

**Original Research Article****Predictive Value of Hounsfield Unit, Volumetric Stone Burden in Fragmentation and Specific Composition of Urinary Calculi**

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Dr Girish Kumar SharmaEmail: drgirishuro@yahoo.com. Phone No. 9418085416**Abstract**

Introduction: NCCT parameters and images play an important role in determining the best surgical approach in management of urinary stone. Knowledge of chemical composition of stone is crucial in selecting optimal surgical approach and it can be of great help in reducing the stone recurrence rate.

Objective: Our study aimed at assessing the predictive value of HU and VSB in success of ESWL / URSL and to evaluate whether HU value can predict the urinary calculi composition.

Material and Methods: Our study included 55 patients of upper urinary tract calculi diagnosed on NCCT. Patients were grouped as Group A (n=29) with renal / upper ureteral calculi subjected to ESWL and Group B (n=26) with stone in mid / lower ureter subjected to URSL.

Observations: A statistically significant association of VSB was found with the no. of sessions required to achieve SFS following ESWL (p value < 0.01) in Group A patients. In Group B patients, single session stone free rate following URSL was 96.15%. HU value was not an independent predictor of SFS in either of the group. However VSB and HU value had an impact on total duration of procedure and energy settings required for fragmentation during URSL. The correlation between HU value and chemical composition of calculi could not be clearly depicted as none of the calculi was of pure nature.

Conclusion: VSB was an independent predictor influencing the outcome of ESWL. HU value was not independent predictor of successful outcome of ESWL / URSL in our study.

Keywords/Abbreviations: ESWL–Extracorporeal Shock Wave Lithotripsy, URSL–Ureteroscopic Lithotripsy, SFS–Stone Free Status, VSB–Volumetric Stone Burden, HU–Hounsfield Unit.

INTRODUCTION

Non-contrast Computed Tomography (NCCT) is diagnostically superior in evaluation of suspected urolithiasis. Apart from diagnosis, NCCT is useful

in pre-operative planning and has been demonstrated to be an independent predictor of successful treatment with Shockwave Lithotripsy (SWL).^[1]

Extracorporeal Shock Wave Lithotripsy (ESWL) dramatically altered the management of urolithiasis in the early 1980s and still is a preferred procedure for renal and ureteral stones.^[2-3] With technical advances in the area of ureteroscope designing and energy delivering sources, Ureteroscopic Lithotripsy (URSL) has emerged as a minimally invasive procedure for diagnosis and treatment of pathology in any region of ureter and PCS with advantage of higher stone free rate (SFR) in single session.

No consensus data exists relating the Hounsfield Unit (HU) value and stone fragility, although evidences points to higher HU stones being resistant to ESWL.^[4] While it is difficult to confirm stone composition without sample analysis results or a history of metabolic syndrome, imaging can be of help in predicting stone fragmentation and possibly composition.

Aim of this study was to assess the predictive value of HU and Volumetric Stone Burden (VSB) in fragmentation of renal and ureteric calculi and to evaluate whether HU value can predict the specific composition of urinary calculi.

MATERIAL AND METHODS

Our study included 29 patients with symptomatic renal or upper ureteric calculus and 26 patients with mid or lower ureteric calculus, diagnosed on NCCT and were treated by ESWL (Group A patients) and URSL (Group B patients) respectively after urological workup.

NCCT was performed on 64 slice CT scanner, model VCT Xte; GE Healthcare (helical technique, 120KV, 5 mm collimation). The slice containing the largest diameter of the calculus was identified and region of interest (ROI) was drawn along the margin of calculus and HU was recorded. Maximum transverse diameter (D) and maximum height (H) of the calculus was measured and VSB was calculated: $VSB (mm^3) = D^2 \times H \times \pi \times 1/6$.

FTIR Spectroscopy – a reliable method for in-vitro quantitative determination of proportion of various constituents in calculi was used for

analyzing fragments of calculi retrieved after URSL and ESWL.

