Inferior Pelvicalyceal Anatomy – An Important Determinant of Residual Stone Clearance after Shock Wave Lithotripsy.

Umar Farouqi[1], Yogendra S. Gaharwar[2], B.Surya Prakash[3], D. Kashinatham[4]

[1]Associate Consultant, Department of Urology, Max Hospital Patparganj, New Delhi.
[2]DNB Resident, Department of Urology, Yashoda Hospital, Hyderabad.
[3]Head of Department, Department of Urology, Yashoda Hospital, Hyderabad.
[4]Senior Consultant, Department of Urology, Yashoda Hospital, Hyderabad.

ABSTRACT

Background: Shock wave lithotripsy (SWL) has revolutionized the treatment of renal stones. Clearance of stones after SWL depends upon a multitude of factors. The purpose of this study was to evaluate the effect of inferior calyceal anatomy on the stone clearance after SWL for renal stones. **Methods:** The study included a total 52 patients with age between 21 and 81 years admitted in our hospital with renal stones who were treated with SWL. The factors studied were- Infundibulo-pelvic angle (IPA), Infundibular length (IL), Infundibular width (IW) and their affect on stone clearance. **Results:** In the lower caliceal system three factors for stone clearance were studied; patients with an infundibulo-pelvic angle (IPA) of more than 89.3 degree had a statistically significant clearance as compared an angle less than that (p=0.0000 ; 95% confidence interval [CI] , 0.774 to 1.1036); patients with an infundibular length (IL) of less than 26mm had a statistically significant clearance (p=0.0004; 95% confidence interval [CI] , 0.616 to 0.0945); the infundibular width did not have a significant role in stone clearance in our study. **Conclusion:** In the lower calyceal system, the infundibulo-pelvic angle (IPA) and the infundibular length (IL) play a significant role in stone clearance.

Keywords: inferior pelvi-calyceal anatomy , residual stone , shock wave lithotripsy .

INTRODUCTION

As the world moves from invasive modalities of therapy to noninvasive ones in all fields of medicine, one invention stands out as the most revolutionary invention of the century: Shock-Wave lithotripsy (SWL). What was a mere figment of some-one's imagination has become an actual reality with the advent of SWL. The Hippocratic Oath that "I will never cut for a stone" has become a welcome reality with the help of SWL.

Since the first report of its efficacy and safety in early 1980's , SWL has become the treatment of choice for most renal stones in adults.[1] The stone clearance rate after ESWL in some studies is achieved in about 96 % cases , although clearance rates are lower for caliceal than for pelvic calculi.[2] Usually , this method eradicates stones in approximately 70 % cases, with a range varying from 45 to 95 %.[3] SWL has emerged as the primary treatment of choice for renal calculi less than 1.5 – 2.0 cm in size.[4]

It is a safe and simple technique in which renal and ureteric calculi are pulverized into small fragments by the shockwaves and then allowed to pass spontaneously in small fragments along with the urine.

Name & Address of Corresponding Author
Dr Umar Farouqi
Associate Consultant,
Department of Urology,
Max Hospital Patparganj,
New Delhi, India.
E-mail: drumarfarouqi@gmail.com

SWL is a non-invasive procedure and needs less or no anesthesia in comparison to other procedures. The success in SWL arises from the effective fragmentation and clearance of stones. Successful SWL is usually defined as stone free or residual fragments of less than 4 mm in size at three months of follow up.[5] However the successful treatment remains lower than the disintegration rate. Several factors have been identified which affect the clearance of residual stones fragments after SWL. Among the various factors affecting the outcome, some of important ones are:[6]

1. Stone Burden.
2. Stone Composition.
3. Stone Location.
4. Inferior Pelvi-Calyceal Anatomy .
5. Body Mass Index (BMI).

The natural history of the residual fragments depends upon the initial location; residual fragments located in the renal pelvis have a spontaneous clearance rate of 66%. The spontaneous clearance rate of residual fragments in middle calyx is about 50% and in inferior calyx it is 37 %.[7] Poorer clearance rate for the lower caliceal system is considered due to gravity.

Width, length of the infundibulum and infundibulopelvic angle has been shown to be relevant for stone clearance after SWL for lower pole stones.

Stone clearance has been shown to be poorer for an acutely angled than for an obtusely angled inferior calyx and better for a shorter calyx with a wider infundibulum than for a longer calyx with a narrower neck.[8]

It was found that patient with all the three unfavourable factors have only 17 percent success rate;[9] also in some studies it was found that infundibulopelvic angle was the only significant factor predicting the stone free status after SWL for lower pole calculi.[10]
The present observational study was aimed to study the effect of the inferior calyceal anatomy on the clearance of residual stone fragments after shock wave lithotripsy.

