

Is scoring system of computed tomography based metric parameters can accurately predicts shock wave lithotripsy stone-free rates and aid in the development of treatment strategies?

Yasser ALI Badran, Alsayed Saad Abdelaziz¹, Mohamed Ahmed Shehab, Hazem Abdelsabour Dief Mohamed², Absel-Aziz Ali Emara, Ali Mohamed Ali Elnabtity³, Maged Mohammed Ghanem⁴, Hesham Abdel Azim ELHelaly⁵

Departments of Urology and ⁴Radiology, Al-Azar University, Cairo, ¹Department of Urology, Al-Azar University, Dmietta, ²Department of Urology, Al-Azhar university, Assiut, ³Department of Anesthesia, Zagazig University, Zagazig, ⁵Department of Urology, El Fayoum University, Al Fayoum, Egypt

Abstract

Objective: The objective was to determine the predicting success of shock wave lithotripsy (SWL) using a combination of computed tomography based metric parameters to improve the treatment plan.

Patients and Methods: Consecutive 180 patients with symptomatic upper urinary tract calculi 20 mm or less were enrolled in our study underwent extracorporeal SWL were divided into two main groups, according to the stone size, Group A (92 patients with stone ≤ 10 mm) and Group B (88 patients with stone > 10 mm). Both groups were evaluated, according to the skin to stone distance (SSD) and Hounsfield units (≤ 500 , 500–1000 and > 1000 HU).

Results: Both groups were comparable in baseline data and stone characteristics. About 92.3% of Group A rendered stone-free, whereas 77.2% were stone-free in Group B ($P = 0.001$). Furthermore, in both group SWL success rates was a significantly higher for stones with lower attenuation < 830 HU than with stones > 830 HU ($P < 0.034$). SSD were statistically differences in SWL outcome ($P < 0.02$). Simultaneous consideration of three parameters stone size, stone attenuation value, and SSD; we found that stone-free rate (SFR) was 100% for stone attenuation value < 830 HU for stone < 10 mm or > 10 mm but total number SWL sessions and shock waves required for the larger stone group were higher than in the smaller group ($P < 0.01$). Furthermore, SFR was 83.3% and 37.5% for stone < 10 mm, mean HU > 830 , SSD 90 mm and SSD > 120 mm, respectively. On the other hand, SFR was 52.6% and 28.57% for stone > 10 mm, mean HU > 830 , SSD < 90 mm and SSD > 120 mm, respectively.

Conclusion: Stone size, stone density (HU), and SSD is simple to calculate and can be reported by radiologists to applying combined score help to augment predictive power of SWL, reduce cost, and improving of treatment strategies.

Key Words: Hounsfield units, stone, upper urinary tract

Address for correspondence:

Dr. Yaser Ali Badran, Department of Urology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt. E-mail: yaserbdran44@yahoo.com

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INTRODUCTION

Urinary stone disease is a common disease affecting about 5–15% of the population worldwide and is one of the common reasons for patients visiting urology clinic.^[1] The ideal treatment for proximal ureteral and renal stones has become controversial with noninvasive, cost-effectiveness nature of shock wave lithotripsy (SWL) and the expansion of endoscopic digital technology. According to update 2012 EUA ureteral stones guidelines, SWL and flexible ureteroscopy should be first line therapies for proximal ureteral stones. On the other hand, SWL remains the primary treatment of choice for renal calculi <1.5–2 cm.^[2]

Despite the fact of that SWL is a safe, noninvasive, currently accepted and highly successful treatment in urolithiasis, several factors influencing the stone clearance and success rate such as stone size, body mass index (BMI), skin to stone distance (SSD), as well as stone attenuation measured by HU,^[3,4] and secondary ureteral and pelvic stone obstruction as hydronephrosis and perinephric fat stranding.^[5,6] Because there are many factors affecting stone disintegration, this study was conducting to determine the predicting success of SWL help to reduce cost and increase the quality of treatment.

