and 20 mm are treated with FUR with good results [5].

The spatial anatomy of the lower pole group of calices influences the success rate of FUR [7, 12]. Patients with unfavorable parameters show lower stone-free rates when FUR was the method of choice [7, 12]. The three-dimensional anatomy of the collector system is well known [23]. Previous studies have analyzed the inferior pole anatomy applied to SWL and showed that multiple inferior pole calices, with width smaller than 4 mm, along with the angle between the renal pelvis and inferior infundibulum, are the most influential factors for elimination of stone fragments after ESWL [21, 22].

The aim of this study was to analyze the three-dimensional anatomy of the inferior pole collecting system and the mid-renal-zone classification in human endocasts for better application of flexible ureteroscopy for intrarenal stone treatment.

Materials and methods

The present work received institutional review committee approval. This study was carried out in accordance with the ethical standards of the hospital's institutional committee on human experimentation.

We analyzed 170 three-dimensional polyester resin endocasts of the kidney collecting system belonging to our research unit. The endocasts were obtained from 85 fresh adult cadavers whose genitourinary system presented no macroscopically detectable pathologies. Kidneys with any anomalies were excluded from the sample. The ureters were dissected and injected with a yellow resin to obtain three-dimensional endocasts, according to the technique previously described [20, 23]. After polymerization of the resin, kidney samples were placed in acid for corrosion of organic matter, which yielded three-dimensional endocasts of the collecting systems.

We divided the endocasts into four groups: A1—kidney midzone (KM) drained by minor calices that are dependent on the superior or on the inferior caliceal groups; A2—KM drained by crossed calices, one draining into the superior caliceal group and another draining into the inferior caliceal group; B1—KM drained by a major caliceal group independent both of the superior and inferior groups; and B2—KM drained by minor calices entering directly into the renal pelvis [23].

In the inferior pole, we studied the following: (a) number of minor calices; (b) width and length of the infundibulum and the minor calices; (c) presence of perpendicular calices; (d) angle between the lower infundibulum and renal pelvis (LIP), measured by Sampaio's [22] and Elbahnasy's method [4]; and (e) angle between the lower infundibulum and the inferior minor calices (LIICA). The measurements were made with the aid of the Microsoft Powerpoint software [13], as shown in Fig. 1. The data were analyzed using ANOVA and the unpaired *T* test ($p < 0.05$).

Results

We found 57 endocasts of group A1 (33.53 %); 23 (13.53 %) of group A2; 59 (34.71 %) of group B1; and 31 (18.23 %) of group B2. Figure 2 shows the anatomical structures of the four groups studied. The anatomical characteristics of the inferior pole, including measurements of angles, calices and infundibulum, are shown in Table 1.

The LIP measured by Elbahnasy's method was >90° in 70 endocasts (29.42 %); ≤60° in 21 (12.35 %) and between 61° and 90° in 120 (70.6 %). Among the 21 endocasts with LIP <60°, 4 (2.35 %) were of group A1, 2 (1.18 %) of group A2, 8 (4.7 %) of group B1 and 7 (4.12 %) from group B2, and no difference was noticed in the distribution comparing the four groups ($p = 0.8667$). There was only one endocasts with LIP <30° from group B1. The LIP angle values were larger when measured by Sampaio's method: 123 endocasts (72.35 %) >90°; 45 (26.47 %) between 61° and 90°; and only two endocasts (1.18 %) <60°. The frequencies of LIP distributed in each group are shown in Table 2. Comparison of measurement results of LIP angles by Sampaio's and Elbahnasy's methods showed significant statistical difference ($p < 0.0001$ in groups A1, B1 and B2 and $p = 0.0003$ in group A2).

The inferior pole was drained by four or more calices in 84 cases (49.41 %), distributed in groups as follows: A1 = 35 cases (41.67 %); A2 = 18 (21.43 %); B1 = 22 (26.19 %); and B2 = 9 (10.71 %). In the remaining cases (50.59 %), the inferior pole was drained by a single midline caliceal infundibulum, receiving one to three fused papillae.

In the 170 cases studied, the inferior renal pole was drained by an average of 3.62 minor calices. The frequency of calices in each group can be seen in Tables 1 and 3. Perpendicular minor calices were observed in 15 cases (8.82 %). The frequency by groups is shown in Table 1.