Follow-up of patients was done at 2nd and 4th week with X-ray and USG of the KUB region. NCCT KUB was done if required. Patients with ureteric calculi were defined as stone free if no stone or fragment of size <2 mm in size was seen on follow-up imaging. Patients with renal calculi were defined stone free if no stone or CIRF of <4mm was seen on follow up imaging.

NCCT features of calculi and ESWL (Group A patients: n = 29)

Out of 29 patients subjected for ESWL, 24 patients had renal and 5 had upper ureteric calculus. Out of 24 renal stone patients, lower pole calculus was seen in 8 patients. In 10 patients, there was multiple renal stone whereas in 19 patients, renal and upper ureteric calculus was solitary.

CT attenuation of calculus (HU value): In 14 patients (48.2%), the CT attenuation value was >1000 HU whereas CT attenuation value of 600-1000 HU and of <600 HU was reported in 12 patients (41.3%) and 3 patients (10.3%) respectively. The mean CT attenuation of calculus was 935 HU and maximum attenuation value was 1450 HU. [Fig -1]

Volumetric Stone Burden (VSB): Most of the patients (n=17; 58.6%) had VSB of <500mm³. VSB of 500-2000 mm³ and >2000 mm³ was seen in 34.4 % (n=10) and 6.8 % (n = 2) respectively. The mean VSB was 955.1 mm³ and the largest calculus had a VSB of 10932 mm³. [Fig - 2]

Group A patients were positioned properly on treatment table for ESWL under IV antibiotic cover and diclofenac analgesia. The ESWL procedure was done using electromagnetic lithotripter, Duet Magna (Direx) incorporating two electromagnetic shockwave transducer at complementary angles to the horizon and having the facility of X ray and/or ultrasonic imaging device to localize the stone. The treatment was started on a lower energy setting with a step-wise power ramping, gradual increase of shock-wave frequency (1kV to 20 kV; 60-100ppm) and

maximum of 3000 shocks were delivered in one session. Intermittent visualization ensured accurate focusing and change in stone size, outline or separation/fainting indicated stone fragmentation. In post-procedural period, an alpha-blocker drug was prescribed and patients were reviewed at 2nd and 4th week to assess the SFS. Patients were subjected to a maximum of 3 sessions of ESWL with a gap of one month after the initial procedure, for each anatomical site bearing calculus.

NCCT features of calculi and URSL (Group B patients; n =26)

Most of the patients (n=15: 57.6%) who underwent URSL had mid ureteric calculus. Lower ureteric calculus was detected in eleven (42.30%) patients.

In twelve patients (46.15 %) CT attenuation value was in range of 600-1000 HU. The mean CT attenuation of calculi was 900 HU and the maximum was 1250 HU. [Fig – 3]

Most of the patients (n=16) had VSB of <100mm³, mean VSB was 124.9mm³. The largest calculus had VSB of 906 mm³. [Fig – 4]

The first step in URSL was retrograde placement of floppy-tipped hydrophilic guide wire in PCS under fluoroscopic guidance. Semi rigid ureteroscope (Karl storz 8Fr, 43cm) was then advanced under direct guidance, and once stone was visualized, pneumatic lithotripter (Nidhi, ≤ 3Fr Probe) was used to fragment the calculus. Stone fragments were retrieved and sent for stone analysis. On completion of procedure, double J stent was placed if required and alpha-blocker drug was prescribed. Patients were reviewed at 2nd and 4th week to assess the SFS.

OBSERVATIONS

Stone free status after ESWL/URSL:

SFS was attained in 2 patients (6.89%) after first session of ESWL. In these patients, mean HU and VSB of calculus was 1150 ± 424.2 HU and 95 ± 108.8 mm³ respectively.

Sixteen patients(55.1%) who achieved SFS after second session of ESWL had mean HU and VSB

of 905.3±231 HU and 237.4 ± 166.8 mm³ whereas nine patients (31%) who achieved SFS after 3rd session had mean HU and VSB of 925.66 ± 288.85 HU and 1206.1 ± 889.9 mm³ respectively.