PATIENTS AND METHODS

After our hospital and Institutional Ethics Board approval, our prospective study including 180 patients with radio-opaque single renal and upper ureteral stone of 5–20 mm diameter was selected from outpatient clinic of urology over the period, from September 2012 and May 2014. All patients underwent detailed medical history, general, and local examination laboratory investigations including urinalysis, complete blood cell count, serum creatinine, liver function tests and coagulation profile, renal ultrasonography; plain X-ray for kidneys, ureter and urinary bladder (KUB); and noncontrast computed tomography (NCCT) supplemented by contrast study if indicated.

Patients <18 years old, morbid obesity, severe cardiovascular or neurological diseases, previous unsuccessful extracorporeal SWL (ESWL), urinary tract infection, elevated serum creatinine, coagulation disorders, abnormal renal anatomy (such as horseshoe kidney, duplex kidney or bifid pelvis), urinary tract obstruction at any level in ipsilateral renal unit were excluded from the study.

BMI was calculated for each patient by dividing the patient's weight in kilogram by height in meter square. Within the context of our study, noncontrast spiral CT was performed with General Electric LightSpeed V. CT 64 slice; transverse images were obtained with a slice thickness of 0.63 mm and an

interval of 1.5 mm at 120 kV. The longest stone size and SSD measured by noncontrast spiral CT (NCCT) by three distances from the center of the stone to skin at 0, 45, and 90 angels^[6] and average for each stone was recorded as the representative SSD for each stone. HU for each stone was measured by using three transverses planes in each stone (near the top, in the middle, and near the bottom) was obtained in each plane and the mean HU value was determined by calculating the mean of it.

All patients underwent SWL by using 3rd generation Siemens electro conductive Lithoskop Lithotripter. All patients were treated in outpatient basis on sedoanalgesia. With the patients in supine position, stone localization was done using fluoroscopy guidance. The shock wave frequency was 60–90/min, and number of shocks per session was 3000 for renal stone and 4000 for upper ureteral stone or until the stone was completely fragmented. At the end of the procedure, patients were discharged home on proper analgesic and encouraged to drink plenty of fluids. The patients were followed up, and re-SWL was carried out for a maximum of four sessions depending on the response.

The result of SWL was evaluated by plain KUB. After 2 weeks, another SWL session was performed if plain KUB showed a significant residual fragment >4 mm. The SWL result was considered successful with complete clearance of stone or clinically insignificant fragment ≤4 mm in diameter and considered failure if remnant stone fragment was >4 mm in diameter after four sessions of SWL or after requirement of auxiliary procedure after any session.

Statistical analysis was performed by using (SPSS, Chicago, IL, USA). The Fisher exact test was used to compare categorical variables while Student's *t*-test and analysis of variance test were used to compare continuous variables. Analysis of the mean values of the variables was performed using Mann–Whitney U and Kruskal–Wallis tests. The correlation between stone size and stone attenuation value and the number of shock waves required were performed by using Pearson correlation test. Correlations with *P* < 0.05 values were considered as statistically significant.

RESULTS

All patients who met inclusion criteria were divided into two main groups, according to the stone size, Group A stone ≤10 mm and Group B stone >10 mm. Both groups were evaluated according to SSD, BMI, and Hounsfield units (≤500, 500–1000 and >1000 HU). Both groups were comparable in terms of their demographic data and stone characteristics [Table 1].

In both groups, the stone size and total number of SWL sessions and shock waves required until complete stone fragmentation correlated significantly ($r = 0.776$ and 0.771 ; $P < 0.001$). Furthermore, the attenuation value and total number SWL sessions and shock waves required until complete stone fragmentation correlated significantly ($r = 0.672$ and 0.601 ; $P < 0.001$).

Stratified by size, stones ≤ 10 mm had significantly higher stone-free rate (SFR), shorter time to stone clearance, lower re-treatment rate and fewer number of SWL sessions and shock waves ($P < 0.001$) [Table 2]. According to the attenuation value, the stones were categorized into: ≤ 500 HU, $500-1000$ HU, and >1000 HU. We found that in both groups, stones with lower attenuation value had significantly higher SFR, fewer numbers of SWL sessions, and shock waves ($P < 0.001$) [Table 3]. Receiver operating characteristic curves defined cut-off values for predicting treatment outcome. Treatment success rates were significantly higher for stones <830 HU than with stones >830 HU ($P < 0.034$).