MATERIALS AND METHODS

The present study was carried out at Yashoda Hospital in the Department of Urology during the period from July 2012 to Dec 2014.
The study was carried out to evaluate the effect of inferior calyceal anatomy on the outcome and stone clearance after shock wave lithotripsy (SWL) for inferior calyceal renal stones.
Institutional Ethical Committee approval was obtained. It was a prospective, observational study. The study included a total 52 patients with age between 21 and 81 years admitted in our hospital with renal stones who were treated with shock wave lithotripsy (SWL). The procedure is done routinely in our hospital; about 4 -5 cases are done per week. All the information obtained was recorded on a specially designed proforma.

1. Study Design and patients: It was a Prospective Observational Study. The following clinical data were documented: age and gender of the patients, laterality and location of stones, anatomical parameters of the inferior calyces, and treatment outcome after SWL. Success of SWL was evaluated as the stone free rate at 1 and 3 months after SWL. We investigated treatment outcomes according to inferior calyceal anatomy parameters and analysed the factors affecting success of SWL.

2. Inclusion and Exclusion Criteria:

Inclusion Criteria:

1. Patients with age more than 18 years.
2. Patients of the either gender.
3. Patients with stones in one side kidney only (unilateral).
4. Patients with stones ranging from 4 to 20 millimeters in size.

Exclusion Criteria:

1. Age < 18 years.
2. Presence of congenital anomalies of the kidney or the urinary tract (e.g horse shoe kidney).
3. Presence of multiple stones or branched calculi .
4. Patients with stones of size more than 20 mm. (2 cm).
5. Patients with pregnancy and coagulopathy.
6. Patients with hydronephrosis and untreated urinary tract infection.
7. Patients with non functional kidneys.
8. Patients with bilateral stones.
9. Patients with history of prior surgery on kidneys.
10. A patient not willing for repeat sessions on failure of disintegration at any sessions , despite the treating surgeon's advice.

3. Patient preparation and SWL procedure.

Evaluation of Patient before the Procedure.

(a) **Informed Consent:** Details of present study process including potential side effects and risks involved were explained to all patients and relatives. A detailed informed consent was obtained from the patients.
(b) **History and Examination:** A detailed medical and surgical history including a general and systemic examination was carried out.
(c) **Investigations:** The patients were evaluated by complete urine examination (CUE) , urine culture sensitivity (patients who were culture positive were treated with appropriate antibiotics , documented sterile urine and then taken for the treatment) , ultra-sonography (USG) , X ray kidney , ureter and bladder (KUB) for visualization of stone ; renal function test ; intravenous urography (IVU) and the findings were recorded.

Evaluation of the intravenous urogram (IVU) played an important role in our study. The following inferior calyceal anatomical factors on IVU were studied:[11]

(a) **Infundibular Length (IL)** was defined as the length from the most distal point of lower Calyx, where the targeted stone is located, to the midpoint of both sides of the opening of the lower calyx into the renal pelvis [Figure 1].
(b) **Infundibular Width (IW)** was determined from the narrowest point of the lower calyx [Figure 2].
(c) **Infundibulo-Pelvic angle (IPA)** was the inner angle created by intersection of 2 lines. The first line, the central axis of lower pole infundibulum was drawn by connecting two distal parts of lower infundibulum and opening of infundibulum

into the renal pelvis. The other line, the ureteropelvic line was created by connecting the midpoint of the renal pelvis opposite the margins of the superior and inferior renal sinus to midpoint of ureter opposite the inferior border of lower pole of kidney [Figure 3].

The calculations done on the intravenous urogram are shown in [Figure 4].

