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Success of Extracorporeal Shock Wave Lithotripsy in Renal and Upper Ureteric Calculi Based on A Stone Attenuation Value of 990 Hu

*** Dr. Ramachandra Pudakalkatti Sanjay**	Assistant Professor, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, India. * corresponding author
Dr. Jayaram Sreenivas	Assistant Professor, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, India
Dr. Ramaiah Keshavamurthy	Professor and Head, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, India
Dr. Vilvapathy Senguttuvan Karthikeyan	Senior Resident, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, Indi
Dr. Venkatesh Shivakumar	Assistant Professor, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, India
Dr. ChikkaMoga Siddaiah Manohar	Assistant Professor, Department of Urology, Institute of Nephro Urology, Victoria Hospital Campus, Bangalore 560002, Indi

ABSTRACT

Introduction:
Extracorporeal shockwave lithotripsy (SWL) is the first option for treating solitary non lower-pole renal and upper ureteric calculi <2 cm. Stone attenuation value (SAV) is an important factor in determining its success. The aim of this study was to identify a cutoff SAV for stone clearance.

Methods:
Hundred consecutive patients undergoing SWL for solitary renal and upper ureteral stones from November 2013 to June 2014 were included. SAV on computed tomogram (CT) and other baseline and stone characteristics were noted.

Results:
Based on ROC analysis, the mean SAV of 990 HU was identified to predict success of SWL. Baseline patient characteristics and stone location were comparable between patients with SAV ≤990 HU (group A) and >990 HU (group B). Stone size was higher in group B (13.02 mm, p<0.0001). Patients in group B needed more sittings (p = 0.001) and failure was higher (52.8% vs 0%; p<0.0001). On univariate analysis, stone size, SAV (p<0.0001) and stone location (p = 0.012) were significant factors for failure. On logistic regression, non-lower pole stone location (p = 0.016) and SAV ≤990 HU (p = 0.013) predicted success of SWL. Clearance was 100% in group A and 92.5% in group B (p = 0.0285).

Conclusions:
Cutoff SAV of 990 HU on NCCT predicts success of SWL in non-lower pole renal and upper ureteric calculi <2cm with a Dornier 3 lithotripter. The only other factor which affects stone clearance is the location of stone wherein lower pole calculi have inferior clearance rates.

KEYWORDS: Renal calculus; Shockwave lithortripsy; stone attenuation value; clearance.

INTRODUCTION

Extracorporeal shock wave lithotripsy (SWL) is the first option for the treatment of solitary renal and upper ureteric (UU) calculi of <2cms and <1.5 cm in lower pole (LP) of kidney.[1] The success rate of SWL ranges from 60-90%. Factors affecting stone fragmentation in SWL include stone location, stone size, stone chemical composition, stone attenuation value (SAV), body mass index (BMI), skin stone distance (SSD) and the presence of obstruction or infection.[2-6] Non contrast computed tomography (NCCT) detects density differences as low as 0.5% and has been used to determine the composition and fragility of urinary stones and SAV is an important parameter to predict stone fragmentation and stone clearance rate in SWL.[7-9] Various studies have examined different cut off SAV for success of SWL. Joseph et al observed that stone clearance was 100% in stones <500HU and 54.5% in stones >1000HU.[3] Ouzaid et al identified a 970 HU cut off for success of SWL.[10] Failure of SWL leads to increased costs with requirement of auxiliary procedures. SAV thus helps to counsel patients to undergo SWL or an invasive procedure. It avoids extra medical costs associated with non-productive SWL sessions and to identify alternative patient management strategies.[10,11] This study was conducted to identify a cut off SAV (Hounsfield units – HU) for stone clearance in our population and to compare the stone clearance rate in patients in these two groups for renal and UU calculi.

MATERIALS AND METHODS

This was a hospital-based prospective observational study performed in 100 consecutive consenting patients undergoing SWL for upper urinary tract stones in a tertiary care referral urological center in South India. After obtaining approval

from the Institute Research Council and Ethics Committee, the study was conducted from November 2013 to June 2014.

Study population
All consecutive consenting patients with solitary upper urinary tract calculi with normal renal function referred to the SWL unit of our institute were eligible. Patients with solitary renal or upper ureteric calculus <20 mm and LP renal calculus <15 mm were included. Patients with multiple calculi, BMI >30 kg/m^2, SSD >10 cm, congenital anomalies of the kidneys, uncontrolled coagulopathy, active urinary tract infection (UTI), renal failure, preoperative double J (DJ) stenting and pregnancy were excluded.

