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Original Research Article

The efficacy of Hounsfield unit density of renal calculi in predicting the success of ESWL

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Abstract: The outcomes of extracorporeal shock wave lithotripsy (ESWL) depend on several factors and the stone composition has emerged as the main factor influencing the efficacy of ESWL. The density of the stone varies with composition and the stone attenuation value (SAV) on non-contrast CT can be used to assist in determining the density of urinary calculi in vivo. The aim of this study was to evaluate whether the SAV of urinary calculi on NCCT can be used as an independent predictor of calculus fragmentation by ESWL. The Materials and methods in the study included 50 patients with the single renal calculus of less than 2cm. The Hounsfield unit measured using NCCT. All patients underwent ESWL using the Dornier Compact Sigma Electro Magnetic Shock Wave Emitter. The outcome was evaluated after three months of ESWL session by NCCT. In Results the Patients were divided into three categories according to SAV in NCCT. The overall number of stone-free patients was 46/50 (92.00 %). In 4 patients (8%) ESWL failed and all are of HU>1000 category. In HU>1000 category mean numbers of the shock wave and average energy needed for successful stone disintegration was significantly higher than other two categories. We conclude that the use of NCCT for determining the attenuation values of urinary calculi before ESWL helps to predict treatment outcome. A stone density of > 1165 HU suggests a poor chance of stone disintegration with a Dornier Compact Sigma Lithotripter. The use of this threshold could help to plan alternative treatment in patients with the likelihood of ESWL failure.
Keywords: ESWL, Stone attenuation value, Non-contrast CT, Hounsfield unit, stone density.

INTRODUCTION

ESWL is the preferred treatment modality for renal calculi of <2 cm in diameter, with the success rates of 60–99%. The outcomes of ESWL depends on several factors, including stone size, location, pelvicalyceal anatomy, body mass index (BMI), stone composition, the shock wave generator and the presence of obstruction or infection [2,3]. The stone composition has emerged as the main factor influencing the efficacy of ESWL [4]. The density of the stone varies with composition and affects the fragility of a calculus, which ultimately governs the clinical outcome in ESWL.

The stone attenuation value (SAV) on non-contrast CT (NCCT) can be used to assist in determining the density of urinary calculi in vivo. The failure of ESWL results in wasted medical costs, deterioration in patients with obstructed kidneys, unnecessary exposure to ionising radiation and to shock waves. Hence, it is desirable to distinguish those patients who would benefit from ESWL from those who need an alternative treatment.

The aim of this study was to evaluate whether the SAV of urinary calculi on NCCT, measured as Hounsfield units (HU) can be used as an independent predictor of calculus fragmentation by ESWL.

MATERIALS AND METHODS

It was a prospective observational study conducted in a tertiary care centre. The institute ethical committee clearance and written consent from all patients were taken. In this study, we included adult patient's age more than 18 years presenting with a solitary renal stone of size 0.5-2 cm on a plain X-ray film, USG, and IVU. A total 50 patients of renal stones were studied from February 2013 to November 2014. The patients with evidence of distal urinary tract obstruction, deranged renal function, prior renal surgery, active infection, and stone in the calyceal diverticula, blood coagulation disorders, obesity, uncontrolled hypertension and pregnancy were excluded from the study.

All patients underwent thorough history, clinical examination and haematology, biochemical and urine investigations. Pre-procedural a multi-slice non-contrast CT of KUB region (16 slice, GE Healthcare, BRIVO CT 385 series) was done with 3 mm slices to measure the highest mean stone attenuation value (SAV) and size of the stone. All patients underwent ESWL using the Dornier Compact Sigma Electro Magnetic Shock Wave Emitter. Patients were treated in the supine position by a single experienced urologist. Intravenous analgesia in the form of 1ml (75 mg) diclofenac aqueous was given just prior to the procedure. Energy level ABC up to 200 shocks then increased gradually 1,2,3,4 etc as required with a frequency of 60 shocks/min. The fragmentation of the calculus during the therapy was monitored by fluoroscopy. The session was stopped when the stone disintegrated satisfactorily or machine's upper limit of shock waves per session (3000) was reached. Post ESWL instructions were rest for 3 days, plenty of oral fluids, to pass urine in a strainer for the collection of stone. Patient / attendant explained about possible complications. Analgesic, diuretic, antibiotic and alfa-blocker were routinely advised in all patients. If required second and third session of ESWL was planned. In between two sessions minimum 15 days gap was maintained. None of our patients suffered from major complication

Post-procedural NCCT done after three months of the last ESWL session to document fragmentation and clearance and the outcome of ESWL was described as a success or failure. Success defined as stone-free, i.e., completes stone clearance or clinically insignificant residual fragments (CIRF) ≤ 4 mm with no symptoms after ESWL. Failure was defined as residual stone fragments, i.e., clinically significant residual fragments > 4mm after three sessions of ESWL and or no evidence of fragmentation after three sessions of ESWL.