The spatial caliceal orientation study showed significant difference of groups A1, B1, and B2, where lateral calices were more frequent ($p < 0.0001$) when compared to the anterior and posterior caliceal orientation. In the group A2, no spatial caliceal orientation was predominant ($p = 0.6295$). For the anterior, lateral, and posterior caliceal orientation between groups, differences could be observed between groups A2 and B2 ($p = 0.0378$), with predominantly anterior calices in the group A2. No difference was seen when lateral calices were studied ($p = 0.1487$), but posterior calices analyses showed differences between groups A1 and B2, groups A2 and B1, and groups A2 and B2, with posterior calices more frequent in group A.

The average infundibular length and width in the four collecting renal system groups are shown in Table 1. No infundibular width difference was observed between groups ($p = 0.1778$). Infundibular length differences between groups A1 and B1, groups A2 and B1, and groups A2 and B2 ($p = 0.0004$) showed that, in general, type A caliceal groups are longer than type B caliceal groups.

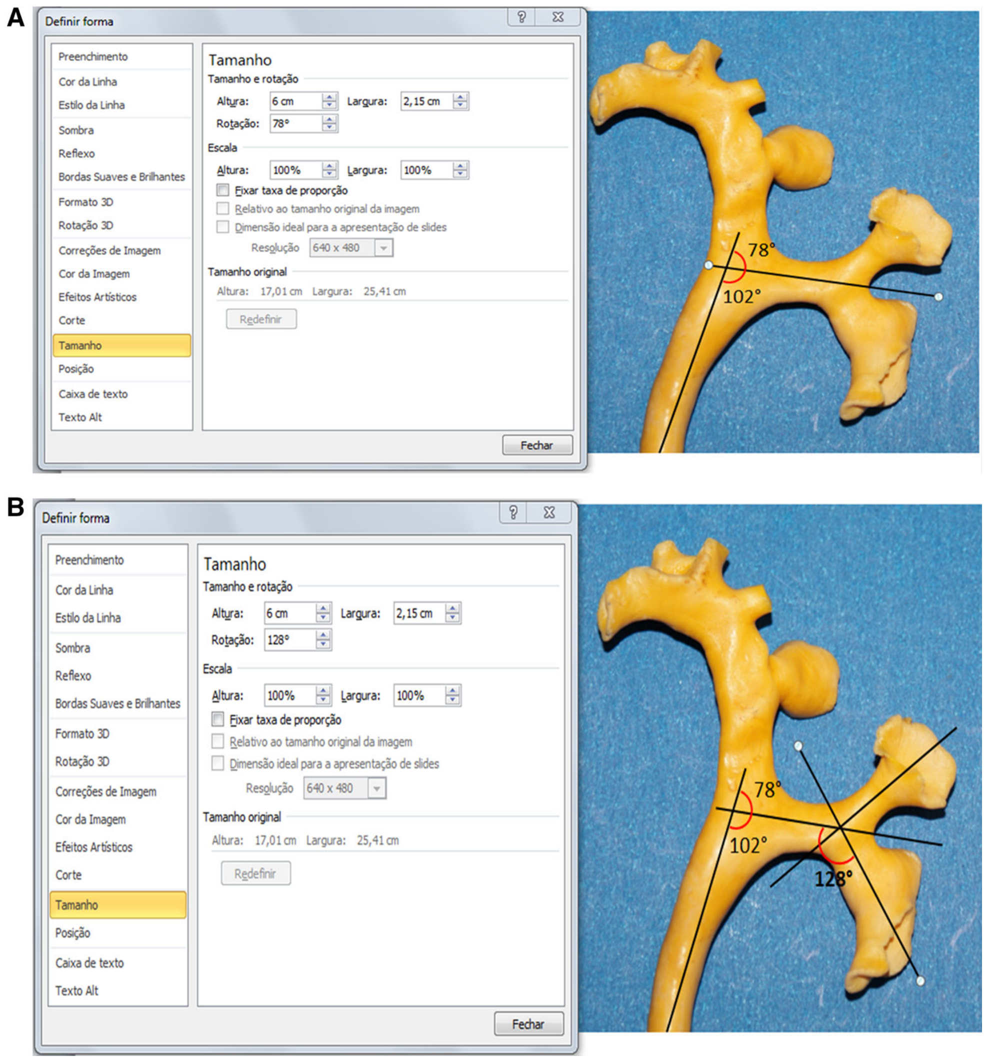

Fig. 1 Example of measurement of angles performed in this study with a computer program (12). **a** The figure shows an endocast of group A1. The angle between the lower infundibulum and renal pelvis (LIP) are measured. **b** The figure also shows an endocast of group A1. The angle between the lower infundibulum and the inferior minor calices (LIICA) are measured

The most inferior infundibular caliceal angle measurement (LIICA 1) was significantly smaller in the group B than in group A ($p = 0.0002$). There were no statistical differences between other LIICA measurements (from LIICA 2 to LIICA 7). The average of all LIICA can be seen in Table 1.

