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Renal Lower Pole Ratio as a Predictor of Lower Pole Stone Clearance after extracorporeal shock wave lithotripsy

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Abstract

Background The Lower pole anatomy (apart from other factors: stone size, shock wave energy) is an important determinant of success after extracorporeal shockwave lithotripsy.

Objectives In this study, we aimed to determine if there is a significant relationship between lower pole ratio (infundibular length: infundibular width) on preoperative excretory urograms and stone fragment clearances after shockwave lithotripsy.

Methods A total of 60 patients with isolated lower pole stones were prospectively included in the study. Anatomical factors, such as infundibular length and width were measured and the lower pole ratio was calculated on pretreatment excretory urogram. Stone fragment clearance was assessed on periodic follow up visits (1-8weeks) with a plain abdominal X-ray for kidney, ureter and bladder.

Results The overall eight-week stone-free rate was 56.66%. Mean stone size ± SD was 11.383 ± 5 mm, mean infundibular length was 11.95 ± 6.52 mm, mean infundibular width was 4.25 ± 1.66 mm and mean lower pole ratio was 3.2 ± 2.4. Stone free status after shockwave lithotripsy was significantly related to infundibular length and width as well as to lower pole ratio. Infundibular length less than 25 mm, width greater than 4 mm and lower pole ratio less than 3.5 were noted to have an improved eight week stone-free rate.

Conclusion Lower pole anatomy is an important predetermining factor for lower pole stone clearance after shockwave lithotripsy. The present study suggests that a lower pole ratio of less than 3.5, which considers both infundibular length and width, is a promising and easily applicable predictor for stone-free status.

Key words Lower pole ratio, extracorporeal shockwave lithotripsy, stone clearance.

List of Abbreviation: SWL = shock wave lithotripsy, ESWL = extracorporeal shock wave lithotripsy, PCNL = percutaneous nephrolithotomy, KUB = kidney, ureter and bladder, CPH = calyceal pelvic height.

Introduction

Replacement of open surgery with minimally invasive techniques for treating stones in the renal tract has greatly reduced patients' morbidity and mortality and the period of hospitalization and convalescence. Extracorporeal shockwave lithotripsy does not require anesthesia and requires little analgesia so that treatment can be given on an outpatient basis, and there is no wound to heal [(1)].

Beginning in 1969 and funded by the German Ministry of Defense, Dornier began a study of the effects of shockwaves on tissue [(2)].

In 1972, on the basis of preliminary studies performed by Dornier Medical Systems [(3)] the development of the Dornier lithotripter progressed through several prototypes, ultimately culminating in February 1980 with the first treatment of a human by shock wave lithotripsy (SWL). The production and distribution of the Dornier HM3 lithotripter began in late 1983, and SWL was approved by the U.S. Food and Drug Administration in 1984. Since Dornier's pioneering work, numerous other companies have demonstrated that shockwaves capable of stone fragmentation may be generated by electromagnetic induction, micro explosions, focused lasers, and piezoelectric crystals. To date, more than 3000 lithotripters of all types have been placed worldwide, and more than 1 million patients are treated annually with SWL [(3)].

Generally, extracorporeal shock wave lithotripsy (ESWL) is characterized by a low complication rate and only by a few absolute contraindications [(4)].

An accurate estimation of the individual's probability of stone clearance may be essential for proper treatment selection to determine who will experience maximum benefit from ESWL. Therefore, the identification of prognostic factors compromising the clinical outcome of ESWL-treated calculi might be crucial to opt for the most appropriate maneuver [(5)].

The likelihood of fragmentation with ESWL depends on stone size and location, anatomy of renal collecting system, degree of obesity, and stone composition. ESWL is most effective for stones < 2 cm in diameter, in favorable anatomical locations. It is less effective for stones > 2 cm diameter, in lower-pole stones, in a calyceal diverticulum (poor drainage), and those composed of cystine or calcium oxalate monohydrate (very hard). Lower stone-free rates as compared with open surgery or percutaneous nephrolithotomy (PCNL) are accepted because of the minimal morbidity of ESWL [(5)].

Calculi situated in the lower calices represent a particular problem. First of all, a large number of renal calculi originate in the lower calices, and, obviously, the clearance rate of these stones appears to be reduced compared to other locations [(6)].