Data were analysed by IBM SPSS Statistics v20.0 software. For the non-parametric data chi-square test (univariate analysis) and Kruskal-Wallis tests were applied and for parametric data, one way ANOVA (with post-hoc Tukey test) was done at 5% significance level. Receiver operative characteristic curve (ROC) was done to find out the most sensitive and specific cut-off point for HU score in determining the success of stone attenuation.

RESULTS

Total 50 patients were included in this study and divided into three categories according to SAV in NCCT [Table 1]. The success rate after the first sitting of ESWL was 83% in category 1, 81% in category 2 and only 59% in category 3. The overall number of stone-free patients were 46/50 (92.00 %). In 4 patients (8%) ESWL failed and all are of HU>1000 category. For successful stone fragmentation by ESWL, the mean number of shock waves and average energy level were needed higher in HU>1000 category than the other two categories [Table 2] and they were statistically significant (p-value< 0.05). The stone density of 1165.50 HU represented the most sensitive (80.4%) and specific (100%) cut-off point for stone fragmentation by ESWL [Figure 1].

Table 1: The patient's particulars and characteristics of stone

Variables		**Value**
N (%)		50(100)
Age (years)	Mean	35
	Range	18 - 58
Sex	Male	30
	Female	20
Side	Right	32
	Left	18
Stone size (mm)	Mean	9.46
	Range	5 - 16
Stone density (HU)	Mean	879
	Range	130 - 1602
Site of stone	Pelvis	16
	Upper calyx	5
	Middle calyx	5
	Lower calyx	20
Categories according to SAV on NCCT	Cat. 1 ≤ 500HU	12
	Cat. 2 501 – 1000HU	16
	Cat. 3> 1000HU	22

Table 2: The effect of SAV on the success of ESWL

Variable	SAV			p value
	Category 1 <500HU	Category 2 1500-1000HU	Category 3 >1000HU	
No of patients	12	16	22	
Complete stone clearance %	100% (12/12)	100% (16/16)	82% (4/22)	
Mean no. of shock waves needed	2285.4 ± 943.1	2284.9 ± 912.6	3167.5 ±1346.6	p = .031
Avg. Eng level	1.67 ± 0.651	1.63 ± 0.619	2.27 ± 0.883	p = .019