One patient with upper ureteric stone and another bearing renal pelvic calculus with mean HU and VSB of 1000±141.42 HU and 6428±6369.6 mm³ respectively were labeled as failure cases (6.89%) because SFS was not achieved even after 3rd session of ESWL.

In Group A patients, VSB had positive correlation with no. of shockwaves/sessions required (p value <0.01) to achieve SFS while CT attenuation value of calculi was not independent predictor (p value 0.712) of SFS following ESWL. [Table -1]

Out of 26 patients (Group B) who underwent URSL, the single session SFS was achieved in 25 patients at 2-4 weeks follow up. In 3 out of these 25 patients who achieved SFS, VSB and CT attenuation value was >250 mm³ and >1000 HU respectively, they required prolonged procedure duration (>1hr) as well as higher energy setting of lithotripter. In one patient, the calculus of VSB 244 mm³ and CT attenuation value 1250 HU located in mid ureter migrated into renal pelvis and couldn't be fragmented; hence considered as failure of URSL (failure rate 3.8%).

Relationship of stone analysis with HU:

The chemical composition of all the 25 calculus fragments retrieved following URSL was determined, whereas the chemical composition could be determined only in 14 patients who underwent ESWL because remaining couldn't collect the fragments. All the calculi on analysis showed mixed chemical composition. Maximum calculi showed calcium oxalate monohydrate (CaOMH) as one of the chief constituents (60-80%) having mean CT attenuation of 939 ± 203.4 HU. Calculi comprising of Calcium oxalate dehydrate - CaODH (20-35%) as one of the constituents was found in 19 patients with mean CT attenuation of 915 ± 221 HU. In one patient uric acid, present as one of the constituents (12%), had a CT attenuation of 950 HU. [Table – 2]

FIGURE – 1: HU values of calculus (Group A patients)

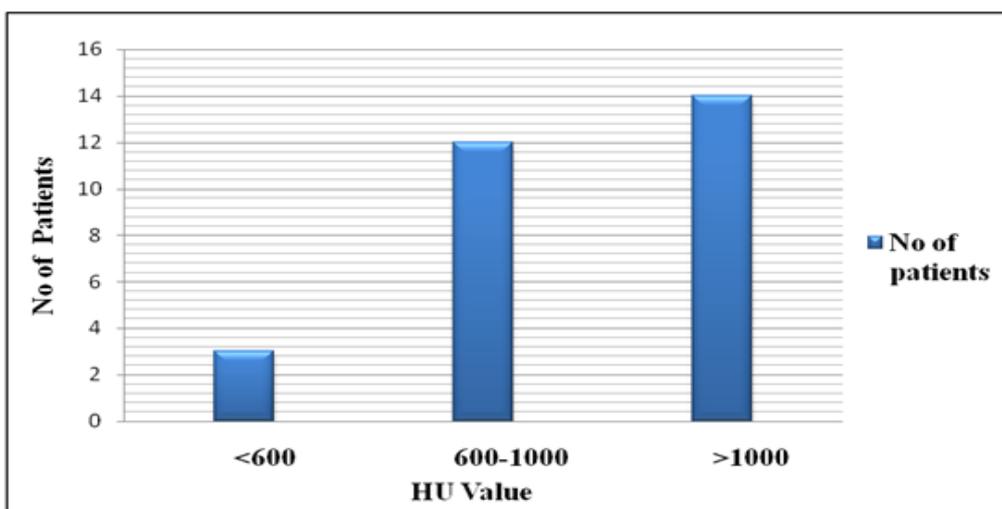


FIGURE – 2: VSB of calculus (Group A patients)