Discussion

Previous knowledge of the anatomy of the renal collector system is important to plan FUR. Previous studies have shown that three-dimensional helical computerized tomography and excretory urography are very accurate to analyze the anatomical parameters of the inferior renal pole, as is measurement of the LIP angle and the width, amount and spatial orientation of the inferior pole calices [3, 6, 17].

Inferior pole stones can be treated with SWL, FUR, and percutaneous nephrolitotripsy [18]. Anatomical aspects of the inferior renal pole, especially caliceal distribution, LIP, infundibular length and calice width, are determinant for the success of each treatment modality [1, 16]. A recent study with 145 patients with complex stones treated with FUR showed that the lowest success rate (83 %) occurred in calculi located in the inferior renal pole [2].

Size and volume of calices are also limiting factors for FUR success, regardless of location [11]. FUR success rates for renal stones smaller than 20 mm are higher than in SWL and have similar complication rates [5, 10, 14]. Geavlete [7] showed that LIP <30° and straight infundibulum are the major limiting factors for FUR success in inferior renal pole stones. Jessen [12] performed 111 FUR procedures in patients with inferior renal pole stones and noticed that the only parameter that altered stone-free rates after FUR was infundibular length. In this study, the author measured retrograde pielographies, according to Elbahnasy's method [4].

Resorlu [19] conducted a study involving 67 patients with inferior renal pole stones submitted to FUR. Measurements of collecting renal system in pre-operative