Secondly, ESWL fragments even from other parts of the kidney are recovered in favor of the lower calyces. This issue may be mainly attributed to the gravity. Moreover, the geometrical features of the lower calyx anatomy are also supposed to hamper the clearance. Prognostic factors such as the angle, length, or tightness of the infundibulum were analyzed in detail [(6)].

ESWL is a sophisticated procedure and demands skill. Knowledge about the characteristic features of the lithotripter is essential. Lithotripters vary in the source of shock wave generation, and later generation devices use smaller focal zones, allowing higher peak point pressures [(7)].

As any surgical procedure, ESWL yields a better clinical outcome when it is performed by an experienced user familiar with the device. Thus, urology training programs are recommended to focus carefully on ESWL because it is the least invasive of the common modalities for definitive stone treatment [(7)]. In general, the clearance rate of renal calculi varies, ranging from 45% to 95% [(8)].

The outcome of stone clearance after ESWL is strongly related to stone disintegration and clearance of the fragments [(9)]. Stone disintegration is affected by several factors, including stone factors (burden, number, composition), patient factors (obesity, body habitus), operator`s experience, and machine factor (type of lithotripter, shock wave number, shock wave energy) [(10-12)].

In addition, the clearance rate of stone fragments is influenced by stone location and the patterns of intrarenal collecting system drainage and urinary transport [(13-14)].

Hence, in 1992, Sampaio and Aragao studied the correlation of lower pole collecting system anatomy and ESWL from cadavers [(15)]. Lingeman et al demonstrated that the clearance rate of stone fragments was worse over the lower calyces than over the middle or upper calyces [(13)]. Accordingly, after the measurement of lower calyceal anatomy in excretory urography (EU) initially demonstrated by Elbahnasy et al many authors raised different viewpoints about the measurement of the lower calyceal anatomy [(16)].

Plain-film radiography of the kidneys, ureters and bladder may be sufficient to document the size and location of radiopaque urinary calculi.

Stones that contain calcium, such as calcium oxalate and calcium phosphate stones are easiest to detect by radiography [17]. Less radiopaque calculi, such as pure uric acid stones and stones composed mainly of cystine or magnesium ammonium-phosphate, may be difficult, if not impossible, to detect on plain-film radiographs. Excretory urograms have been considered the standard imaging modality for urinary tract calculi. The excretory urograms provides useful information about the stone (size, location, radiodensity) and its environment (calyceal anatomy, degree of obstruction), as well as the contralateral renal unit (function, anomalies). Excretory urogram is widely available, and its interpretation is well standardized [17] (Fig. 1).

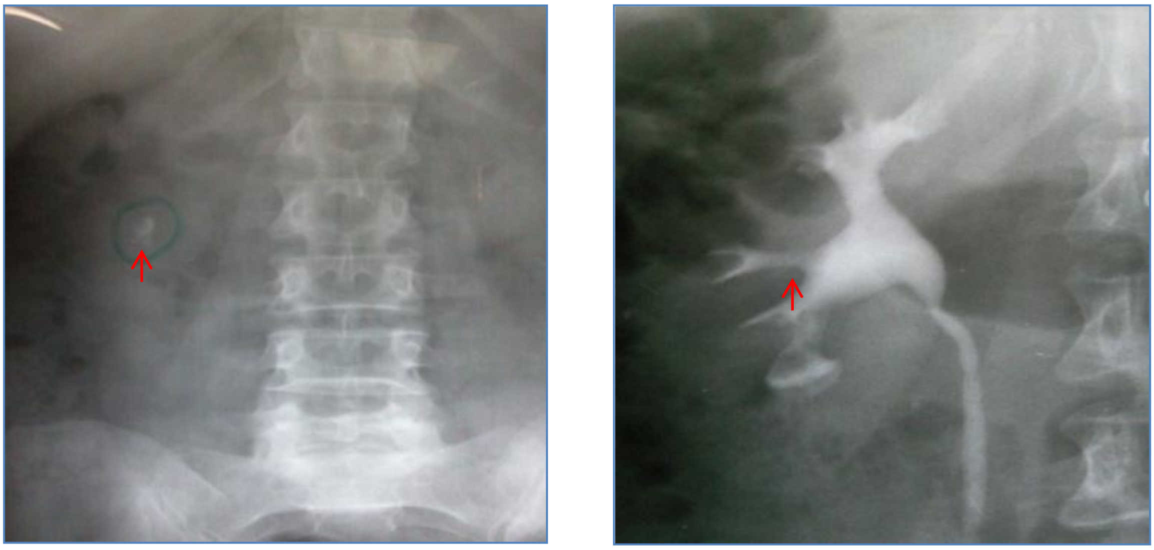

Fig. 1. X-ray (kidney, ureter and bladder) and excretory urogram showing lower pole stone.

