ORIGINAL RESEARCH ARTICLE

Correlation of Stone Attenuation Measurement on Non-Contrast Enhanced Computed Tomography with Stone Fragmentation Using Extracorporeal Shock Wave Lithotripsy in Upper Urinary Calculi

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A B S T R A C T

Introduction: Extracorporeal shock wave lithotripsy (ESWL) has been extensively used in management of urinary calculi, however its success rate is variable depending upon the size and attenuation value of stones. Non-contrast computed tomography (NCCT) can accurately measure these parameters. The purpose of present study was to assess role of NCCT Hounsfield unit (HU) measurement in upper urinary calculi for predicting success rate of ESWL.

Material and methods: The present prospective study was conducted in 30 subjects with symptomatic radio-opaque solitary renal or upper ureter calculus measuring 5-20mm. Patients were divided into two groups (A and B), depending on the CT attenuation values of less or more than 750 HUs respectively. All treatment was done by an electromagnetic lithotripter (Dornier Compact Delta, Singapore) under fluoroscopic guidance. Cases of residual fragments larger than 5 mm or of a stone that did not fragment satisfactorily were considered failures. Mean HU per stone was compared in the stone free and residual stone groups.

Results: Out of 30 subjects, 17 belonged to group A (stone HU value <750HU) and 13 belonged to group B (stone attenuation value ≥750HU). The mean number of shock waves delivered in two groups A and B were 4411.76 and 7615.38 respectively (p<0.0001). Mean stone size in group A was 1.51cm and that in group B was 1.59 (p value- 0.5346). The stone clearance rate in Group A was 100% versus Group B where it was only 15.4% (p <0.001). Overall, mean attenuation values for the stone-free and residual stone groups were significantly different (514.10 versus 970.36 HU, respectively, p <0.0001).

Conclusion: NCCT attenuation value has inverse relationship with ESWL outcome with poor response at HU value ≥750HU.

Key words: Computed Tomography, ESWL, Hounsfield Unit, Urinary Calculi

INTRODUCTION

At its inception in the early 1980s, shock wave lithotripsy was viewed as the ideal minimally invasive therapy for renal calculi.[1] The side effects were minimal and the treatment was believed to be highly effective. It largely swept open lithotomy and even today shockwave lithotripsy (SWL) is the most commonly utilized modality for urolithiasis. Nonetheless, it is evident that SWL is not ideal for all stones.

The ability to identify appropriate candidates for SWL therefore continues to be refined. Advancements in imaging have significantly contributed to this process. In the mid-1990s, computed tomography (CT) began to replace intravenous urography (IVU), abdominal films (KUB), and ultrasound (US) in stone diagnosis. Studies demonstrated that CT had superior sensitivity and specificity for stone diagnosis compared to the aforementioned modalities. Now non-contrast CT (NCCT) is the gold standard for detection of urinary system calculi.[2]

CT is also clinically useful as it is able to show alternate renal and non-renal pathology if present, and also can detect uric acid stones which otherwise may not be detected on KUB films.[3] In the last decade, the utility of CT has gone beyond simple diagnosis. By determining stone attenuation, NCCT can give some idea of composition of stones with uric acid stones being of lower attenuation (200-400HU) and calcium phosphate and calcium oxalate monohydrate stones being of high attenuation (>1000HU). The success rate of ESWL also depends upto stone hardness/fragility which is related

to its density and composition. NCCT determination of attenuation value is helpful and high attenuation correlates with more density.[4] We evaluated the role of NCCT for predicting success rate of ESWL.

MATERIAL AND METHODS

The present prospective study of ESWL outcome (in terms of stone fragmentation) by measuring the calculus density (in Hounsfield units) using non-contrast enhanced CT (NCCT) scan was conducted in Department of Urology, Sri Satya Sai Institute of higher Medical Sciences, Puttaparthy, Andhra Pradesh.

A total of 21 men and 9 women (15-60 years) participated in this prospective study conducted between March 20th 2009 to 31st March 2011. The study was approved by institutional ethics committee. Patients with a symptomatic radio-opaque solitary renal or upper ureter calculus larger than 5 and up to 20 mm. in the largest dimension in satisfactorily functioning and unobstructed renal units were included in the study.

Those with a calculus less than 5 and greater than 20 mm, elevated serum creatinine (greater than 1.5mg/dl), bleeding diathesis, solitary functioning kidney, stents in situ, developing steinstrasse during therapy were excluded from study. The maximal linear diameter of the calculus was measured by plain x-ray of the kidneys, ureters and bladder.

Unenhanced (no oral or intravenous contrast) CT using 5 mm contiguous sections through the renal calculus was performed using a soft tissue setting of a window width and level of 280 and 15 Hounsfield units respectively, on a Siemens Somatom Emotion 6 slice scanner (Siemens Medical Solutions, Munich, Germany) at 110 – 140 kv, 72-90 mA and scan time 10-15 seconds.

The image showing the calculus in largest dimension was selected and a pixel map of the largest possible region of interest with in the calculus was generated. The mean calculus attenuation value was calculated. Patients were divided into two groups (A and B), depending on the CT attenuation values of less or more than 750 HUs respectively.

