

A. Symes · G. Shaw · D. Corry · S. Choong

## Pelvi-calyceal height, a predictor of success when treating lower pole stones with extracorporeal shockwave lithotripsy

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**Abstract** Extra corporeal shockwave lithotripsy (ESWL) is the treatment of choice for the majority of renal stones, however, it has the lowest success rate in complete clearance of stones located in the lower pole. We assess whether pelvi-calyceal height is a useful measurement in predicting successful stone clearance from the lower pole. A total of 105 patients with a solitary lower pole calculus of less than 20 mm treated with ESWL were reviewed. Stone size, location and pelvi-calyceal height were measured by intravenous urogram. Success was defined as complete stone clearance. Fifty-four patients (51.4%) had successful treatments, with the remaining 51 (48.6%) having incomplete stone clearance (including two patients in whom treatment had no effect). There was a statistically significant difference ( $P < 0.0001$ ) in pelvi-calyceal height between the two groups. Mean pelvi-calyceal height in patients with complete stone clearance was 15.1 mm (SD = 3.9) compared with 22.9 mm (SD = 5.2) for those with incomplete clearance. Pelvi-calyceal height is a useful predictor of success when treating lower pole renal stones with ESWL.

**Keywords** ESWL · Lithotripsy · Pelvi-calyceal height · Lower pole stones

### Introduction

Extracorporeal shockwave lithotripsy (ESWL) is one of the main treatment modalities for renal calculi. Its efficacy depends on clearance of calculus debris following

stone fragmentation. There are many factors that determine whether ESWL will be successful, including stone size and composition, collecting system anatomy, the definition of stone clearance rate, stone burden, imaging modality, treatment modality and the available technology. ESWL has the lowest success rate in complete clearance of stones located in the lower pole [1, 2]. It has a poorer stone clearance rate than percutaneous nephrolithotomy (PCNL) when treating lower pole stones [2].

Calyceal anatomy of the lower pole and its impact on stone clearance has been previously documented [3, 4]. ESWL is effective at fragmenting lower pole calyceal stones (around 90%), however the complete clearance of all fragments (stone free rate) is lower (around 60%) [2]. Several radiographic features, such as infundibular and infundibulopelvic angle, infundibular width (diameter), infundibular length, and pelvi-calyceal height have been reported to be significant predictors of stone-free status after ESWL [3, 4, 6]. Stone clearance has been shown to be poorer for an acutely angled inferior calyx, and better for a shorter calyx with a wide infundibulum [3]. In practice, the use of some of these parameters is limited. There have been a number of reports with conflicting treatment results for lower pole calyceal stones, when the anatomical factor was the pelvi-calyceal angle. This may in part be due to problems of measurement affected by infundibular peristalsis and the status of hydration during excretory urography. In addition, the variance between x-rays may all alter the angle. Inter and intra-operator differences in measurement of pelvi-calyceal angle may also simply reflect the varied and complex anatomy at the pelvi-calyceal region [5].

It is clear from previous studies that anatomical measurements such as pelvi-calyceal angle and infundibular diameter and length have not been reproducible in delineating whether ESWL will be successful in treating lower pole stones. The simplest measure of calyceal dependence is the pelvi-calyceal height [6]. It is quick, easy and reproducible in the clinical setting. It does not suffer some of the measurement problems

A. Symes (✉) · G. Shaw · D. Corry · S. Choong  
Stone Unit, Institute of Urology,  
University College London,  
London W1W 7EY, UK  
E-mail: andysymes@mac.com  
Tel.: +44-207-3879300  
Fax: +44-207-6799296

associated with more complex ways of assessing the lower pole. The purpose of this study was to evaluate whether this single anatomical parameter, pelvi-calyceal height, is helpful in the decision making process as to which patients with lower pole stones are likely to benefit from ESWL.

