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The efficacy of radiographic anatomical measurement methods in predicting success after extracorporeal shockwave lithotripsy for lower pole kidney stones

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ABSTRACT

Objectives: To assess the impact of lower pole calyceal anatomy on clearace of lower pole stones after extracorporeal shockwave lithotripsy (ESWL) by means of a new and previously defined radiographic measurement method.

Materials and Methods: Sixty-four patients with solitary radiopaque lower pole kidney stones were enrolled in the study. Infundibulopelvic angle (IPA), infundibulotransverse angle (ITA), infundibular lenght(IL), and infundibular width (IW) were measured on the intravenous urographies which were taken before the procedure.

Results: 48 of 64 patients (75%) were stone-free after a follow-up period of 3 months. The IPA,ITA,IL and IW were determined as statistically significant factors, while age,gender and stone area were found to have no impact on clearance.

Conclusion: By the help of radiographic measurement methods related to lower pole kidney anatomy, appropriate patient selection and increment in success after ESWL may be achieved.

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INTRODUCTION

Urinary stone disease is a common urological problem with several treatment alternatives. Besides its high level of patient approval and low complication rates, the non-invasive nature and cost- effectiveness of extracorporeal shockwave lithotripsy (ESWL) have rendered this treatment modality a preferred option for most of the urinary calculi (1-5). It has been determined that many factors, including the size, composition and location of the stone and the infundibulopelvic anatomy of kidney are involved in the success of ESWL (6-8). The success rate of ESWL in the lower pole stones was reported to be the poorest when any other locations were taken into account (1,9). Gravity dependent position was thought to be a crucial factor in retention of the fragments rather than stone disintegration (9). Moreover particular spatial anatomical factors seem to be important in spite of the contradicting data.

The anatomical features of the lower pole collecting system and its possible effects on fragment passage were firstly investigated by Sampaio and Aragao (10). They concluded that the Infundibulopelvic angle (IPA) (Angle between the main lower infundibulum and renal pelvis), the lower infundibular diameters and the distribution of lower calices might be important in the clearance of disintegrated fragments of ESWL. After this study many authors have defined and evaluated several methods to predict the success of ESWL in lower pole kidney stones. In the current study in addition to previous methods a new method utilizing the radiographic anatomy was evaluated in order to determine the influence of lower polar anatomy on success of ESWL.

MATERIAL AND METHODS

Patients, treated by ESWL with the diagnosis of lower pole kidney stones, between January 2004 and February 2008 were reviewed retrospectively. Cases with single radiopaque lower pole stones, 20mm. or less in size, were selected to comprise the study population. Radiolucent or multiple renal stones, abnormal renal or vertebral anatomy (rotation abnormalities, scoliosis, etc...), history of previous surgical intervention, severe hydronephrosis and follow-up less than 3 months were accepted as exclusion criteria.

Before ESWL all patients underwent renal ultrasonography and plain film of the urinary system in addition to intravenous urography (IVU). All IVUs were performed from 1m. distance by bolus radiopaque injection and without compression device application. Stone surface area was calculated on the anteroposterior plain film of IVU series, by multiplying the stone length by stone width in mm (11). IVU films taken at 10-15 minutes were utilized to measure IPA, infundibulotransvers angle (ITA), infundibular length (IL) and infundibular width (IW). Apart from the method of El-Bahnasy et al. (Figure-1), the method described by Sampaio et al. (Figure-2) was also used to measure the IPA (10,12). A line between the most distal point of the infundibulum containing the stone and midpoint at the lower lip of the renal pelvis was determined as IL. IW was measured at the narrowest point of infundibulum along the infundibulopelvic axis. ITA was described as the angle between the central axis of the lower pole infundibulum and a line, perpendicular to the midvertebral line (Figure-3).

A third-generation lithotripter, the electrohydraulic Stone Litho3pter (PCK, Ankara, Turkey) was used in the treatment of patients. All patients received diclofenac sodium preoperatively for the

Figure 1 - El-Bahnasy defined infundibulopelvic angle as the inner angle between the ureteropelvic axis (A line connecting the central point of the pelvis opposite the margins of superior and inferior renal sinuses to the central point of the ureter opposite the lower kidney pole) and central axis of lower pole infundibulum.