The mean SSD in success and failure groups, respectively, were 90.9 ± 11.9 mm versus 130.4 ± 12.2 mm in Group A ($P < 0.05$) and 90.3 ± 12.3 mm versus 120.8 ± 13.1 mm in Group B ($P < 0.05$), and the mean BMI in success and failure groups, respectively, were 33.57 ± 3.1 versus 35.2 ± 2.1 in Group A (P value 0.05) and 31.43 ± 2.9 versus 30.99 ± 0.9 in Group B ($P < 0.98$) and not significantly different in SWL outcome [Table 2]. Some of the our results were not what one would expect, like hydronephrosis or perinephric stranding being second and third best in terms of SFR [Table 2].

DISCUSSION

Upper urinary tract calculi are commonly encountered in Urology Department, currently open surgery virtually obsolete, traditionally SWL and PNL were considered the first line therapy for renal stone, nowadays retrograde intra renal surgery using flexible smaller-diameter ureteroscopes combined with a greater angle of deflection of the tip and advances in laser technology has become an attractive option. According to the current guidelines SWL and flexible ureteroscopy should be

Table 1: Patient characteristic

Number of patients	Group A (stone ≤ 10 mm) (n=92)		Group B (stone > 10 mm) (n=88)		P#
	Kidney (n=40)	Ureter (n=52)	Kidney (n=45)	Ureter (n=43)	
Age (mean \pm SD)	18-66 (36 \pm 13.7)	16-62 (33 \pm 12.4)	20-63 (34 \pm 12.03)	17-58 (36 \pm 11.2)	>0.05
Sex					
Male	21	28	23	24	>0.05
Female	19	24	22	19	>0.05
Laterality					
Right	18	23	21	20	>0.05
Left	22	29	24	23	>0.05
Stone location	40	52	45	43	>0.05
Stone size/mm	4.3-10 (7.4 \pm 1.3)	4.1-10 (6.2 \pm 1.04)	10.1-20 (14.7 \pm 5.2)	10.1-20 (13.2 \pm 4.3)	>0.05
Hydronephrosis	9	32	19	31	>0.05
JJ stent insertion	None	5	8	22	>0.05
Perinephric stranding	4	19	11	29	>0.05
SSD (mean \pm SD)/mm	111 \pm 10.6		107 \pm 12.9		>0.05
BMI	34.3 \pm 4.3		33.23 \pm 1.9		>0.05

Data presented as #P value between the total numbers in the 2 stone size categories. SD: Standard deviation, SSD: Skin-to-stone distance, BMI: Body mass index

Table 2: Outcome of SWL according suggested predictive factors

	Group A (stone ≤ 10 mm)				Group B (stone > 10 mm)			
	Success		Failure		Success		Failure	
	Kidney (n=38)	Ureter (n=47)	Kidney (n=2)	Ureter (n=5)	Kidney (n=37)	Ureter (n=31)	Kidney (n=8)	Ureter (n=12)
Stone size (mean \pm SD)	5.7 \pm 1.3 mm*#		8.3 \pm 1.5 mm*		13 \pm 1.9 mm*#		18 \pm 1.6 mm*	
SSD (mean \pm SD)/mm	90.9 \pm 11.9 mm*#		130 \pm 12.2 mm*		90.3 \pm 12.3 mm*#		120.8 \pm 13.1*#	
BMI (mean \pm SD)	33.57 \pm 3.1		35.2 \pm 2.1		31.43 \pm 2.9		30.99 \pm 0.9	
Hydronephrosis								
Present	7*#	28*#	2*	4*	13*#	21*#	6*	10
Absent	31	19	0	1	24	10	2	2
Perinephric stranding								
Present	2*#	14*#	2*	5	5*#	20*#	6*	7*
Absent	36	28	0	3	32	11	2	5

Data presented as *P value between success and failure group within the same stone size category, Data presented as #P value between the total number in the 2 stone size categories. SD: Standard deviation, BMI: Body mass index, SSD: Skin-to-stone distance

the first line therapy for upper ureteral stone.^[7] Over the last decade, SWL success rates have been correlated with BMI, stone density, stone burden, and SSD. Our study predicting the success of SWL of upper urinary tract stone helps to increase the quality of treatment [Table 4].