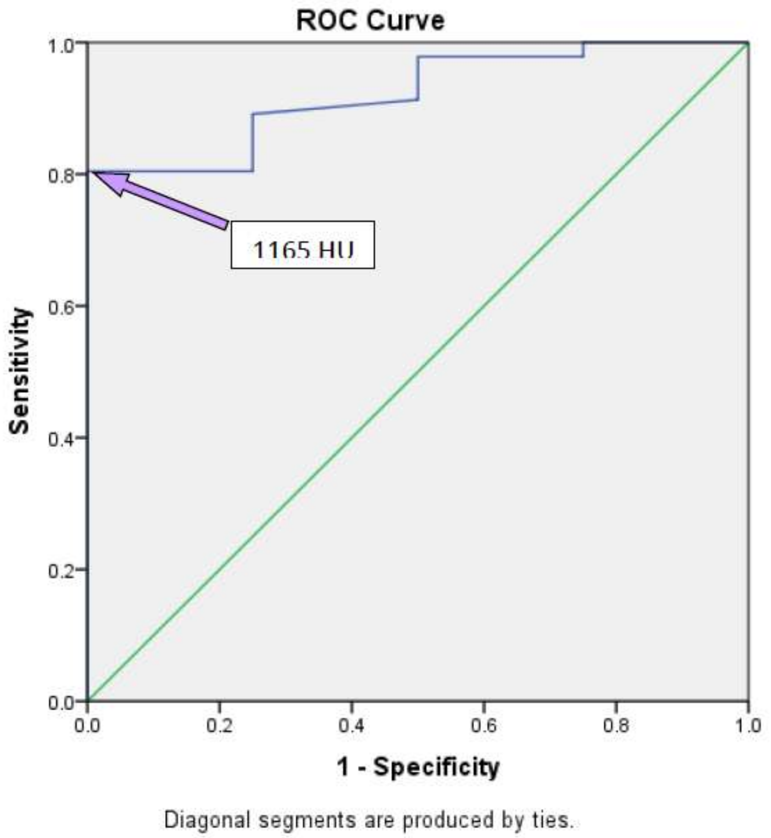

Fig 1: **Receiver – Operating Characteristic**

DISCUSSION

ESWL has revolutionized the management of urolithiasis, with further decreases in morbidity and mortality rates [23]. Proper case selection depends on several factors for both the success of ESWL and the avoidanceof the side-effects of this treatment. Dretler and Polykoff introduced the concept of stone fragility on ESWL, based on the composition of the stone [6]. Cystine and brushite calculi are the most resistant to ESWL, followed by calcium oxalate monohydrate, struvite, calcium oxalate dihydrate, and uric acid stones. Stone composition affects the fragmentation and the type of fragments produced. Except for cystinuric patients and patients who have had previous stone analysis, the accurate prediction of the stone composition is not possible [26]. Stone shape, homogeneity, and radiographic density in comparison with bone on a plain abdominal film have been used to predict stone composition and fragility, but the overall accuracy of predicting stone composition from plain radiographs was reported to be only 39% and therefore inadequate for clinical use [15,27]. NCCT can capture a density difference of 0.5%, as opposed to a plain film, which requires a density difference of >5% [3]. The NCCT provides an abundance of information on urinary tract calculi, including the size, shape, number, location, SAV, and skin-to-stone distance [2]. Joseph *et al.;* grouped patients according to the SAV in the same categories as used in the present study [19]. The rate of stone clearance was 100% in group 1, 85.7% in group 2 and 54.5% in group 3. Patients in group 3 required a higher median number of shock waves for stone fragmentation than those in groups 1 and 2 (7300, 2500 and 3390, respectively). The mean SAV and number of shock waves required for stone fragmentation were significantly positively correlated, and those authors concluded that the success rate for stones with a SAV>1000 HU was significantly lower than that of stones with an SAV <1000 HU. Pareek *et al.;* found that the mean (SD) SAV for the stone-free and residual-fragment groups were significantly different, at 577.8 (182.5) vs. 910.4 (190.2) HU, respectively, concluding that renal calculi with a high SAV (>900 HU) are more amenable to endoscopic manipulation as the initial treatment rather than ESWL [29]. Gupta *et al.;* concluded that the worst outcome was in patients with a SAV>750 HU and a stone diameter >1.1 cm, as 77% of those patients needed more than three sessions of ESWL, and the clearance rate was 60%.[13] Wang *et al.;*. concluded that a SAV>900 HU is a significant predictor of the failure of ESWL [30].

In the present study, the overall number of stone-free patients after ESWL for kidney stones was 46/50 (92.00 %). In 4 patients (8%) ESWL failed, which is consistent with previous studies reporting a failure rate of 5–20%. The present study confirmed the results of previous studies for the effect of the SAV on the results of ESWL. 83.33 % of patients with a SAV ≤ 500 HU were stone-free after one session and rest 16.66 % cases required two sessions, irrespective of the size and location of the stone. In this group, it was apparent that the stones start to fragment, and complete the fragmentation, at a low average energy level 1.67 ± 0.651. Nevertheless, the stones needed <2500 shock waves to achieve complete stone fragmentation, with a mean (range) of 2118.75 (650 -3000)shock waves. In patients with SAVs of 501–1000 HU the ESWL was successful in 100 %, with about 81.25 % of the patients needing one and 18.75 % needed two ESWL sessions; with a mean (range) of 2284.87 (800 – 4600) shock waves. In patients with a SAV>1000 HU, ESWL was successful in 81.81%, 59.09% of them in a single session, 22.72% requiring two sessions. They required a mean (range) of 3083.40 (924 – 5800) shock waves. In patients with SAVs of >1000 HU, significantly higher mean a number of shock waves and average energy needed than other two groups. Herein, we propose a new threshold of 1165 HU, calculated using the Youden index on the outcome of a prospective cohort, to predict successful ESWL treatment. This threshold, obtained by measurements by a single radiologist. This is higher than previous similar studies and which was around 1000 HU. Explanations are likely due to small sample size, mean stone size < 10 mm which is less than previous studies, ESWL done by a single experienced urologist, a procedure done in almost painless condition by the third generation Dornier Compact Sigma machine and sometimes >4 mm stone can pass spontaneously before follow-up. Besides, among the patients, 9 had a stone density of >1165 HU and had a successful outcome. This means that any of the predictive factors taken separately cannot identify all patients who are likely to benefit from ESWL and exclude those that will have a poor outcome. A modern approach should combine all the discriminators including stone location, size, and skin to stone distance, BMI, and stone density. Finally, although CT is associated with greater radiation exposure and costs than plain radiography, the density calculation is more accurate and it improves patient selection for ESWL and selected patients are likely to become stone free or have CIRF. For others, alternative treatments, including Percutaneous nephrolithotomy or, ureteroscopy could improve care by avoiding repetitive treatments and ultimately this could potentially be more cost-effective.

CONCLUSION

The use of NCCT for determining the attenuation values of urinary calculi before ESWL helps to predict treatment outcome. A stone density of **>** 1165 HU suggests a poor chance of stone disintegration with a Dornier Compact Sigma Lithotripter. The use of this threshold could help to plan alternative treatment in patients with the likelihood of ESWL failure. However, the large randomized controlled trial is needed for further confirmation.

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