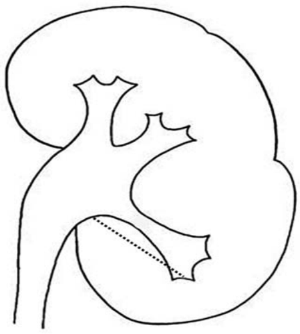

Figure 1: Infundibular Length (IL)

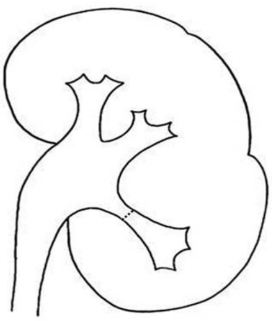

Figure 2: Infundibular Width (IW)

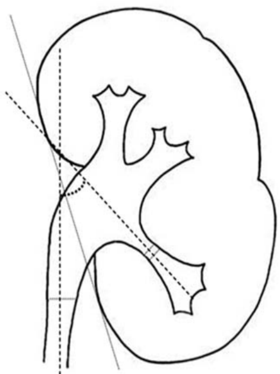

Figure 3: Infundibulo-Pelvic Angle (IPA)

Preoperative preparation:
Patients were evaluated by the anaesthesiologists pre operatively and were kept nil per oral for 4-6 hours. Preoperative antibiotics included a single dose of 1.0 gm of ceftriaxone given 20-30 min before the procedure.

Patient and Side Identification: Pre operatively all the patients were made to wear bands on their hands with their names , in patient admission numbers, side of surgery and name of the in charge surgeon. All patients had their side marking done preoperatively with skin marking pencils

Figure 4: Intravenousurogram showing the measurements of infundibulopelvic angle (thick white arrow), infundibular length (straight line) and infundibular width (thin arrow).

Procedure:
Anesthesia: In our study patients were given spinal anaesthesia with 25 gauge spinal needle (QB needle or Whittakar needle) using 3-4 ml of 0.5 percent bupivacaine HEAVY . A double J stent was put on the affected side prior to the procedure.

SWL Procedure: All were subjected to SWL using an Electro Hydraulic Direx Lithotripter model Compact XL (Initia Group) .The procedure was performed in the supine position with the shock wave head by the side of the patient. The procedure was started at a low power of 15 KV and slowly increased to 21 KV, within the initial 600 shocks, which allowed the stone to be broken into smaller pieces. Regular monitoring of the focal point was done during the procedure in 0 and 30 degree using the fluoroscope (proper lead aprons with thyroid guards used for radiation protection). A minimum of 1000 to a maximum of 3000 shots were given in each sitting. The interval between repeated treatment sessions, if required, was 2 and 3 weeks from the initial SWL sitting to allow passage of fragmented debris and kidney recovery.

Treatment Outcome Measurement and Follow up
Patients were evaluated at 1 and 3 months after the last ESWL session by physical examination, urine analysis and imaging modalities like kidney-ureter-bladder X-ray and ultrasound. Success was defined as stone free status or clinically insignificant residual fragments. Stone free status [Figure 5] indicated no evidence of residual stone on imaging studies and CIRF were asymptomatic non obstructive, non-infectious stones smaller than 4 mm.[5] Patients with significant residual stones at

end of 3 months were considered as treatment failure and were subjected to other treatment modalities like repeat ESWL, URSL for ureteric residual stones or percutaneous removal, depending upon the size of the residual stones. Double J stent was removed at 3 to 4 weeks interval.

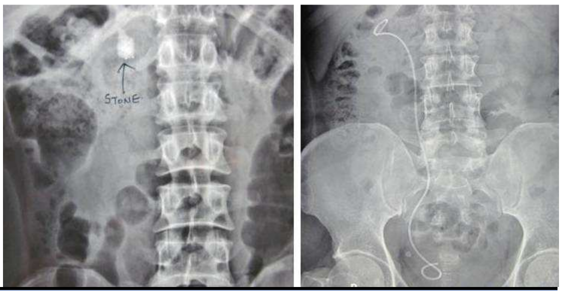

Figure 5: Pre SWL X-ray KUB (left side) showing calculus and post SWL (right side) free of stone with DJ stent.

Statistical Analysis

Statistical analysis was performed by Chi square, Student t-test and ANOVA. Data was presented as mean +/- range and frequency (percentage and total). ROC curves were plotted and a p- value of less than 0.05 was considered as statistically significant.

Ethical Statement:

This study was carried out after the approval by the Institutional Ethical Review Board of Yashoda Academy of Medical Education and Research (YAMER).

RESULTS

The study included 52 patients with inferior calyceal stones. The mean age of the patients was 47.17 +/- 4.12 [Figure 6] Preoperative evaluation of the pelvi-calyceal anatomy was done by an intravenous urogram .Three anatomical factors were studied; Infundibular Length (IL), Infundibular Width (IW) and Infundibulo Pelvic Angle (IPA) [Table 1]. We studied the impact of the infundibulo pelvic angle (IPA) on the rate of stone clearance. The value of the IPA in our study ranged from 28.3 degree to 103.2 degree with a mean angle of 79.48 degrees.