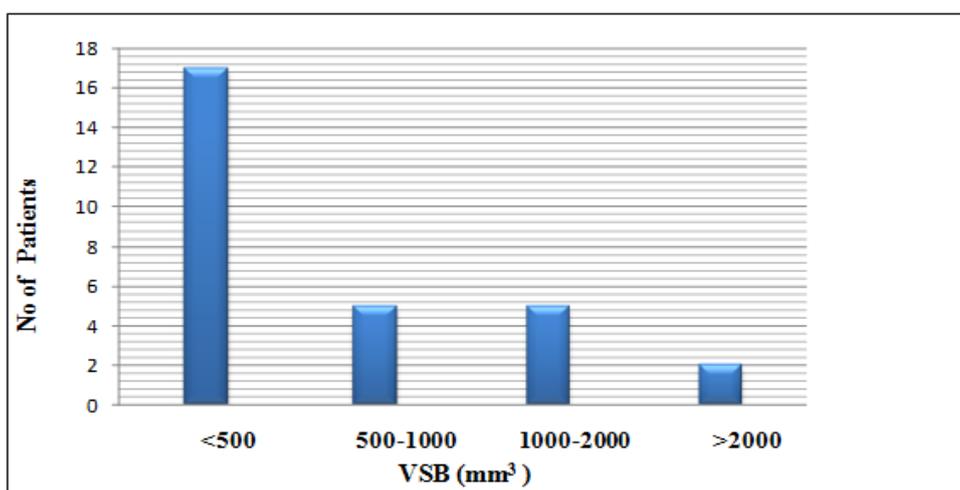


FIGURE -3: HU values of calculus (Group B patients)

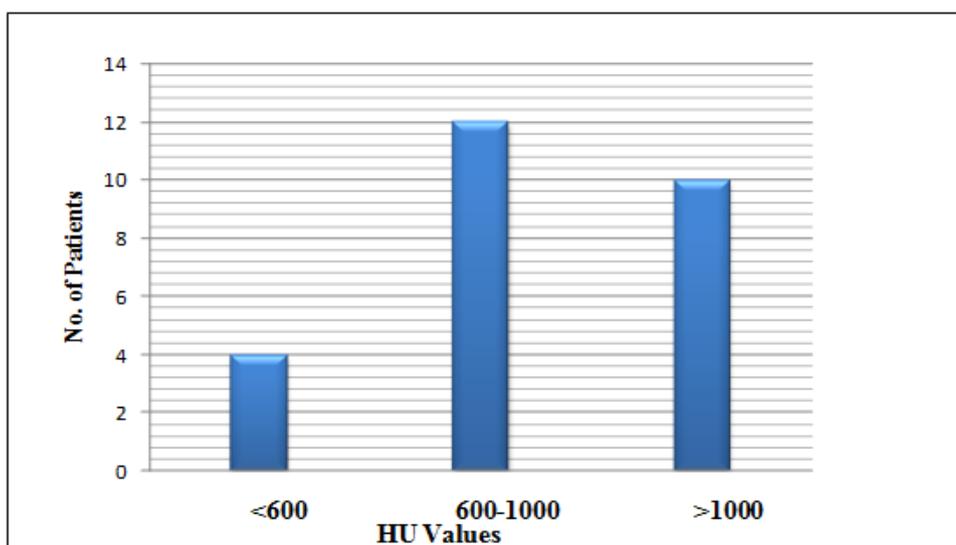


FIGURE – 4: VSB of calculus (Group B patients)