Evaluation
After history and physical examination, routine investigations like complete blood count, blood urea, serum creatinine, urine microscopy and culture and sensitivity were done. Appropriate antibiotics were prescribed for patients with UTI and urine cultures were repeated to document sterile urine before SWL. All patients underwent US (Philips, 5 MHz linear array probe) and NCCT (Siemens, 100 mA, 120 kV) of kidneys, ureters and bladder (KUB). Demographic data like age, gender, BMI, stone size, location and SAV were noted. The maximum dimension of the calculus was taken as the size (millimetres – mm).

Brief procedure
SWL was performed using Dornier 3 (Dornier Compact Delta II, Dornier Medtech, Munich, Germany) electromagnetic lithotripter under ultrasound (US) using a 4.3 MHz linear probe (BK Medicals, Herlev, United States) or fluoroscopy (FS 2000, Dornier MedTech Systems GmBH, Lissone MI, Italy) guidance. Shocks were given at a frequency of 60 per minute, at 11.5 kV and 2000 shocks were given in each sitting. A maximum of three sittings were given at one week intervals. Post SWL US was done at 3 months from the last sitting to assess for success of SWL.

Outcome
The primary endpoint was to determine the best SAV to predict success after SWL. The secondary endpoints were to find out factors predicting success. Effectiveness quotient (EQ) was calculated as %stone free/(100%+retreatment+%auxiliary procedures)x100.

Statistical analysis
Statistical analysis was performed using SPSS version 20 for Windows (IBM Corp., Armonk, NY, USA). After assessing the normality of data, the variables were summarized using mean, standard error, median, interquartile range, and percentages based on the characteristics of the variable. Independent samples t-test or Mann Whitney U test were used as appropriate for analysis of continuous variables based on the normality of the distribution and Chi-Square test was used for categorical variables. A receiver operating characteristics (ROC) curve was constructed to identify the appropriate cut-off SAV for success of SWL. The baseline, stone and SWL characteristics were compared between two groups based on SAV. Univariate analysis was performed and then binomial logistic regression was used to identify the predictors of success of SWL after controlling for confounding to identify factors predicting success of SWL in these two groups. The P value of <0.05 was considered statistically significant.

RESULTS
A total of 100 patients were included. The mean (± SD) age was 37.63 ± 13.37 years and 68 (68%) were males and 67 (67%) had left sided calculi. The mean (± SD) stone size was 11.09 ± 2.87 mm and the mean (± SD) SAV was 981 ± 345.8 HU. The mean (± SD) number of shocks received was 5178 ± 1411.8 and SWL was successful in 95% patients.

Cut off SAV
Based on ROC analysis with area under the curve of 0.794 (p<0.0001) (Fig 1), we chose the cut off SAV for predicting success of SWL in our study as 990 HU. This SAV predicted a success rate of 89.4% with a sensitivity of 62.69% (95% CI: 50.72 – 73.28) and specificity of 84.89% (95% CI: 69.08 – 93.35) with a diagnostic accuracy of 70% (95% CI: 77.41 – 95.37), positive predictive value of 89.36% (95%CI: 77.41 – 95.37) and negative predictive value of 52.83% (95%CI: 39.66 – 65.62). We then divided our study population into two groups based on 990 HU into Group A (≤990 HU) and Group B (>990 HU).

Comparison based on SAV
Groups A and B were comparable with respect to age, sex, BMI, side, SSD and stone size. The proportion of patients with upper and mid pole calculi was statistically significantly higher in Group B (Table 1). A statistically significantly higher proportion of patients in group B received 3 sittings. All patients in group A had complete stone clearance (Table 2).

Predictors of success of SWL
On univariate analysis, stone size, stone SAV and location were significant (Table 3). On multivariate linear logistic regression analysis, the predictive factors for success of SWL were stone location in upper, midpole, pelvis or upper ureter and a stone density of ≤990 HU (Table 4). We identified that a SAV cut off of 990 HU was able to predict stone clearance independent of other factors like age, gender, BMI, SSD and size.

SWL characteristics
Group B patients needed statistically significantly more number of shocks and sessions of SWL with a higher complication rate, need for auxiliary procedure and lower clearance rate than group A patients (Table 5). Thus the cut off SAV of 990 HU was able to predict success and complications effectively in our study population. Success was least (24%) with LP renal calculi and maximum in upper and midpole (43%) followed by renal pelvic and upper ureteric calculi (32%).