## Patients and methods

Between January 1999 and December 2002, 105 patients with a solitary lower pole calculus of less than 20 mm treated with ESWL were retrospectively reviewed. Patients with anatomical abnormalities (horseshoe, pelvic and malrotated kidneys, bifid pelvis, bifid ureters, etc.), or those whom had had previous surgery, were excluded. Stone size, location and pelvi-calyceal height (Fig. 1) were measured by x-ray and intravenous urogram (IVU). The number of treatments and shocks, and the relative intensity of shockwaves were recorded. Success was defined as complete stone clearance at initial follow up 6–12 weeks after treatment.

Pelvi-calyceal height was defined from the IVU as the distance between a horizontal line from the lowest point of the calyx containing the stone to the highest point of the lower lip of the renal pelvis (Fig. 1).

All patients were treated using a third generation Dornier lithotripter. Ultrasound was used in all cases for stone localization. Unless contraindicated, all patients received diclofenac suppositories for analgesia with the option of additional intra-muscular pethidine if required. The intensity of each treatment was based on patient tolerance with the number of shocks for each treatment aimed at 3,000. The number of treatments

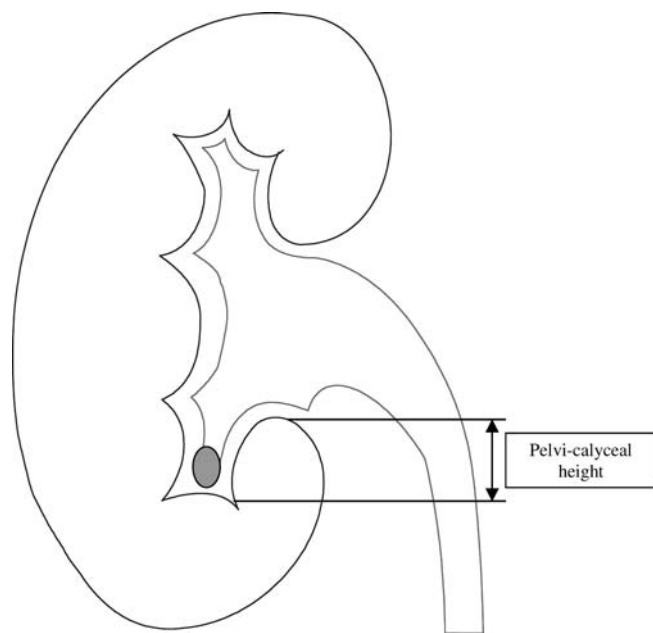


Fig. 1 Measurement of pelvi-calyceal height

depended on successful stone fragmentation or clearance with each session spaced 4 weeks apart. Patients routinely received antibiotics and analgesics for 3 days after treatment and were encouraged to drink plenty of fluids. After three sessions, patients were reviewed in the outpatient clinic by a urologist. Radio-opaque stones were followed up with plain x-ray and radiolucent stones with ultrasound. Initial follow-up was at 6–12 weeks with further appointments at 6–12 months.

## Results

A total of 105 patients were treated: 68 males and 37 females. Their average age was 49.9 years (range 19–83). The mean stone size treated was 10.2 mm (range 5–17). There were no deaths or serious complications.

Successful treatment was carried out in 54 patients (51.4%) with no evidence of residual stone. Of the remaining 51 (48.6%) with incomplete stone clearance (including two patients in whom treatment had no effect), 34 (32.4%) were asymptomatic. In patients who responded to ESWL ( $n=103$ ) there was no statistically significant difference in mean stone fragment size (as determined on plain x-ray prior to final treatment) between patients who eventually went on to become stone free and those that did not (3.9 mm vs 4.5 mm;  $P=0.18$  Mann-Whitney U-test). The mean number of sessions per patient was 2.88 ( $\pm 0.55$ ). There was no significant difference in the mean number of shocks in patients that became stone free (8,802 vs 9,102;  $P=0.53$  Mann-Whitney U-test), nor in mean intensity of shocks (41% vs 42.8%;  $P=0.23$  Mann-Whitney U-test).