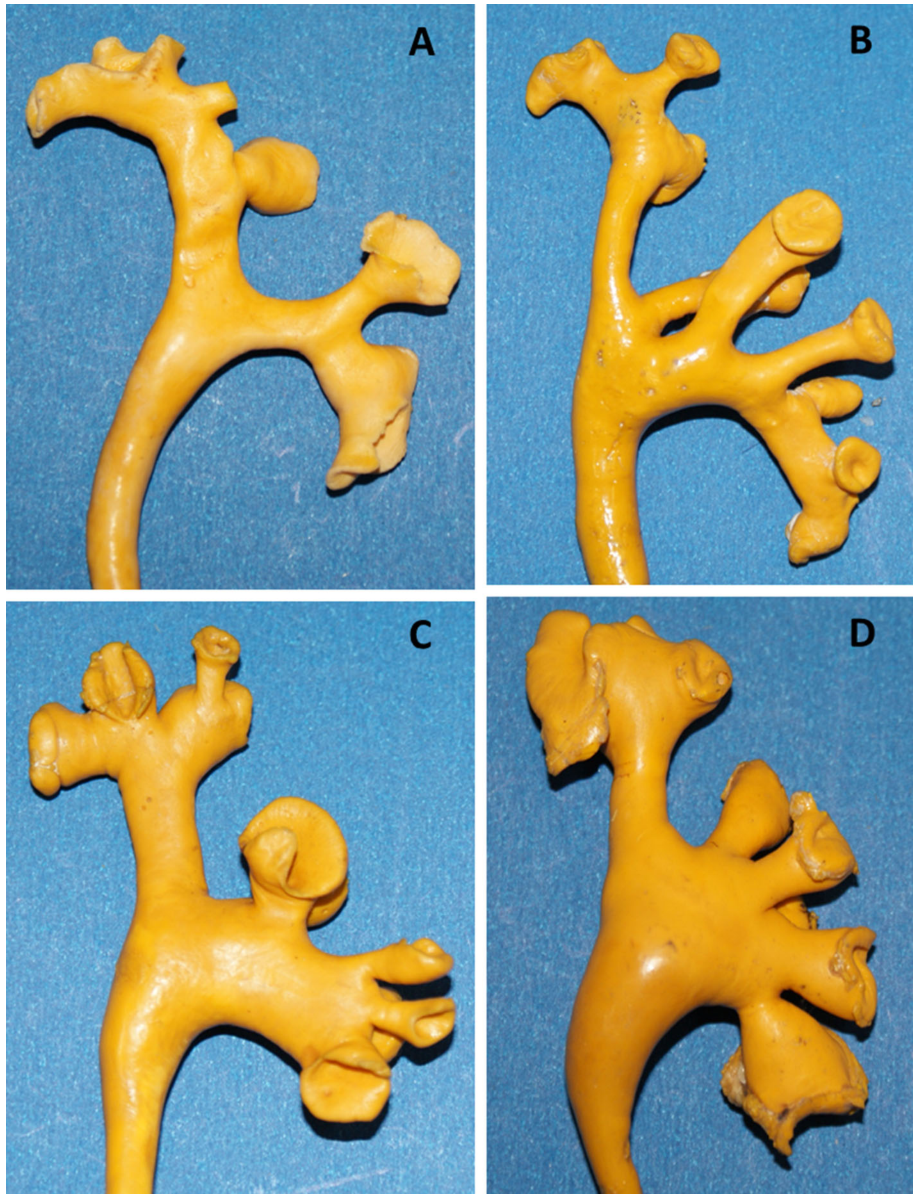

Fig. 2 Classification of renal collector system types. **a** Endocast of group A1—kidney midzone (KM) drained by minor calices that are dependent on the superior or on the inferior caliceal groups; **b** Endocast of group A2—KM drained by crossed calices, one draining into the superior caliceal group and another draining into the inferior caliceal group; **c** Endocast of group B1—KM drained by a major caliceal group independent both of the superior and inferior groups; and **d** Endocast of group B2—KM drained by minor calices entering directly into the renal pelvis

excretory urography were performed also using Elbahnasy's method [4]. The author observed that LIP equal to 45°, infundibular length equal to 30 mm and width of 5 mm are cut-offs to discriminate between favorable and unfavorable parameters.

According to Elbahnasy [4], the following factors are considered favorable to elimination of calculi from the inferior pole: LIP >70°, infundibular length ≤3 mm and infundibular width >5 mm. In contrast, LIP <70°, infundibular length >3 cm and infundibular width ≤5 mm are considered unfavorable factors. Different cut-offs were recommended by Sampaio [21], who considered LIP angle <90° and infundibular width <4 mm to be inhibiting factors for evacuation of stone fragments.

Knoll [15] conducted a study with 40 patients comparing different methods to study the anatomy of the inferior renal pole and observed a significant difference in the results depending on individual experience of the physician responsible for measurements, corroborating the need for well-defined anatomical parameters to help surgeons during FUR.

All 170 endocasts of this study were made with polyester resin (Resapol T-208). This resin hardens without contraction, allowing precise parameter measurements.

LIP is one of the most important factors for successful FUR results, although there is controversy about the limit considered unfavorable, varying from <30° to <90°, depending on the study [4, 5, 7, 8, 10, 22, 23]. Of the three-

Table 1 Average of measurements performed in inferior renal pole from 170 endocasts