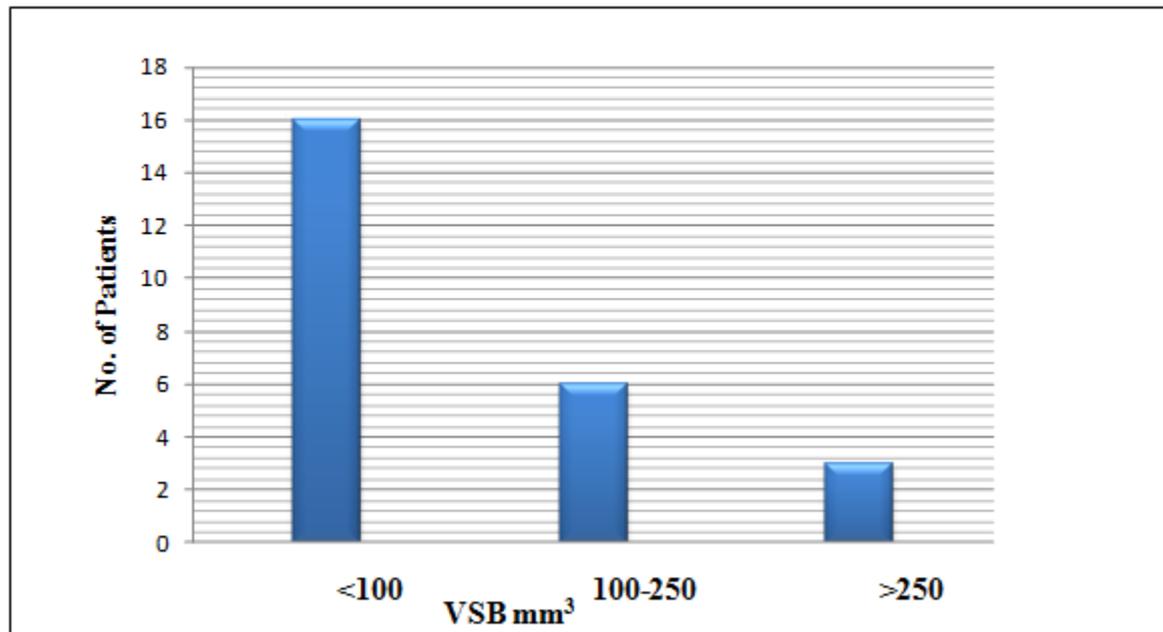


TABLE-1

[Relationship of VSB, HU with number of session to achieve SFS following ESWL]

No of session	No of patients	SFS	VSB		HU	
			Mean	S.D	Mean	S.D
First	29	2	95.00	108.8	1150	424.2
Second	27	16	237.4	166.8	905.3	231.0
Third	11	9	1206.1	888.9	925.66	288.85
P value			<0.01		0.712	

TABLE – 2

[Relationship of stone composition with HU values]

Present study		Nakasato et al (2015) ³²		
Composition		Mean HU ±S.D	Chemical composition	Mean HU±S.D
CaOMH	>80%	843.2 ± 299.3	100-80%	772±224
	60-80%	939 ± 203.4	<80-60%	807±221
	<60%	882 ± 260.3	<60-50%	736±173
CaODH	<20%	872.8 ± 246.4	100-80%	694±224
	20-35%	915.4 ± 221.7	<80-60%	672±177
	>35%	895 ± 275.8	<60-50%	761±236
Matrix	<5%	991 ± 255.3	-	-
	>5%	874 ± 192.3	-	-
Carbonate apatite	-	980.8 ± 227.8	-	-
Uric acid	12%	950	-	412±40
Calcium phosphate	-	-	-	758±231
Unclassifiable	-	-	-	676±249

DISCUSSION

NCCT was first reported for the evaluation of urinary stones in 1970s and was initially introduced for diagnosis of radiolucent stones ^[5] but currently is considered as the modality of choice for diagnosis of stone disease in patients presenting with acute renal pain.

SWL technology has advanced rapidly in terms of shockwave generation, focusing, patient coupling, and stone localization, this has made it the most widely used modality for renal calculi ^[6] as well as a safe and accepted option in treatment of ureteral stones. ^[3]

A number of studies suggest that stone density of >1000HU is commonly considered as strongly predictive of ESWL failure. ^[7] Hameed et al

reported that successful outcome of ESWL was decreased in calculus with HU > 1350 and required application of more shock waves. ^[8] A study by Massoud et al reported that patients with Stone attenuation value (SAV) of > 956HU were not ideal candidate and SAV was an independent predictor of ESWL outcome. ^[9]

Bandi et al found VSB to be strongest predictor of ESWL outcome in multivariate analysis (p< 0.001) in their study of patients with upper urinary tract calculi. ^[10]

In our series, two patients (6.89%) attained SFS after first session while 55.1% and 31 % of the patients attained SFS following second and third session of ESWL. VSB had positive correlation with the number of sessions required to achieve

SFS following ESWL (p value - <0.01) while CT attenuation value was not an independent predictor (p value – 0.712) in our study.