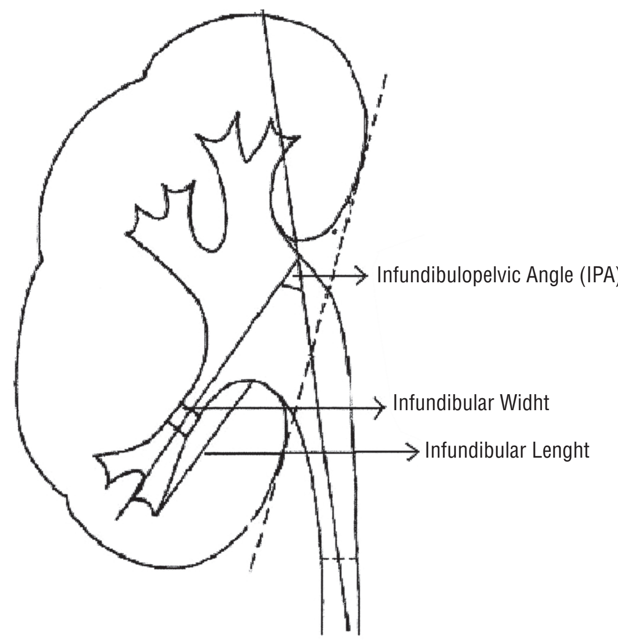
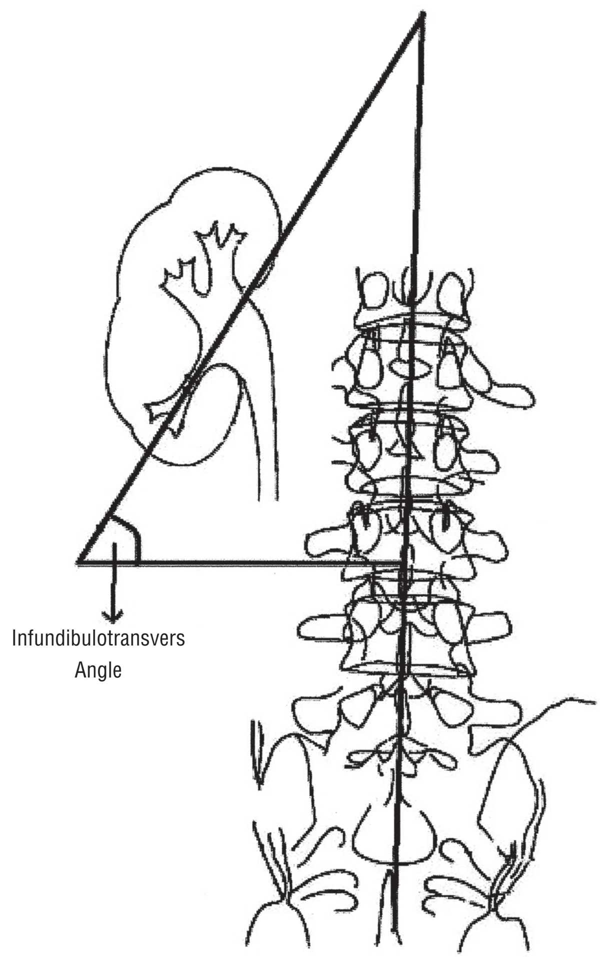


Figure 2 - Infundibulopelvic angle described by Sampaio et al. The angle formed by the central axis of the infundibulum containing the calculi and another axis connecting the central points of the ureter at the lower pole and ureteropelvic region.

Figure 3 - Infundibulutransverse angle was described as the angle between the central axis of the lower pole infundibulum and a line which is obtained by drawing a perpendicular to midvertebral line (A line passing through the mid portions of vertebral bodies, connecting the spines).



pain management. That 1500-2000 shocks at 15-20kv. were delivered in every ESWL session was learned from patient charts. During ESWL and follow-up periods no postural drainage was performed and no additional medication was given.

According to routine follow-up procedures of the department, all patients were evaluated after every ESWL session with renal ultrasonography and plain films. Following the last ESWL session that resulted in residual fragments smaller than 4mm, the patients were monitored for 3 months to control the stone-free status.