Methods

In the time period between September 2008 and September 2011, a total of 80 patients, referred from the urology outpatient clinic in the Surgical Specialties Hospital, underwent ESWL for a solitary radio opaque lower pole renal stone detected on (excretory urograms) performed in the radiology department of the same hospital.

Exclusion criteria included stones greater than 20 mm, a documented pyelonephritis, previous renal surgery in two patients and renal anomalies (duplex kidney) in two patients. Sixteen patients defaulted follow-up or X-ray.

A total of 60 patients (34 male and 26 female) between 21 and 71 years old who underwent ESWL with Storze SLX FII machine were included in the study. Stone length was measured as the maximum diameter of the stone on the plain X-ray (KUB film). Pre-ESWL excretory urograms (5 minutes and 10 minutes films) were used to determine the lower pole infundibular length and width as previously described (Fig. 2).

The lower pole ratio (infundibular length: width) was then calculated. Lower pole infundibular length is the distance in mm from the most distal point at the bottom of the calyx to the midpoint at the lower lip of the renal pelvis. Lower pole infundibular width was measured at the narrowest point along the infundibular axis in mm [16] (Fig. 3).

Success of ESWL was determined by the stone-free status after 8 weeks. The patients were scheduled for follow up visits in outpatient clinic at (1st, 2nd, 3rd, 4th, 6th, and 8th week) post primary treatment. Routine abdominal X-rays of the KUB film were employed for follow up. Any stone fragment detectable on kidney, ureter and bladder abdominal X-rays (KUB films), regardless of size, persisting after 8 weeks was defined as a residual stone and they were managed with another treatment line.

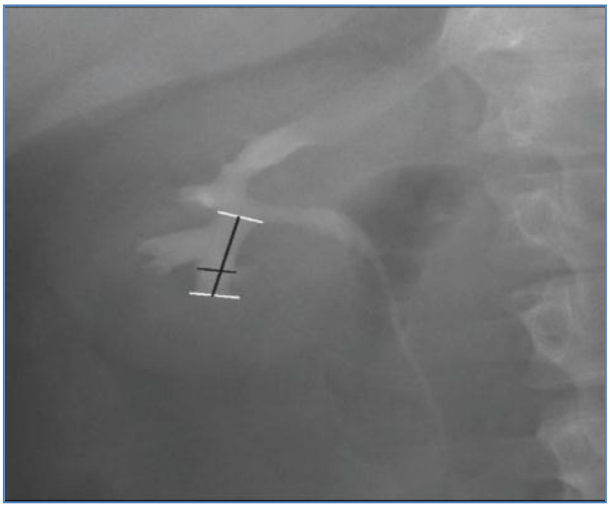

Fig. 2. Measuring lower pole infundibular length in 10 min. Excretory urogram (EU) film

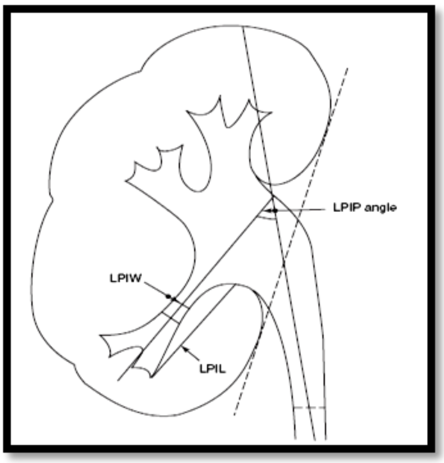

Fig. 3. Measurement of lower pole infundibular length, width and infundibulopelvic angle. LPIP angle, lower pole infundibulo-pelvic angle: LPIL. lower pole infundibular length: LPIW. lower pole infundibular width

Results

All 60 solitary stones were located in the lower pole, with a mean stone diameter of (11.38 ± 4.5 mm) for a patients group with a mean age of (46.31 ± 13.08 years). Of the 50 patients (28 males and 22 females), 34 were stone-free eight weeks after treatment for an overall stone clearance rate of 56.66%. There was no significant difference in the ages, sex distribution and mean stone sizes in the stone-free and residual stone group.