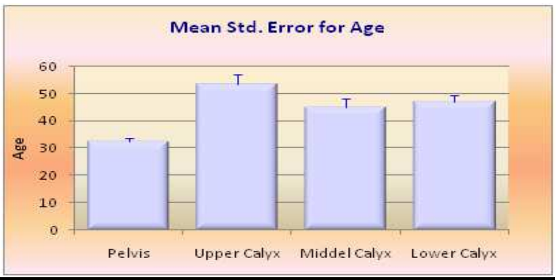

Figure 6: Representing Mean Standard Error Age of Patients.

Table 1: Inferior Calyceal Variables

Variable	Lowest	Highest	Mean
Infundibular Length (mm)	**14.00**	**41.00**	**27.34**
Infundibular Width (mm)	**3.00**	**12.00**	**6.55**
Infundibulo-Pelvicngle.	**28.3 º**	**103.2 º**	**79.48 º**

It was found that patient with an angle of 89.3 degree or more had a statistically significant clearance of stones as compared to the patient with an angle less than that. (p=0.0000). The ROC curve showed an area under the curve of 0.93926; standard error of 0.08389; confidence interval CI (95%) of 0.7396 to 0.99016 [Figure 7]. The value of 89.3^0 had a sensitivity of 0.92; specificity of 0.88; positive predictive value of 88.46 and negative predictive value of 92.307.

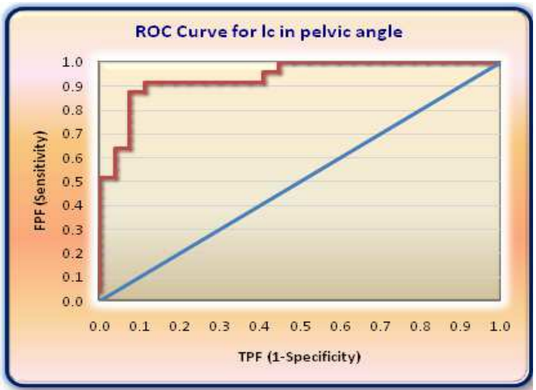

Figure 7: ROC Curve Infundibulo-Pelvic Angle.

The infundibular length value ranged from 14.00 mm to 41.00 mm with a mean value of 27.34 mm. The patients with an infundibular length of 26 mm or less had a statistically significant clearance as compared to those patients with longer infundibular length.(p=0.00041) . The ROC curve showed an area under the curve of 0.7807; standard error of 0.08389 ; confidence interval CI (95%) of 0.6191 to 0.937 [Figure 8].The value of 26 mm had a sensitivity of 0.8148 ; specificity of 0.64; positive predictive value of 70.967 and negative predictive value of 76.19.

The infundibular width ranged from 3.00 mm to 12.00 mm with a mean value of 6.55 mm. The patients with an infundibular width of 6 mm or more had more stone clearance as compared to those patients with value less than this, however it was not statistically significant (p=0.0633). The ROC curve showed an area under the curve of 0.62813; standard error of 0.08389; confidence interval CI (95%) of 0.548 to 0.9064 [Figure 9]. The value of 6 mm had a sensitivity of 0.7599; specificity of 0.55; positive predictive value of 61.29 and negative predictive value of 71.42.

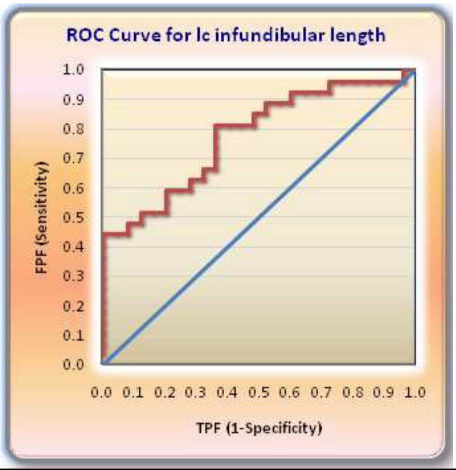

Figure 8: ROC Curve Infundibular Length.