Pelvi-calyceal heights ranged from 8–35 mm. There was a statistically significant difference ( $P<0.0001$ ; Mann-Whitney U-test) in pelvi-calyceal height between those who were stone free and those who were not (Table 1). In patients with complete stone clearance the mean height was 15.1 mm (SD=3.9). In patients with incomplete stone clearance the mean height was 22.9 mm (SD=5.2). At a pelvi-calyceal height of less than or equal to 2.5 cm there was a 58% successful stone clearance rate. At less than or equal to 2 cm the success rate increased to 67%. Below 1.5 cm the success rate was 97%. There was a statistically significant difference ( $P<0.0001$ ; Fisher's exact test) in stone clearance rates between pelvi-calyceal heights of less than and greater than 1.5 cm, less than and greater than 2 cm, and less than and greater than 2.5 cm (Table 2). Stone size had no statistically significant difference on stone free rates.

## Discussion

This study confirms the poor results seen in other studies when treating lower pole calyceal stones with ESWL [2, 3]. Lingeman et al. performed a meta-analysis of 13 previous studies that looked at using ESWL to treat lower pole stones, as well as three studies using PCNL

**Table 1** Stone clearance and pelvi-calyceal height

	Complete clearance (mean)	Incomplete clearance (mean)	<i>P</i> : Mann-Whitney U-test
Pelvi-calyceal height (mm)	15.1	22.9	<0.0001

[2]. They showed that the results of ESWL were uniformly poor, especially when compared with PCNL. The overall stone free rate for ESWL when applied to lower pole calculi was 60%, compared to 90% for PCNL. Similar figures for ESWL are seen in this study, despite successful fragmentation in all but two patients. Through a regression analysis, Lingeman et al. demonstrated that increasing stone burden was associated with progressively less successful stone free outcomes for patients treated with ESWL. This is not seen in this study, possibly due to the narrow range of stone sizes.

Several investigators have proposed that in addition to gravity dependant effects, anatomic features play an important role in the evacuation of stone fragments from the lower pole. A cadaveric study by Sampaio and Aragao examined 3-dimensional casts of the lower pole [4]. In 56.8% of casts they found that the inferior pole was drained by multiple infundibula, and in 39.7% they found calyceal infundibular diameters of less than 4 mm. They proposed that a combination of these factors might result in poor drainage and hence lower fragment clearance. In addition they proposed that if the angle formed between the lower infundibulum and the renal pelvis (infundibulopelvic angle) was greater than 90°, then this should facilitate drainage of fragments from the lower pole. In a retrospective study Elbahasy et al. assessed the infundibulopelvic angle, infundibular length, and infundibular width, in solitary lower pole calyceal calculi treated with ESWL [3]. They demonstrated statistically significant relationships between all three measurements and stone clearance rates. All patients with an infundibulopelvic angle of greater than 90° were stone free after treatment with ESWL. Overall the mean infundibulopelvic angle was significantly greater (75° vs 51°) in stone free patients. Patients with an infundibular width of more than 5 mm had a 60% stone free rate compared to a 33% stone free rate for those

**Table 2** Stone free status in relation to pelvi-calyceal height

	No. stone free	No. with residual fragments	<i>P</i> : Fishers exact test
Pelvi-calyceal height (mm)			
< 15	28	1	<0.0001
≥15	26	50	
< 20	50	12	<0.0001
≥20	4	39	
< 25	52	33	<0.0001
≥25	2	18	

with a width of less than 5 mm. Lastly, there was a significant inverse relationship between infundibular length and stone free status following ESWL (32 mm stone free vs 38 mm residual fragments). Keeley et al. found that the presence of an obtusely angled infundibulopelvic angle was the only factor to attain significance in predicting stone free status [7].

Other authors have not found collecting system anatomy to be predictive of lower pole stone clearance. Madbouly et al. examined 108 patients undergoing ESWL for lower pole stones [8]. They did not find that infundibular length, infundibular width or infundibulopelvic angle were predictors of stone free status, although they commented on the fact that patients with renal scarring had the least chance of becoming stone free. In a separate study, Sorenson and Chandhoke again did not find that these anatomic factors were predictive of successful stone clearance, even when stones were stratified by size [9].