Stone size is a leading independent predictor factor on SFR after SWL, in a current study, an SFR of 92.39%, 77.2% was detected for stones <10 mm and stone larger than 10 mm, respectively. Our data collaborates with recent studies have shown high success rates of 92% and 74% for stone <10 mm and 11–20 mm, respectively.^[8] Joshi *et al.*, demonstrates that SFR was 97%, 97%, and 90%, respectively; for stone <10 mm, 10–15 mm, and >15 mm in 3 months follow-up (three sessions) [Table 5].^[9]

Several studies revealed that the energy of the shock wave and shock amount needed for fragmentation was related to stone density and that the higher the HU values, the stronger the shock wave energy and more shock wave numbers and session needed to achieve fragmentation.^[4] Gupta *et al.*,^[10] found that stone density ≤750 HU undergo successful treatment outcome requiring less number of shock wave and session with clearance rate 90% versus 60% for stone density >750 HU. Hameed *et al.*,^[11] reported that successful fragmentation using ESWL was decreased in stones with HU >1350, which required the application of more shock waves. El-Assmy *et al.*,^[12] used the Hounsfield value of the stones to predict

stone composition and density, and the fragmentation success using ESWL, and selected HU >1000 as their cut-off value.

Stone density was found to be a significant predictor of success, as well as the failure on multivariate analysis.^[13-15] Beyond this, it is remarkable that stone density was a better independent predictor than the size of the stone.^[16] Our results were comparable to recent studies, who reported that an HU is a significant predictor of success of SWL outcome.^[15,17,18] In our study, analyzing density values showed that the group with >1000 HU values was significantly different from those with HU values of <500 HU ($P = 0.001$) and 500–1000 HU ($P = 0.02$). When the unsuccessful groups were evaluated, the >830 HU value was highlighted as the threshold.

According to our study, stone size is one of two factors that affect the success of SWL. When the correlation was evaluated, the stones size ($r = 0.776$) was the most significant affecting factor predicting the result of SWL rather than the stone density ($r = 0.672$). Contrary to previous results reported in the literature,^[16,19] we believe that stone size is the more independent predictor of successful lithotripsy for renal and ureteric calculi rather than stone density.

Stone size and mean stone HU are not alone a definitive factors determining the success rate and it should be combined with other parameters. BMI is also used as predictor, which is related indirectly to the SSD, which reflects the SW path

Table 3: Post-SWL stone clearance, number of SWL sessions, and shockwaves required stratified by stone size

SWL	Group (A) stone ≤10 mm (n=92) (kidney 40, ureter 52)				Group (B) stone >10 mm (n=88) (kidney 45, ureter 43)			
	Success group		Failure group		Success (n=68)		Failure (n=20)	
	Kidney (n=38)	Ureter (n=47)	Kidney (n=2)	Ureter (n=5)	Kidney (n=37)	Ureter (n=31)	Kidney (n=8)	Ureter (n=12)
1 st session	21	27	1	1	13	9	0	2
2 nd session	14	13	0	2	15	12	3	5
3 rd session	3	7	1	2	5	7	3	3
4 th session	0	0	0	0	4	3	2	2
	38 (95%)	47 (90.4%)	2 (5%)	5 (9.6%)	37 (82.2%)	31 (72.1%)	8 (17.8%)	12 (27.9%)
Total SFR	85 (92.39%)*,#		7 (7.61%)*		68 (77.2%)*,#		20 (22.8%)*	
Number of shocks	3413±1510*				5413±2100*			
Number of session	1.5±0.7*				2.8±1.1*			

Data presented as * P_a value between success and failure group within the same stone size category, Data presented as # P_b value, between the total number in the 2 stone size categories. SWL: Shock wave lithotripsy, SFR: Stone-free rate

Table 4: Post-SWL stone clearance, number of SWL sessions, and shockwaves required stratified by stone attenuation value and stone size