Significant difference between the stone-free and the residual stone groups were noted in the follow up period and the number of shock waves required, since the residual stone group were more reluctant to treatment (Table 1).

Table 1. Patient's characteristics and ESWL data

Parameter	Patients group			
	Stone free		Residual Stone	
	mean ± SD	range	mean ± SD	range
Age (years)	43.41 ± 15.42	21-71	50.12 ± 10.15	32-65
Number of shocks	3412 ± 1270	1500 - 6000	5058 ± 1614.5**	3000 - 7000
Stone Diameter (mm)	10.47 ± 4.33	6-20	12.58 ± 4.52	8-20
Follow Up Period (weeks)	1.56 ± 1	1-4	5.62 ± 2.2*	1-8

* = $P < 0.001$, ** $P = 0.00004$

The male:female ratio = 21:13 for stone free group and 17:9 for the residual stone group. The mean infundibular length was 11.95 ± 6.52mm, mean infundibular width was 4.25 ± 1.66 mm and the mean lower pole ratio was 3.2 ± 2.4. Univariate analysis revealed that infundibular length, width and lower pole ratios were significant predictors for stone clearance (Table 2).

Table 2. Univariat analysis of anatomical factors of Patient's groups predicting 8-weeks stone-free status

Parameters	Patients Group		*P* value
	Stone free	Residual Stone	
Mean Infundibular length (mm)	9.53 ± 5.21	15.12 ± 6.81	0.00065*
Mean Infundibular width (mm)	4.82 ± 1.59	3.42 ± 1.50	0.00017*
Mean Lower pole ratio	1.96 ± 1.06	4.87 ± 2.96	0.00001*

We evaluated the effect of lower pole anatomy on stone clearance based on the criteria described by Elbahasy *et al* (16) and Madbouly *et al* (18). We found that eight-weeks stone-free rates improved significantly in infundibular width of more than 4 mm (*P* = 0.0442) and that infundibular width of ≤ 4 mm predicted stone persistence and failure of ESWL (*P* = 0.0001) as noticed in Table 3.

Table 3. Infundibular width (mm) in Patient's groups

Infundibular width (mm)		Patients Group			*P* Value
		Stone free	Residual Stone	Total	
≤ 4	No.	13	22	35	
	% within infundibular	37.1	62.9	100	0.055
	% from Total	21.7	36.7	58.3	0.11
> 4	No.	21	4	25	
	% within infundibular	84.0	16.0	100	0.000006
	% from Total	35.0	6.7	41.7	0.00033
Total	No.	34	26	60	
	% within infundibular	56.7	43.3	100	
P value within patient group		0.0442	0.0001		

Most of patients in this study, 93.3%, had infundibular lengths of less than 25 mm. Infundibular length of less than 25 mm predicted successful treatment (*P* = 0.0001), while patients with infundibular length of ≥ 25 mm all had failed treatment with ESWL (Table 4).

Table 4. Infundibular length (mm) in Patient's groups

Infundibular length (mm)		Patients Group			*P Value*
		Stone free	Residual Stone	Total	
< 25	No.	34	22	56	0.038
	% within infundibular	60.7	39.3	100	0.044
	% from Total	56.7	36.7	93.3	
≥ 25	No.	0	4	4	
	% within infundibular	0.0	100	100	
	% from Total	0.0	6.7	6.7	
Total	No.	34	26	60	
	% within infundibular	56.7	43.3	100	
P value within patient group		0.0001			

Forty-two patients (70%) had lower pole ratio of 3.5 or less compared to 18 (30%) with lower pole ratio > 3.5 and this ratio was associated with better stone clearance (*P* < 0.0002) as seen in (Table 5).

Table 5. Lower pole ratio in patient's groups

L.P Ratio	Patients Group				Total		*P* value
	Stone free		Residual Stone				
	No.	%	No.	%	No.	%	
≤ 3.5	34	100	8	31	42	70	0.0002
> 3.5	0	0	18	69	18	30	
Total	34	100	26	100	60	100	

* = *P* < 0.05.