No fragmentation of the kidney stones in three consecutive ESWL sessions or any residual stone fragment in any size after the end of 3-month follow-up were defined as treatment failure.

Patients were grouped according to the success of ESWL. Predictive value of all variables was tested by discriminant analysis and categorical data was compared by Chi-square test. P values < 0.05 were accepted as statistically significant. Chi-square test and discriminant analysis were performed by means of SPSS version 15 (SPSS Inc., Chicago, IL, USA) for Windows.

RESULTS

Sixty-four patients (32 female, 32 male patients with a mean age of 43) who had met the entry criteria were enrolled in the study. 48 patients (75%) were stone free after the follow-up period. Number of males and females were equal (50% male, 50% female). The age and gender differences of the patients had no significant influences on the success rate ($p < 0.05$). Mean IPA in the stone-free and the residual stone groups, measured with the methods of El-Bahnasy and Sampaio were 50.2 ± 9.82, 99.41 ± 18.3 and 37.75 ± 11.6, 69.43 ± 12.08 respectively. IL was 24.45 ± 4.18mm in the stone-free group and 31.81 ± 7.3mm. in the residual group. Mean values for the novel method, ITA, were 69.81 ± 22.26 and 50.22 ± 9.82 in residual and stone-free groups respectively. Detailed data of evaluated variables are presented in Table-1.

Statistical significance statuses of the variables are shown on Table-2. According to the discriminant analysis, statistically significant variables that could differentiate stone-free patients from those with residual stones were IPA (both Sampaio and El-Bahnasy), IL, IW, ITA. Stone area was found to be an insignificant factor.

Given the structure matrix analysis, presented in Table-3, IPA measured by Sampaio's method was found to have the highest power to discriminate the stone-free and residual stone groups. It was followed by IL and ITA.

To find the most effective cut off points of IPAs (measured by two methods) and ITA, sensitivity and specificity values of every angle between 20

Table 1 - Mean and standard deviation values of the variables.

Success	Mean	Std. Deviation	Valid N
Residual Stone			
IPA (El-Bahnasy) (degree)	37.75	11.61	16
IW (mm)	4.68	2.44	16
IL (mm)	31.81	7.34	16
Stone Area (mm^2)	127.68	132.6	16
IPA (Sampaio) (degree)	69.43	12.08	16
ITA (degree)	69.81	22.26	16
Number of Shocks	5975	569.8	16
Stone-free			
IPA (El-Bahnasy) (degree)	50.22	9.82	48
IW (mm)	6.66	2.92	48
IL (mm)	24.45	4.18	48
Stone Area (mm^2)	88.06	70.02	48
IPA (Sampaio) (degree)	99.41	18.3	48
ITA (degree)	51.22	10.55	48
Number of Shocks	3729.1	2645.6	48
Total			
IPA (El-Bahnasy) (degree)	47.1	11.56	64
IW (mm)	6.17	2.92	64
IL (mm)	26.29	6.01	64
Stone Area (mm^2)	97.96	90.24	64
IPA (Sampaio) (degree)	91.92	21.35	64
ITA (degree)	55.87	16.33	64
Number of Shocks	4290.6	2501.9	64

and 100 were calculated in 10 degree increments. The highest sensitivity rate with a reasonable specificity was obtained at 70 degrees for the IPA, measured by Sampaio's method. The probability of stone clearance was estimated to be 8.6 folds higher (Odd's ratio) at angles over 70 degrees (Table-4). The sensitivity and specificity rate of ITA at 60^o were found to be 83% and 50% respectively. Stone clearance rate was calculated to be 5 times higher at angles over 60^o for ITA.

Table 2 - Significance status of variables.

	Wilks' Lambda	F	Significance (p values)
IPA-1 (El-Bahnasy) (degree)	0.778	17.66	0.000
IW (mm)	0.913	5.92	0.018
IL (mm)	0.715	24.68	0.000
Stone Area (mm^2)	0.963	2.36	0.129
IPA-2 (Sampaio) (degree)	0.625	37.27	0.000
ITA (degree)	0.754	20.27	0.000
Number of Shocks	0.847	11.24	0.001
IPA-1 + IPA-2	0.624	37.4	0.000
IPA-1 + ITA	0.966	0.273	0.603
IPA-2 + ITA	0.998	0.146	0.703
IPA-1 + IPA-2 + ITA	0.798	15.65	0.000

The cut off points (IPA measured with El--Bahnasy's method and ITA) and their sensitivity and specificity rates are presented on Table-4.