DISCUSSION
SWL is still considered the best treatment for calculi less than 20 mm, but the outcome of this therapy depends on different factors including stone composition, stone location, calyceal anatomy and stone size. Stone composition is the most important determinant in the outcome of treatment, however, it is not possible to identify it before treatment.[10] NCCT KUB has become an integral part of upper urinary tract calculi evaluation and SAV has been found to predict success.[11]

While SWL can remove up to 90% of stones in adults, the success rates for SWL depend on the efficacy of the lithotripter, stone location, composition and body habitus.[11] Renal pelvic stones have a higher clearance rate than calyceal stones and it is the worst for LP renal calculi, failure being up to 35% of patients. Percutaneous nephrolithotomy (PNL) and retrograde intrarenal surgery (RIRS) have been preferred for LP stones, however results are contradictory. PCNL has relatively higher morbidity and RIRS has not been able to clear LP renal calculi better than SWL. Hence, SWL is still recommended for stones with a diameter of <20 mm, despite the lower clearance rate of LP renal calculi.

SAV of 1000, 750, 970 and 1200 HU have been proposed to predict SWL success.[3,8,10] Ouzaid et al calculated using the Youden index and Jackknife test a cut off SAV of 970 HU with 100% sensitivity and 81% specificity.[10] We observed that a cut off SAV of 990 HU yielded a 63% sensitivity and 85% specificity in our study. We also observed that based on this SAV of 990 HU we reasonably identified that LP calculi had a significantly lesser chance of clearance. Other factors like size, age, gender, BMI and SSD were not predictive factors for clearance. As observed by Elkoushy et al, absence of DJ stent significantly determines stone clearance.[12] We included only patients without preoperative DJ stent and only patients with >990 HU urinary calculi developed complications necessitating placement of DJ stent. Pre SWL DJ stent was placed only in >20 mm stones.[11]

Shah et al based on their analysis on a cut off SAV of 1200

HU.[8] Patients with stones >1200 HU needed more shocks and at a higher intensity and also had more complications with lesser clearance. Clearance rate was 100% with stones ≤990 HU in our study with no complications and in patients with >990 HU also we identified better clearance than Shah et al. This shows that the cut off SAV of 990 HU is better than 1200 HU.[8] Joseph et al identified that stones with SAV >950 HU failed to fragment even with 7500 shockwaves, similar to Pareek et al.[3,13] Gupta et al showed worst outcomes with SAV >750 HU and stone size >1.1 cm.[9] We identified that cut off SAV of 990 HU predicted success independent of stone size in upper urinary tract calculi indicated for SWL.

End point for clearance in our study was taken as 3 months. The 4 week period seems to be short as additional fragments may pass up to 3 months and may overestimate failure rates. However 4-6 mm stones have been shown to pass spontaneously within a post procedure period of 39 days in 95% of cases.[10,11] We have not used NCCT KUB for assessing clearance. Plain X-ray KUB has been used to predict the success of SWL by comparing stone density with bone density. This method is not foolproof and not accurate due to presence of bowel gas or neighboring bony structures and it is subjective.[10] Although CT has greater radiation exposure and costs more than plain X-ray KUB, it has greater sensitivity in detecting residual fragments.[11]

The merits of this study are that a strict SWL protocol was followed. ROC analysis was used to identify the cutoff SAV to predict success of SWL. Our study had a few limitations. Follow up CT was not used at end of 3 months to detect stone clearance due to cost barrier. Pain assessment was not done in our population, however since all patients underwent SWL based on protocol and only total number and intensity of shocks varied based on patient threshold for pain and not on SAV of stone. General or regional anesthesia was not used in our study and this may be the reason for the need for more number of shocks in our study for SWL.

CONCLUSIONS

The cut off stone attenuation value of 990 HU on NCCT before SWL predicts success of shock wave lithotripsy in renal and upper ureteric calculi with a Dornier 3 lithotripter. The only other factor which affects stone clearance is the location of stone wherein lower pole calculi have inferior clearance rates.