Discussion

Though ESWL is widely used in the treatment of renal stones, its efficacy in clearing lower pole stones has been questionable. In this study, the eight-week stone-free rate of 56.66% is comparable to other centers, which reported stone-free rates between 25 and 85% [(19)].

In a meta-analysis of the management lower pole stone, Lingeman *et al* [(14)] suggested that stone-free rate was significantly affected by stone size, dropping from 74% in lower pole stones less than 10 mm to 56.3% and 32.6% in stone size between 10 and 20 mm and more than 20 mm, respectively.

Most authors agreed that lower pole stone greater than 20 mm should be treated with percutaneous removal, but controversy arises when it comes to the primary management of lower pole stones between 10 and 20 mm in size. It is for this reason we decided to limit the present study stone size to less than 20 mm, with the majority of the stones between 10 and 20 mm [(15)].

The reason for the dismal result for lower pole stone clearance is due to fragment retention rather than failure of stone disintegration. Sampaio and Aragao first described the importance of inferior pole collecting system in ESWL in 1992 [(15)]. Subsequently, Elbahnasy *et al* [(16)] established the role of lower pole spatial anatomy, namely the infundibular length, width and angle in predicting the success of ESWL.

Other important anatomical factors affecting stone clearance after ESWL included calyceal pelvic height (CPH) by Tuckey *et al* [(20)] renal morphology by Madbouly *et al* [(18)] and number of minor calyces by Sumino *et al*.[21]

We excluded patients with abnormal renal morphology either congenital or acquired from infection or renal surgery. We did not consider the measurement of CPH as it may vary with respiration or postural changing of the kidney.[21]

In the present study, we used the method of Elbahnasy *et al*. for the measurement of lower pole spatial anatomy [(16)]. The mean infundibular length in our patients was found to be shorter than that described by Elbahasy *et al* [(16)] and Madbouly *et al* [(18)] (11.95 ± 6.52 mm *vs.* 29.9 mm and 36.4 mm, respectively). This difference may be due to the different study population or different imaging films used in excretory urograms. Unfortunately no other Asian study is available for reference. However, the mean infundibular width was comparable using the lower pole anatomical predictors proposed by Elbahasy *et al* [(16)]. In this study lower pole eight-weeks stone-free rates were significantly better in patients with infundibular widths of more than 4 mm and infundibular lengths of less than 25 mm. Univariate analyses confirmed that both infundibular length and width were important predictors for stone-free rate and that infundibular width (using the mean infundibular width) was a stronger predictor. The mean

infundibular length was significantly shorter and the infundibular width significantly wider in the stone-free group.
An interesting article by Knoll *et al* [22] showed a high interpersonal variation in the measurement of the lower pole anatomy. In the present study, we measured the parameters twice on two separate contrast-filled films by two urologists. The average of the measurements was taken for the final analysis. Most of the measurements were within the 10 percent margin. However, this is an important consideration for the measurement of the parameters and further prospective studies will need to be done to improve the reproducibility of these measurements.
Anatomical measurements of the lower pole were all derived from intravenous urograms, which neglected the 3-D anatomy of the lower pole, especially the lower pole infundibular opening. However, it is time consuming and expensive to employ CT scans with 3-D reconstruction to obtain 3-D measurements. We measured the narrowest point along the infundibular axis as the infundibular width and it correlated well with the success of shockwave lithotripsy for lower pole stone. We propose the use of a lower pole ratio for predicting the success of ESWL, as it considers both these important factors. Patients with a lower pole ratio of 3.5 or less had a significantly better stone clearance rate when compared to those with a ratio >3.5 (*P* value=0.0002) making it a better candidate for predicting eight-weeks stone-free status compared to infundibular length or width alone.
In conclusion, lower pole spatial anatomy, namely the infundibular length and width, has a significant role in the stone-free status after ESWL. Classifications of an infundibular width > 4 mm and an infundibular length ≤ 25 mm had an impact on the eight-week stone-free rate. A lower pole ratio of 3.5 seems to be a promising predictor, as it considers both anatomical factors. This will be especially helpful in deciding the first-line treatment for lower pole stones measuring between 10 and 20 mm in maximum diameter.

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Author contribution

Dr. Adil Al Soufi and Dr. Raghib Jassam were diagnosed and collected the cases and Dr. Saif Al Haideri follows the patients during their treatment course and statistically interpreting the data.