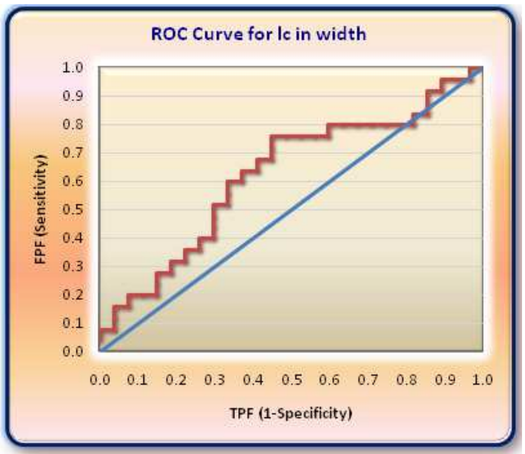

Figure 9: ROC Curve Infundibular Width.

DISCUSSION

Before the advent of SWL and other minimally invasive procedures like ureterorenoscopy and PCNL, open surgery represented the treatment of choice for most of the renal and ureteric stone patients.

In current time ESWL has been established as the *"sine quo non''* for the management of most of the renal and ureteric stone patients.

The obvious advantages offered by ESWL include it's non-invasive character, favorable clinical outcome, low complication rates and a few absolute contraindications (eg. Pregnancy, bleeding diathesis, aortic aneurysms.).[12]

However not all kidney stones are amenable to treatment by ESWL. The success of ESWL depends upon various factors,[13] which decide the stone free rate after treatment.

The objective of ESWL is to obtain a fragmentation of the calculus into fragments that can be expelled through the renal collecting system. According to Politis et al., although correct fragmentation is obtained in 98 % cases after ESWL, the fragments are eliminated in only 75 % cases.[14]

The kidneys with small stones (<15 mm in largest diameter) become stone free in 78% cases, whereas kidneys with large stones (>15 mm) are stone free in 66 % cases. Furthermore small stones have significantly lower complication rates.[14]

It has been found that increasing stone free rates are seen with smaller stones.[15] Because of an unsatisfactory success rate, patients with bigger stone size are often treated with alternate procedures such as ureterorenoscopy or percutaneous nephrolithotomy. Although stone size is a proven factor in the outcome of SWL, stone free rates after SWL are adversely affected by the multiplicity of stones.

Coz et al[16] analyzed the outcome of SWL according to site in 2016 patients of urinary tract stones. Stone free rates of lower caliceal stones and upper or iliac ureter stones were lower than the overall stone free rate. Best stone free rates are observed in stones in pelvic ureter, the renal pelvis and the upper and middle calyx. After disintegration, the clearance of fragments depends upon their location in the pelvi-calyceal system.

Successful ESWL is usually defined as stone free or residual fragments of less than 4 mm in size at three months of follow-up.[6]

The natural history of these residual fragments depends upon the initial location; residual fragments located in the renal pelvis have a spontaneous clearance rate of 66%. The spontaneous clearance rate of residual fragments in middle calyx is about 50% and in inferior calyx, it is 37 %.[7] Poorer clearance rate for the lower caliceal system is considered due to gravity.

Width, length and infundibulopelvic anatomy has been shown to be relevant for stone clearance after ESWL for lower pole stones.

Stone clearance has been shown to be poorer for an acutely angled than for an obtusely angled inferior calyx and better for a shorter calyx with a wider infundibulum than for a longer calyx with a narrower neck.[15]

It was found that patient with all the three unfavorable factors have only 17 per cent success rate[9] also in some studies it was found that infundibulopelvic angle was the only significant factor predicting the stone free status after ESWL for lower pole calculi.[17]

Three anatomical factors related to the lower caliceal system were measured.[18]

(A) Infundibular Length (IL)
(B) Infundibular Width (IW)
(C) Infundibular Pelvic Angle (IPA)