Table 3 - Structure Matrix. Negative values indicates inverse relationship of variables with success.

	Function
	1
IPA-1 (Sampaio)	0.646
IL	-0.525
ITA	-0.476
IPA-2 (El-Bahnasy)	0.445
Number of Shocks	-0.355
IW	0.257
Stone Area	-0.163
IPA-1 + IPA-2	0.648
IPA-1 + ITA	0.055
IPA-2 + ITA	0.045
IPA-1 + IPA-2 + ITA	0.419

DISCUSSION

The ambiguity in determining a reliable factor for predicting the success of ESWL in lower pole kidney stones have resulted in several studies in which the significance of many anatomical factors have been investigated. After the study carried by Bagley and Rittenber (13) which analyzed the effect of lower pole infundibular length on the clearance of fragments after ureteroscopic intervention, the pioneer study about the spatial anatomy of lower pole was conducted by Sampaio and Aragao (10). The interrelationship was investigated by the help of 3-D polyester resin endocasts of collecting systems, which were procured from cadavers. Sampaio et al. concluded that IPA, diameter of lower pole infundibulum and inferior pole calyceal distribution may have played an important role in drainage of the lower pole collecting system (10). In a subsequent assessment of the same authors, the significance of the radiographic measurements was evaluated and previously determined factors were found to be important in the evacuation of fragments after ESWL (14).

Afterwards, in order to define more constant radiographic landmarks, a new method was suggested by El-Bahnasy et al. to measure the lo-

Table 4 - Sensitivity and specificity rates of IPAs (Sampaio and El- Bahnasy) and ITA when different angles were taken as cut off points.

IPA (Sampaio)	60º	70º	80º
Sensitivity	95%	89.5%	79.5%
Specificity	25%	50%	93.3%
ITA	50º	60º	70º
Sensitivity	48%	83%	100%
Specificity	75%	50%	31%
IPA (El-Bahnasy)	30º	40º	50º
Sensitivity	94%	81%	39.5%
Specificity	21%	62.5%	100%

wer pole IPA (12). The effect of infundibular width and length was investigated as well. All IPA, IW, IL were established as statistically significant factors that influence the clearance of stone fragments following ESWL (12). Keeley et al. suggested that IPA was the only factor associated with stone free status (15). Likewise Ghoneim et al. identified the lower pole IPA and IL as significant factors in stone clearance, however he found IW not to have significance on fragment evacuation (16). In several other studies investigating the significance of pelvicalyceal anatomy IW, IL and IPA, whether solely or together, were found to have impact on clearance of fragments (10,12,15-23) (Table-5).

Contradicting studies, investigating the importance of the lower pole kidney anatomy also exist in the literature. Madbouly et al., Sorensen et al. and Sahinkanat reported that they didn't observe any significant impact of the lower pole pelvicalyceal anatomy on the outcome after ESWL (24,25).

In our current study, methods of both Sampaio and El-Bahnasy were used to determine the IPA. In the final analysis, the angle was observed to be significantly obtuse in the stone-free patients regardless of the methods ($p = 0.001$). Although Sampaio's original study reported a critical angle of 90º as the most reasonable sensitivity and specificity rates (Table-4),

Table 5 - Results of some studies investigating the effect of IPA, IL and IW on success after ESWL.