Conflict of Interest

The author declares no conflict of interest.

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References

1. Wickham JEA. Minimally invasive surgery, treatment of urinary stones. BMJ. 1993; 307: 1414-7.
2. Matlaga BR, Lingeman JE. Campbell-Walash urology 10th ed. Chap. 48, Surgical Management of Upper Urinary Tract Calculi, 2010; p.p 1324-60.
3. Chaussy C, Fuchs G. Extracorporeal lithotripsy in the treatment of renal lithiasis. 5 years' experience. J Urol (Paris). 1986; 92: 339-43.
4. Skolarikos A, Alivizatos G, de la Rosette J. Extracorporeal shock wave lithotripsy 25 years later: complications and their prevention. Eur Urol. 2006; 50: 981-90.
5. Albala DM, Gomella LG, Allen F. Oxford American Handbook of Urology, Chap. 8, 1st ed., 2011; p.p 372-73.
6. Tiselius HG, Ackermann D, Alken P, et al. Working Party on Lithiasis. Guidelines on urolithiasis. Eur Urol. 2001; 40: 362-71.
7. Augustin H. Prediction of stone-free rate after ESWL. Eur Urol. 2007; 52: 318-20.
8. Clayman RV, McClennan BL, Garvin TJ, et al. Lithostar: an electromagnetic acoustic shock wave unit for extracorporeal lithotripsy. J Endourol. 1989; 3: 307-10.
9. Ruggera L, Beltrami P, Ballario R, et al. Impact of anatomical pyelocalyceal topography in the treatment of renal lower calyces stones with extracorporeal shock wave lithotripsy. Int J Urol. 2005; 12: 525-32.

10. Gerber R, Studer UE, Danuser H. Is newer always better? A comparative study of 3 lithotriptor generations. J Urol. 2005; 173: 2013-6.
11. Graber SF, Danuser H, Hochreiter WW, et al. A prospective randomized trial comparing 2 lithotriptors for stone disintegration and induced renal trauma. J Urol. 2003; 169: 54-7.
12. Portis AJ, Yan Y, Pattaras JG, et al. Matched pair analysis of shock wave lithotripsy effectiveness for comparison of lithotripters, J Urol. 2003; 169: 58-62.
13. Schulz E, Hengst E, Brundig P, et al. Disturbed urinary transport in the pelvi-calyceal system in calcium-oxalate stone patients. Urol Res. 1987; 15: 109-13.
14. Lingeman JE, Siegel YI, Steele B, et al. Management of lower pole nephrolithiasis: a critical analysis. J Urol. 1994; 151: 663-7.
15. Sampaio FJB, Aragao AHM. Inferior pole collecting system anatomy: it`s probable role in extracorporeal shock wave lithotripsy. J Urol. 1992; 147: 322-4.
16. Elbahnasy AM, Clayman RV, Shalhav AL, et al. Lower-pole caliceal stone clearance after shockwave lithotripsy, percutaneous nephrostolithotomy, and flexible ureteroscopy: impact of radiographic spatial anatomy. J Endourol. 1998; 12: 113-9.
17. Portis AJ, Sundram CP. Diagnosis and Initial Management of Kidney Stones. Am Fam Physician. 2001; 63(7): 1329-34.
18. Madbouly K, Sheir KZ, Elsobky E. Impact of lower pole renal anatomy on stone clearance after shock wave lithotripsy: Fact or Fiction? J Urol. 2001; 165: 1415-18.
19. Chen RN, Streem SB. Extracorporeal shock wave lithotripsy for lower pole calculi: long-term radiographic and clinical outcome. J Urol. 1996; 156: 1572-5.
20. Tuckey J, Devasia A, Murthy L. Is there a simpler method for predicting lower pole stone clearance after shock wave lithotripsy than measuring infundibulopelvic angle? J Endourol. 2000; 14: 475-8.
21. Sumino Y, Mimata H, Tasaki Y. Predictors of lower pole renal stone clearance after extracorporeal shock wave lithotripsy. J Urol. 2002; 168: 1344-7.
22. Knoll T, Musial A, Trojan L. Measurement of renal anatomy for prediction of lower pole caliceal stone clearance: reproducibility of different parameters. J Endourol. 2003; 17: 447-51.

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