IL was defined as the length from the most distal point of lower calyx, where the targeted stone is located, to the midpoint of both sides of the opening of the lower calyx into the renal pelvis.
IW was determined from the narrowest point of the lower calyx.
IPA was the inner angle created by intersection of 2 lines. The first line, the central axis of lower pole infundibulum was drawn by connecting two distal parts of lower infundibulum and opening of infundibulum into the renal pelvis. The other line, the ureteropelvic line was created by connecting the midpoint of the renal pelvis opposite the margins of the superior and inferior renal sinus to midpoint of ureter opposite the inferior border of lower pole of kidney. The infundibular length ranged from 14.00 to 41 mm with a mean value of 27.34. The infundibular width ranged from 3.00 to 12.00 mm with a mean value of 6.55. The infundibulopelvic angle ranged from 28.3 to 103.2° t a mean value of 79.48°. In the study by Chi-Chuh Lin [18], the mean IL was 32.3 ± 6.0 mm (range 2.7-46.1 mm), mean IW was 4.2 ± 0.6 mm (range 2.6 – 5.6 mm) and mean IPA was 41.6 ± 5.5° (range 29-60 º). Arzoz – Fabregas et al[11]. Included in their study patients who had infundibular width of 6.5 +/- 8.2 mm, Length of 25.9 +/- 6.7 mm and Infundibulopelvic angle of 51.9 +/- 13.4. Ruggera (L) et al[19] **,** studied the patient of lower caliceal stones, the various values were
Patients with an angle of 89.3° or more had statistically significant clearance of stones as compared to the patients with angle less than that (p= 0.000). S.Azab et al[20] studied 150 patients with solitary radiopaque lower caliceal renal stones. In patients with Infundibulopelvic angle > 45°, stone clearance was 52%, whereas it was 32% in patients with infundibulopelvic angle of <45°, with no significant difference. Ruggera L et al[19] **,** studied the effect of the infundibulopelvic angle on the stone clearance in lower caliceal stones. It was found that with IPA of >70° had a statistically significant clearance as compared to those with angle <70°. Sampano & Aragao[21] analyzed that the inferior pole collecting system anatomy in 146 3D polyester resin corrosion endocasts of pelvi-caliceal system. They suggested that a lower pole angle <90° had lesser stone clearance. Keeley et al[22] reported on 116 patients who underwent shock wave lithotripsy for lower pole stones. The lower pole IPA was the only factor to attain significance in predicting stone free status. The stone free rates were 34% & 66% in patients of lower pole IPA less than or greater than 100° respectively. As in our study the patients with an obtuse angle of IPA had more stone clearance than those with acute angle.
The effect of infundibular length on the stone clearance rate in lower calyx was studied. The patients with infundibular length of 26 mm or more had a statistically significant clearance of stones as compared to patients with length less than that(p=0.00041). Gupta et al[15] studied the effect of infundibular length on stone clearance and found that the patients with caliceal length 30mm had 77% clearance as compared to those with > 30 mm who had 64% clearance. Elbahnasy et al[9]found that Caliceal length < 30 mm had 75% stone clearance and those >30mm had 42% stone clearance. C.C. Lin et al[18]**,** in their study found no statistically significant difference in infundibular width (p=0.053) and IPA (p=0.182) as far as stone clearance was concerned. However, the infundibular length of the stone free group (31.2mm) was significantly shorter than that of residual stone group (31.5mm; p=0.044). Srivastava et al[23] studied the effect of infundibular length on stone clearance and found that infundibular length <25 mm showed a significant clearance as compared to >25 mm in length. Yan Kit Fong et al[24] **,** showed on multivanate analysis that infundibular length was a significant factor for stone clearance in lower calyx (p=0.013). Soyupeh S et al[25] , in their study demonstrated that patients with a favourable lower polar anatomy, i.e., IPA >70°, IL < 30mm and IW >5mm were heaving a significantly better stone clearance. As compared to the above studies, the infundibular length was also a significant factor delivering the stone clearance in the lower calyceal stones.
The effect of the infundibular width on the stone clearance was studied and it was found that patients with an infundibular width of 6 mm or more had more stone clearance than those less than that; however, it was not of statistical significance. (p=0.0633).
Gupta et al[15] in their study showed that caliceal width > 5mm has 73% stone clearance and <5 mm had 41% stone clearance. Elbahnasy et al[9]**,** showed that Calyceal width >5 mm has 60% stone clearance and < 5mm had 33% stone clearance. Yan Kit Fong et al[24] in their study found that an infundibular width >5 mm had a statistically significant stone clearance than that of the width <5 mm (P=0.001). TacBeom Kim et al[26] observed a significant difference in the stone clearance rate in two groups of patients as far as the infundibular length is concerned. Azab. S and Osama A[20] **,** compared the infundibular width of <4 mm to >4 mm as far as tone clearance is concerned and found no significant difference between the two groups. Rugera L et al [19], found a statistically significant difference of stone clearance in the patients with a mean IW of 7 mm, as compared to patients with a width of 5.5 mm. Thus as compared to above studies the tighter infundibular width group in our study had lesser stone clearance; however, it could not reach the statistical significance.

CONCLUSION

It could be concluded that inferior calyceal anatomy has a definite impact on the stone clearance after SWL; with a favorable infundibulopelvic angle, infundibular length and width having a significantly better stone clearance. In future, studies comparing the combined effect of calyceal anatomy and the stone parameters like the Housenfield units (HU) and stone morphometery will be more informative in predicting stone clearance after SWL.

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