Measurements	Group A1	Group A2	Group B1	Group B2
LIP (mean ± SD) (Elbahnasy's method)	88.6 ± 19.46	91.74 ± 18.15	79.47 ± 15.46	70.45 ± 15.28
LIP (mean ± SD) (Sampaio's method)	108.4 ± 17.76	112.2 ± 17.05	97.34 ± 15.55	93.19 ± 17.59
Infundibular length (mean ± SD)	2.92 ± 0.49	3.09 ± 0.45	2.67 ± 0.5	2.63 ± 0.49
Mc (mean ± SD)	4 ± 1.25	4.52 ± 1.12	3.22 ± 0.91	3.03 ± 0.95
Pc (*n*)	6	1	6	2
Mc diameter (mean ± SD)	0.89 ± 0.26	1.01 ± 0.22	0.92 ± 0.28	0.85 ± 0.3
LIICA 1	(−) 64.49 ± 25.84	(−) 78.17 ± 26.93	(−) 50.42 ± 27.46	(−) 54.22 ± 29.39
LIICA 2	(−) 16.14 ± 29.88	(−) 21.39 ± 27.64	1.05 ± 29.16	0.65 ± 21.53
LIICA 3	10.11 ± 31.05	7.04 ± 28.61	15.10 ± 20.44	19.71 ± 27.82
LIICA 4	21.94 ± 35.70	14.78 ± 24.48	32.68 ± 17.87	22.22 ± 17.94
LIICA 5	37.75 ± 33.93	35.75 ± 29.26	36.00 ± 14.72	(−) 49
LIICA 6	48.13 ± 39.82	36.25 ± 35.33	0	58
LIICA 7	0	63	0	0

All measurements are shown in centimeters and angles in degrees

A1 kidney midzone (KM) drained by minor calices (Mc) that are dependent on the superior or on the inferior caliceal groups, *A2* KM drained by crossed calices, one draining into the superior caliceal group and another draining into the inferior caliceal group, *B1* KM drained by a major caliceal group independent both of the superior and inferior groups, *B2* KM drained by Mc entering directly into the renal pelvis, *LIP* angle between the lower infundibulum and renal pelvis, *LIICA* angle between the lower infundibulum and the inferior minor calices, Pc perpendicular calices, *SD* standard deviation

Table 2 Angle measurements between the lower infundibulum and renal pelvis (LIP) in all four collecting renal system types, by Sampaio's and Elbahnasy's methods

Group	LIP (Sampaio's method)			LIP (Elbahnasy's method)		
	<60°	61°–90°	>90°	<60°	61°–90°	>90°
A1	0 (0 %)	11 (6.47 %)	46 (27.06 %)	4 (2.35 %)	31 (18.23 %)	22 (12.94 %)
A2	0 (0 %)	2 (1.18 %)	21 (12.35 %)	2 (1.18 %)	7 (4.12 %)	14 (8.24 %)
B1	2 (1.18 %)	13 (7.65 %)	44 (25.88 %)	8 (4.70 %)	39 (22.94 %)	12 (7.06 %)
B2	0 (0 %)	19 (11.17 %)	12 (7.06 %)	7 (4.12 %)	22 (12.94 %)	2 (1.18 %)
Total	2 (1.18 %)	45 (26.47 %)	123 (72.35 %)	21 (12.35 %)	99 (58.23 %)	50 (29.42 %)

A1 endocast with kidney midzone (KM) drained by minor calices (Mc) that are dependent on the superior or on the inferior caliceal groups, *A2* KM drained by crossed calices, one draining into the superior caliceal group and another draining into the inferior caliceal group, *B1* KM drained by a major caliceal group independent both of the superior and inferior groups, and *B2* KM drained by Mc entering directly into the renal pelvis

Table 3 Number of minor calices (Mc) and the frequency in each collecting renal system type

Group	1 Mc	2 Mc	3 Mc	4 Mc	5 Mc	6 Mc	7 Mc	4 a 7 Mc
A1	1 (0.59 %)	4 (2.35 %)	17 (10 %)	15 (8.82 %)	13 (7.65 %)	6 (3.53 %)	1 (0.59 %)	35 (41.67 %)
A2	0	0	5 (2.94 %)	6 (3.53 %)	8 (4.71 %)	3 (1.77 %)	1 (0.59 %)	18 (21.43 %)
B1	2 (1.18 %)	9 (5.29 %)	26 (15.29 %)	18 (10.59 %)	4 (2.35 %)	0	0	22 (26.19 %)
B2	0	10 (5.88 %)	12 (7.06 %)	8 (4.71 %)	0	1 (0.59 %)	0	9 (10.71 %)
Total	3 (1.77 %)	23 (13.52 %)	60 (35.29 %)	47 (27.65 %)	25 (14.71 %)	10 (5.89 %)	2 (1.18 %)	