This study demonstrates a link between pelvi-calyceal height and the successful treatment of solitary lower pole calyceal stones with ESWL. This disagrees with the findings of Onal et al. who assessed the impact of pelvi-calyceal anatomy on stone clearance after ESWL for paediatric lower pole stones [10]. They found that pelvi-calyceal height had no significant effect on stone clearance ( $P=0.51$ ; Mann-Whitney U-test), although they only looked at children under the age of 16. Our findings do, however, agree with those of Tuckey et al. who found significantly higher stone free rates for pelvi-calyceal heights of less than 15 mm compared to those greater than 15 mm [6]. If gravity is considered as one of the key factors in preventing clearance of stone fragments from the lower pole then this association is logical. This view is further supported by studies that have shown inversion therapy to be a useful adjunct to ESWL. Brownlee et al. evaluated inversion therapy along with intravenous hydration and percussion on patients with residual stone fragments following previous ESWL [11]. They reported that 86% of patients treated with multiple inversion sessions subsequently became stone free. Pace et al. compared the effectiveness of mechanical percussion, inversion, and frusemide-induced diuresis with observation for eliminating lower calyceal fragments 3 months following ESWL [12]. Some 40% of the patients actively treated subsequently became stone free, compared with only 3% in the observation group.

Stone fragment size following ESWL is one of the most important factors in determining whether a kidney will become stone free. In this study, there was no statistically significant difference in stone fragment size after treatment between patients who became stone free and those who did not. Patients did not routinely have imaging immediately after ESWL, and therefore these findings were based on plain x-rays performed prior to commencement of final treatment. The exact final stone fragment sizes were therefore unknown, and may have shown significant differences between the two groups.

Even imaging soon after ESWL may not show true stone fragment size as disintegration can continue to occur some time after treatment. This issue will need to be addressed in a future prospective study. Stone composition will clearly affect stone fragmentation. Unfortunately stone analysis was not available for the majority of patients in this study and a comparison of stone composition could not be made between the two groups.

It is our practice for all patients undergoing ESWL to have an IVU prior to commencement of treatment, so that the anatomy and drainage of the collecting system can be defined. Although most patients are treated under ultrasound guidance, ultrasound does not provide as detailed a picture as an IVU for the anatomy and drainage of the pelvi-calyceal system. Multi-detector computed tomography (MDCT) provides the most detailed picture, however, it is not always readily available, may have long waiting times, and requires radiological expertise in interpretation. To gain the most from it, it requires viewing on a workstation with reconstructive images, and until it is available routinely for all patients undergoing ESWL, it will be our continued practice to work all patients up with an IVU.

There are clearly many factors that have to be assessed when deciding whether to offer patients with lower pole calculi ESWL. These include patient preference, stone type and size, and the treatment modalities available. While ESWL for lower pole stones undoubtedly has a lower success rate, it still has low associated morbidity and does not require general anaesthesia or inpatient treatment. Although we offer ESWL as an outpatient treatment, it usually requires multiple sessions, and this can have a significant impact on the patients' lives, especially when unsuccessful. In some centres, ESWL is administered under general anaesthesia to inpatients, and this can result in far greater disruption to patients' lives compared to a single surgical intervention, such as percutaneous nephrolithotomy (PCNL).

In light of our findings, patients with pelvi-calyceal heights of greater than 15 mm, who have lower pole stones, are advised of the high chance of treatment failure with ESWL. All treatment modalities are discussed with them in the outpatient clinic, and ultimately a joint decision is reached. Despite everything, some patients are keen to avoid surgery and will opt for ESWL, while others would rather undergo a single procedure with a high success rate, such as PCNL, to rid them of a troublesome stone. We still feel ESWL has a valuable role and that assessment of pelvi-calyceal

height offers the urologist a useful clinical adjunct. One of the main arguments against the use of anatomic measurements in predicting lower pole stone clearance is that the collecting system is a dynamic environment, and such measurements are static. While we concur, until the development of potential dynamic measurements or improvements in imaging techniques [13], pelvi-calyceal height may offer some help in deciding which patients with lower pole stones will benefit from ESWL.

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