In series of Kim et al, VSB and location of stone was found to be the prime factor in determining success of URSL. The success rate of URSL in their series was 76%, 93.8% and 98.7% for upper, mid and lower ureteric calculus respectively and revealed that HU value didn't affect the successful outcome of URSL.^[11] However, they did not assess the duration of procedure and energy setting for fragmentation during URSL while dealing with the calculus of higher HU value.

In series of Choi JW et al, HU of ureteral stone was not a significant predictor of ESWL outcome in the univariate analysis (p>0.05).^[12] In series of Nakasato et al, success rate of ESWL was 66.5% and stone location followed by HU value was the strongest factor in predicting its success.^[13]

Yip et al compared the efficacy of URSL and ESWL and reported single session stone clearance rate of 100% and 95% for mid and lower ureteric stone respectively in the URSL arm. While single session success rate of 51% and overall success rate of 78% after retreatment was reported in the ESWL arm.^[14]

In our study, single session stone free rate of URSL was 96.15 % for mid and lower ureteric calculus at 2-4 month follow-up. There was single failure because of up migration of calculus during URSL having VSB of 244 mm³ and HU value of 1250. In our study HU value of calculus was not independent predictor of successful outcome of URSL, similar to study of Kim et al, who presumed that success of URSL depends mainly on intensity of fragmentation power that can be delivered directly to the stone. Higher VSB and CT attenuation value of calculus had an impact on total duration of URSL and higher energy for fragmentation was required for achieving SFS in our study.

In various studies, there is marked overlap of NCCT attenuation values in different stone classes, as well as prediction of stone composition in-vivo was found to be difficult unless the retrieved stones were analysed. Torricelli FC et al

concluded that single energy NCCT may predict calcium oxalate stones with high degree of accuracy but there was an overlap in radiographic profile of cystine and uric acid stone.^[15] Shahnani et al couldn't predict exact composition in cystine, uric acid and struvite calculi based on HU and HD value.^[16]

Ribeiro de Oliveria T et al retrospectively analysed treated patients of urinary stones, who had stone biochemical analysis and correspondent NCCT study. The mean attenuation value for each subgroup of stone in their patients was; 638 HU for calcium stone, 431 HU for uric acid stone and 756 HU for infectious stones. Non pure calculi were found in majority of their patients and prediction of stone composition using attenuation value was not feasible in-vivo.^[17]

The CT attenuation value depends on the percentage of various constituents of the calculus, as depicted in Table – 2 of our study, and showing a comparison with the study of Nakasato et al. The correlation between CT attenuation value and chemical composition of calculi couldn't be clearly depicted in our study as none of the calculi was of pure nature. Secondly, the fragments collected by the patients following ESWL subjected for analysis were considered to be the only chief component, which might not have represented the actual percentage composition of the calculus. So, we couldn't exclude the possibility that our study might have influenced the stone analysis results.

Minimally invasive techniques, ESWL/URSL has enormous short term benefits to patients, which deals with the present stone disease but doesn't address the underlying cause and has no impact on recurrence rates. Evidence - based medical interventions and prophylactic measures have significant impact on reducing the incidence and recurrence rate of urolithiasis. So accurate identification of all component present in calculi is necessary and should be combined with relevant blood and urine analysis reports for identification of treatable urolithogenic factors to reduce the rate of recurrence.

CONCLUSION

Based on NCCT profile, i.e. attenuation value measured prior to ESWL/URSL, prediction of stone composition and definite differentiation of stones in cases of mixed type calculi is challenging without chemical analysis. It appears that HU value can predict the fragmentation of stone by ESWL and should be used to optimize the ESWL outcome but was not an independent predictor in our study. However, VSB bears positive correlation with number of shockwaves/sessions required to achieve SFS following ESWL.

The improvements in Ureteroscopic and energy delivering technology have enabled URSL to become a preferred modality for most ureteral stone in achieving SFS in single session. However, higher VSB and HU value influences the duration of procedure and energy setting required for fragmentation.

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