A1 endocast where the kidney midzone (KM) is drained by minor calices (Mc) that are dependent on the superior or on the inferior caliceal groups, *A2* KM drained by crossed calices, one draining into the superior caliceal group and another draining into the inferior caliceal group, *B1* KM drained by a major caliceal group independent both of the superior and inferior groups, *B2* KM drained by Mc entering directly into the renal pelvis

dimensional endocasts in this sample, according to Elbahnasy's method, LIP was <60° in only in only 21 (12 %), of which 71.42 % were group B endocasts. LIP values <45° were observed in six cases (3.52 %), predominantly from group B collecting system, including three from group B1 and two from group B2. The remaining endocast was in group A1. LIP <30° occurred in only one case. Considering measurements according to Sampaio's method, there were only two cases (1.18 %) with LIP <60°, both from group B1, and there were no endocasts with LIP <45°.

The presence of multiple calices can cause additional inferior renal pole treatment difficulties [21, 22]. In our sample, the inferior renal pole was drained by four or more calices in 84 cases (49.41 %), in which 41 % were from group A1 and 26 % from group B1. There was a statistical difference in the number of inferior pole calices between group A and group B endocasts ($p < 0.0001$), with prevalence of group A.

Perpendicular minor calices (PC) can be superimposed on other structures, making radiographic visualization difficult [23]. Additional treatment difficulty can also be posed by the presence of PC stones for ESWL or FUR. Perpendicular minor calices were observed in less than 10 % of our sample, including six cases (40 %) belonging to group A1 and six cases (40 %) to group B1.

Long infundibular length (>3 cm) and narrow width (<5 mm) lead to lower FUR success rates [4]. In our sample, no statistical differences were found in inferior caliceal width among the four groups, but the infundibular length was longer in endocasts belonging to group A. Group A2 endocasts showed length greater than 3 cm.

The majority of unfavorable LIP angle endocasts were observed in the group B, regardless of using Elbahnasy's or Sampaio's method. Group A endocasts showed more numerous and longer inferior calices.

For the first time, tridimensional inferior renal pole anatomic parameters in each of the four collecting renal system groups were analyzed, to help surgeons perform FUR. The major limitation of the study was the impossibility of having previously performed FUR in endocasts to confirm the caliceal accessibility with a flexible ureteroscope.

Conclusion

Accurate knowledge of the spatial anatomy of the lower pole is of utmost importance during FUR. Collector systems with kidney midzone drained by minor calices that are dependent on the superior or on the inferior caliceal groups presented at least two restrictive anatomical features. The mid-renal-zone classification was predictive of anatomical risk factors for lower pole ureteroscopy difficulties.

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Conflict of interest The authors declare that they have no conflict of interest as statement in the manuscript.