Stone Hounsfield	Group (A) stone ≤10 mm (n=92)				Group (B) stone >10 mm (n=88)							
	Success (n=85)		Failure (n=7)		Total number of shock waves*	Number of SWL sessions*	Success (n=68)		Failure (n=20)		Total number of shock waves*	Number of SWL sessions*
	Kidney	Ureter	Kidney	Ureter			Kidney	Ureter	Kidney	Ureter		
HU <500	12*	23*	0	0	2192.8±134.7*,#	1.3±0.5*,#	19*	14*	0	0	2821±1694*,#	1.5±0.6*,#
HU 500-1000	20*,#	17*,#	1	1	3647±1598*,#	1.7±0.8*,#	13*,#	13*,#	2	4	5273±2356*,#	2.3±0.7*,#
HU >1000	6*,#	7*,#	1	4	4835±18473*,#	2.3±1.1*,#	5*,#	4*,#	6	8	7975±2.987*,#	2.8±1.5*,#
	38	47	2	5			37	31	8	12		

Data presented as * P_a value between the total number in the 3 stone attenuation and same stone size categories. Data presented as # P_b value, between success groups within the same stone attenuation and 2 stone size categories. HU: Hounsfield unit, SWL: Shock wave lithotripsy

Table 5: Combination score; combined analysis of CT-based metric parameters

Stone size	Stone HU	SSD	SFR (%)
Stone <10 mm	Stone HU <830	SSD <90 or >120	100
	Stone HU >830	SSD <90	83.30
	Stone HU >830	SSD >120	37.50
Stone >10 mm	Stone HU <830	SSD <90	100
	Stone HU >830	SSD <90	52.60
	Stone HU >830	SSD >120	28.57

*HU: Hounsfield unit, **SSD: Skin to stone distance, ***SFR: Stone-free rate. CT: Computed tomography

in the body, since BMI may not directly reflect central body fat distribution, it cannot reliably used as surrogate marker for SSD, the utility of BMI in predicting successful is variable, Pareek *et al.*,^[4] demonstrates that BMI independently predict SWL outcome, they suggest that patient with BMI >30 kg/m² would be suitable treated by endoscopic manipulation, Yang and colleague^[20] demonstrates similar results which BMI and buttock circumference being noted as predictors of SWL failure, conversely our study corroborates with recent studies that BMI is not predictive factor for SWL outcome.^[5,21]

The energy of shock wave diminished by 10–20% for every 6 cm it traverses. SSD is a readily available metric that attempts to measure the presumed path of the shock wave from stone to the skin. In our series, SSD was a significant predictor of SWL success in agreement with recent studies reported that SSD <10 cm can predict the success of SWL.^[17,19,22,23]

Interestingly, we found that the efficacy of SWL decrease in ureteral stone in compare to renal stone because we found that a difference in SSD between renal and ureteral stones by 2–2.5 cm. This is probably due to the anatomical medial position of the UPJ and proximal ureter compared to the renal calices. Moreover, the SW path of ureteric calculi affected by visceral fat (intra-abdominal fat distribution) and para/perirenal fat, whoever SW path of renal calculi affected by para/perirenal fat.

Simultaneous consideration of CT-based metric parameters can be challenging, combined analysis of preoperative factors can augment predictive power and allow easier application of these tools in clinical practice. Simultaneous consideration of three parameters (stone size, stone attenuation value, and SSD) was utilized in our study, we found that SFR was 100% for stone attenuation value <830 HU for stone <10 mm or >10 mm, but total number SWL sessions and shock waves required for the larger stone group were higher than in the smaller group ($P < 0.01$); and SFR was 83.3% and 37.5% for stone <10 mm, mean HU >830, SSD 90 mm and SSD >120 mm, respectively. On the other hand, SFR was 52.6% and 28.57% for stone >10 mm, mean HU >830, SSD <90 mm and SSD >120 mm, respectively.

CONCLUSION

Readily available predictive tools are necessary to enhance SWL success and cost effectiveness. Stone size, stone density, and SSD is simple to calculate and can be reported by radiologists. Applying combined score help to augment the predictive power of SWL, reduce cost, and aid in the development of treatment strategies.

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Conflicts of interest

There are no conflicts of interest.

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