Compliance with Ethical Standards:
The authors declare no conflict of interest. No funding was obtained.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Table 1: Patient and stone characteristics based on stone density 990 HU

Characteristics	Group A ≤990 HU N = 47	Group B (>990 HU) N = 53	P-value
Sex (Male: Female)	33:14	35:66	0.655
Mean Age(years)	35.6 ± 13.9	39.43 ± 12.77	0.153
BMI(kg/m^2)	23.8 ± 12.1	23.5 ± 11.8	0.889
Side (Right:Left) N	28:19	29:24	0.624
Location, N (%)			
Upper and midpole	21(44.7)	12(22.6)	0.018
Lower pole	12 (25.5)	11(20.8)	
Pelvis and upper ureter	14(29.8)	30(56.6)	
Stone size, mm Mean ± SD	8.91 ± 1.54	13.02 ± 2.34	<0.0001

Table: 2 Treatment course and outcome classified based on stone density 990 HU

Characteristic	Stone density ≤990 HU	Stone density >990 HU	P value
No. of sittings			
1	7 (14.9)	1(1.9)	0.001
2	18(38.3)	9(17)	
3	22(46.8)	43 (81.1)	
Outcome of SWL			
Failure, N (%)	0	5 (9.4)	<0.0001
Success, N (%)	47 (100)	48 (90.6)	

Table 3a: Univariate analysis of factors associated with success of SWL

S.No	Characteristics	Success of SWL	Mean	SD	T statistic	P value
	Age of patient, years	Success	37.39	14.305	-0.257	0.798
		Failure	38.12	11.423		
	Stone size, mm	Success	10.28	2.748	-0.4355	<0.0001
		Failure	12.73	2.401		
	Stone density, HU	Success	868.66	340.443	-5.211	<0.0001
		Failure	1209.09	223.416		

Table 3b: Factors associated with success of SWL

S.No	Characteristic	Factor	Failure	Success	P value
1	Gender	Male	24(35.2)	44(64.8)	0.477
		Female	9(28.1)	23(71.9)	
2	Side	Right	17(29.8)	40(70.2)	0.437
		Left	16 (37.2)	27 (62.8)	
3	Location	UP and MP	5(15.2)	28(84.8)	0.012
		LP	12(52.2)	11(47.8)	
		Pelvis and UU	16(36.4)	28(63.6)	
4	SAV	≤990 HU	0	43 (100)	<0.0001
		>990 HU	5 (9.4)	48 (90.6)	

Table 4: Multivariate logistic regression for predictors of success of SWL

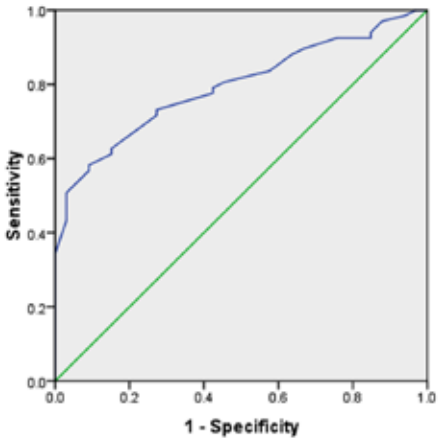
Predictor	Beta coefficient	S.E.	Wald	Sig.	Adjusted OR with 95% CI
Stone size	-.176	.123	2.043	0.153	0.839 (0.659 – 1.067)
Stone location (UP and MP)			8.449	0.015	
Stone location (LP)	.423	.663	.407	0.524	1.526 (0.416 – 5.594)
Stone location (Pelvic and UU)	-1.666	.694	5.757	0.016	0.189 (0.048 – 0.737)
Stone density <990 HU	1.899	.764	6.172	0.013	6.677 (1.493,– 29.86)
Constant	4.292	1.431	8.999	0.003	73.126

Table 5: SWL characteristics based on 990 HU cut off SAV

Variables	Group A ≤990 HU N = 47	Group B >990 HU N = 53	P value
Total number of shocks (N), Mean ± SD	4606 ± 1913	5685 ± 2291	0.001
> 2 sittings, N (%), Mean ± SD	31 ± 54.4	34 ± 79.1	0.017

Complications N (%)	0	5 (7.5)	0.120
Complete Clearance (%)	43 (100)	48 (90.6)	0.0285
Auxiliary Procedure rate (%)	0	5 (7.5)	0.165
EQ ratio (%), Mean ± SD	54.7 ± 13	44.9 ± 16	0.437

Legends to images:
Figure: 1 Receiver operating characteristics curve for appropriate cut-off SAV for success of SWL



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