References

1. Albala DM, Assimos DG, Clayman RV et al (2001) Lower pole I: a prospective randomized trial of extracorporeal shock wave lithotrispsy and percutaneous nephrostolithothomy for lower pole nephrolithiasis-initial results. J Urol 166:2072–2080
2. Cohen J, Cohen S, Grasso M (2013) Ureteropyeloscopic treatment of large, complex intrarenal and proximal ureteral calculi. BJU Int 111:127–131. doi:10.1111/j.1464-410X.2012.11352.x
3. El-Assmy A, Abo-Elghar ME, El-Nahas AR, Youssef RF, El-Diasty T, Sheir KZ (2008) Anatomic predictors of formation of lower caliceal calculi: is it the time for three-dimensional computed tomography urography? J Endourol 22:2175–2179. doi:10.1089/end.2008.0148
4. Elbahnasy AM, Clayman RV, Shalhav AL et al (1998) Lower caliceal stone clearance after shock wave lithotripsy or ureteroscopy: the impact of lower pole radiographic anatomy. J Endourol 159:676–682
5. El Nahas AR, Ibrahim HM, Youssef RF, Sheir KZ (2012) Flexible ureterorenoscopy versus extracorporeal shock wave lithotripsy for treatment of lower pole stones of 10–20 mm. BJU Int 110:898–902. doi:10.1111/j.1464-410X.2012.10961.x
6. Filho DR, Favorito LA, Costa WS, Sampaio FJ (2009) Kidney lower pole pelvicaliceal anatomy: comparative analysis between intravenous urogram and three-dimensional helical computed tomography. J Endourol 12:2035–2040. doi:10.1016/j.urology.2009.04.071
7. Geavlete P, Multescu R, Geaviete B (2008) Influence of pyelocaliceal anatomy on the sucess of flexible ureteroscopic approach. J Endourol 22:2235–2239. doi:10.1089/end.2008.9719
8. Ghani KR, Bultitude M, Hegarty N, Thomas K, Glass J (2012) Flexible ureterorenoscopy (URS) for lower pole calculi. BJU Int 110:294–298. doi:10.1111/j.1464-410X.2012.10616.x
9. Gupta NP, Singh DV, Hemal AK, Suhnasis M (2000) Infundibulopelvic anatomy and clearance of inferior caliceal calculi with shock wave lithotripsy. J Urol 163:24–27
10. Hussain M, Acher P, Penev B, Cynk M (2011) Redefining the limits of flexible ureteroscopy. J Endourol 25:45–49. doi:10.1089/end.2010.0236
11. Ito H, Kawahara T, Terao H, Ogawa T, Yao M, Kubota Y, Matsuzaki J (2013) Evaluation of preoperative measurement of stone surface area as a predictor of stone-free status after combined ureteroscopy with holmium lases lithotripsy: a single center experience. J Endourol 27:715–721. doi:10.1089/end.2012.0548
12. Jessen JP, Honeck P, Knoll T, wendt-Nordahl G (2014) Flexible ureteroreoscopy for lower pole stones: influence of the collecting system's anatomy. J Endourol 28:146–151. doi:10.1089/end.2013.0401
13. Jones JK, Krow A, Hariharan S, Weeks L (2008) Measuring angles on digitalized radiographic images using Microsoft PowerPoint. West Indian Med J 57:14–19
14. Knoll T, Jessen JP, Honeck P, Wendt-Nordahi G (2011) Flexible ureterorenoscopy versus miniaturized PNL for solitary renal calculi of 10–30mm size. World J Urol 29:755–759. doi:10.1007/s00345-011-0784-y
15. Knoll T, Musial A, Trojan L, Ptahnyk T, Michel MS, Alken P, Kohrmann KU (2003) Measurement of renal anatomy for prediction of lower-pole caliceal stone clearance: reproducibility of different parameters. J Endourol 7:447–451

16. Kumar PVS, Joshi HB, Keeley FX, Timoney AG (2000) An acute infundibulopelvic angle predicts failure of flexible ureteroscopy for lower calyceal stones. J Urol 163:339A
17. Miller J, Durack JC, Sorensen MD, Wang JH, Stoller ML (2013) Renal calyceal anatomy characterization with 3-dimensional in vivo computerized tomography imaging. J Urol 189:562–567. doi:10.1016/j.juro.2012.09.040
18. Preminger GM (2006) Management of lower pole renal calculi: shock wave lithothripsy versus percutaneous nephrolithotomy versus flexible ureteroscpy. Urol Res 34:108–111
19. Resorlu B, Oguz U, Resorlu EB, Oztuna D, Unsal A (2012) The impact of pelvicaliceal anatomy on the success of retrograde intrarenal surgery in patients with lower pole renal stones. Urology 79:61–66. doi:10.1016/j.urology.2011.06.031
20. Sampaio FJB (2000) Renal anatomy: endourologic considerations. Urol Clin North Am 27:585–607
21. Sampaio FJ, Aragao AH (1992) Inferior pole collecting system anatomy: its probable role in extracorporeal shock wave lithotripsy. J Urol 147:322–324
22. Sampaio FJB, D'Anunciação AL, Silva EC (1997) Comparative follow-up of patients with acute and obtuse infundibulum-pelvic angle submitted to extracorporeal shockwave lithotripsy for lower caliceal stones: preliminary report and proposed study design. J Endourol 11:157–161
23. Sampaio FJ, Mandarim de Lacerda CA (1988) Anatomic classification of the kidney collecting system for endourologic procedures. J Endourol 2:247–251