	IPA	IL	IW
Sampaio, 1997 (10)	+	N/A	+
Sabnis, 1997 (17)	+	N/A	+
El- Bahnasy, 1998 (12)	+	+	+
Keeley, 1999 (15)	+	N/A	-
Madbouly, 2001 (24)	-	-	-
Sorensen, 2002 (11)	-	-	-
Sumino, 2002 (19)	-	-	+
Fong, 2004 (18)	-	+	+
Ruggera, 2005 (23)	+	+	+
Ghoneim, 2005 (16)	+	+	-
Talas, 2007 (20)	+	-	-
Tan, 2007 (21)	+	+	+
Sahinkanat, 2008 (31)	-	-	-
Lin, 2008 (22)	-	-	+

(+) = Denotes statistically significant factor; **(-) =** Denotes statistically insignificant factor; **N/A =** Not applicable; **IPA =** Infundibulopelvic angle; **IL =** Infundibular length; **IW =** Infundibular width.

we considered 70° to be the cut off point with the method of Sampaio. Additionally, IL and IW were other parameters that correlated with stone-free status (Table-2).

Stone size was reported to be one of the key elements, besides stone location (9,26-29). Sorensen et al. and Abala et al. indicated the negative correlation of stone burden with the stone free rate (11,30). However, in our study no significant relationship could be established between the outcome and the stone burden. From this aspect, our data collaborates with the findings of Ghoneim et al., Keeley et al., Madbouly et al., and Sahinkanat et al. (15,16,24,31). This may be ascribed to our small cohort. Besides, impact of stone size on clearance may not be accurately evaluated due to selection bias as patients with stones lower than 20mm comprise the cohort.

Due to the tortuosity or distortion of the proximal ureter while measuring the IPA, in some cases precise measurement may not be possible. In order to manage with this difficulty, Tuckey et al. proposed calyceal-pelvic height (CPH), which is defined as the distance between the highest point of the lower lip of renal pelvis and the deepest point of calyx encompassing the calculi (32). However the effectiveness of the CPH was not confirmed by some of the subsequent studies (19,25). Having mentioned the complexity of measurement methods Sahinkanat proposed another novel method, parenchyma-to-ureter distance (PUD) to estimate the success of ESWL in lower pole kidney stones. He reported PUD to be the only significant method in determining the stone-free status after ESWL for lower pole kidney stones (31).

By the same token, to provide a more dependable measurement and to eliminate the difficulties encountered on IVU, ITA has been suggested in the current study. Anatomic structures which seem to be more fixed were utilized in the formation of the method. ITA was demonstrated to be a statistically significant variable in the determination of the stone-free patients ($p < 0.01$). 60° may be taken as the critical angle when the sensitivity and the specificity values were regarded (Table-4). ITA also seems to be one of the superior methods among the others in terms of discriminating the stone-free patients from residual stone group (Table-2). It has the third highest power in estimation of the success following ESWL. We believe that the efficacy of the method needs to be investigated in different and larger cohorts.

As the three-dimensional structure of the lower pole pelvicalyceal anatomy and the stone size may not be evaluated precisely by the help of two-dimensional conventional methods, contradicting results are not surprising.

Body habitus, hydration condition and respiratory movements during radiographic procedures may be counted as other factors contributing to the equivocal results (16,24). The importance of positional chances was pointed out by Sengupta et al. (33). He reported the positional change of the body to be a significant factor that causes planar differences of kidneys. Kim et al. observed the motions of the abdominal organs by the means of four-dimensional CT and he reported cranio-caudal average movements of the right and left kidneys to be 14.3mm. and 12.3mm, respectively, in supine position and 12.1 and 12.6mm, respectively, in the prone position (34).

It is appropriate that applicability of the current methods to predict the success of ESWL in lower pole kidney stones should be investigated on 3 dimensional or 4-dimensional imaging technics. We also believe it is essential that a comparison of 2-dimensional and 3-dimensional modalities should be performed. Besides these, ultrasonographic parameters can also be evaluated.

Although there is not a standardized method of assessing the density of calculi currently, kidney stone density reported to be another factor influencing the success of ESWL (35). Combining the aforementioned anatomical factors, and stone morphology or density may increase our selectivity while deciding the appropriate modality of treatment.

CONCLUSIONS

Although IPA, IW and IL were found to be statistically significant 2-dimentional measurement methods in our study, debate on their reliability still exists. ITA seems to be a useful method but its validity should be confirmed by other studies. Novel 3-dimentional measurement methods evaluating the lower pole calyceal anatomy may help us define accurate patients groups that will benefit from ESWL treatment.

CONFLICT OF INTEREST

None declared.

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