All treatment was done by an electromagnetic lithotripter (Dornier Compact Delta, Singapore). Calculi were fragmented under fluoroscopic guidance. A change in calculus size and/or outline, or separation of stone fragments indicated fragmentation. During 1 ESWL session a maximum of 3,000 shocks were delivered at the energy level of 2 to 4, corresponding to 14 to 15 kV.

Treatment was terminated if satisfactory fragmentation was noted earlier. Another ESWL session was done after 6 weeks if follow-up plain x-ray of the kidneys, ureters and bladder showed significant residual fragments. When a calculus did not fragment ever after 3 sessions, the patient was offered alternative therapy. The total number of shock waves delivered to any renal unit were limited to a maximum of 9000 during the course of treatment.

Plain x-ray of the kidneys, ureters and bladder was performed 6 weeks after the completion of treatment for assessing the outcome. Cases of residual fragments larger than 5 mm or of a stone that did not fragment satisfactorily were considered failures. Mean HU per stone was compared in the stone free and residual stone groups.

Stone location	Number of subjects (percentage)
Renal pelvis	10 (33%)
Upper calyx	6 (20%)
Mid-calyx	5 (16.6%)
Lower calyx	2 (6.6%)
Upper ureter	7 (23.3%)

Table-1: Showing distribution of subjects with respect of location of stone

STATISTICAL ANALYSIS

Statistical analysis was performed using student t test using statistical software StatPac version 4.0 (StatPac, Inc., Bloomington, MN). p value of <0.05 was considered to be statistically significant.

RESULTS

A total of 30 patients were studied who met the study inclusion criteria, none of the patient lost to follow-up. Out of these, 21 were males and 9 were females with mean age of 35.43 years.

A total of 7 stones (23.3%) were located in the ureter. A total of 23 stones (76.6%) were located in the kidney (Table 1). Of the intra-renal calculi 10 (33.3%), 6 (20%), 5 (16.6%) and 2 (6.6%) were in the renal pelvis, upper pole, mid pole and lower pole, respectively. The mean number of shock waves delivered in two groups A and B were 4411.76 and 7615.38 respectively (p<0.0001).

Out of these, 17 belonged to group A (stone HU value <750HU) and 13 belonged to group B (stone attenuation value ≥750HU). There was no significant difference in size of stones in two groups. Mean stone size in group A was 1.51cm and that in group B was 1.59 (p value- 0.5346) The mean number of shock waves delivered in two groups A and B were 4411.76 and 7615.38 respectively (p<0.001). The stone clearance rate in Group A was 100% versus Group B where it was only 15.4% (p <0.001). Out of 11 subjects with treatment failure in group B, two had inadequate fragmentation with significant residual stone fragments in urinary system while 9 subjects showed no fragmentation on ESWL (Table 2).

Group	No. of subjects	Mean no. of shock waves delivered	Mean no. of ESWL sessions	Mean stone size	Fragmentation percentage	Significant residual fragments	No fragmentation
Group A	17	4411.76	1.47	1.51cm	17 (100%)	0	0
Group B	13	7615.38	2.46	1.59cm	2 (15.4%)	2	9
p value		<0.001	<0.01	>0.05	<0.001		

Table-2: Showing average stone size, shock waves delivered and stone clearance rate in two groups

Overall, mean attenuation values for the stone-free and residual stone groups were significantly different (514.10 versus 970.36 HU, respectively, p <0.0001).

Two patients developed hematuria after lithotripsy sessions and were managed expectantly.

DISCUSSION

Kidney stones are a significant source of morbidity. 80% of those with kidney stones are men; most stones in women are due to either metabolic defects (such as cystinuria) or infection. Men most commonly experience their first episode between ages 30–40 years, while for women the age at first presentation is somewhat later. Recurrence rates are estimated at 50% over a 10 years period and 75% over 20 years periods with some experiencing ten or more episodes over the course of a lifetime.[5]

In India, more than 5 million patients suffer from urinary stone disease and at least 1/1000 of them need hospitalization at some time in their life for its management.[6] The recurrence of stone disease is higher in males compared to female. It is thought to be due to lithogenic effect of testosterone and lack of inhibiting effect of estrogen hormone.[7]

In India, Maharashtra, Gujarat, Punjab, Haryana, Delhi and Rajasthan are the regions most affected by urinary stone disease. Surgery for removal of urinary stones forms one of the commonest operations in hospitals in these regions.[8]

NCCT can be rapidly performed even in unstable patients and those with renal impairment. It provides an abundance of information on urinary tract calculi, including size, shape, number and location. NCCT can detect even almost all radiolucent stones which can be missed on conventional radiographs. In addition, the attenuation value of calculi measured in HU obtained from non-contrast CT may be used to predict stone composition.[4, 9, 10]

In present study, 70% of the subjects with stone disease were males which is consistent with other studies in literature.[4,11,12] A higher incidence in male subjects can be explained by due to hormonal differences and relative lack of stone inhibitors in males in reproductive age group.[13]

This study provides compelling data suggesting the importance of measuring HU in all patients who undergo non-contrast CT to evaluate urinary calculi. By evaluating patients undergoing ESWL for upper urinary tract calculi we determined whether the success of this procedure could be predicted by pretreatment HU values measured on non-contrast CT. Furthermore, we included only patients with a single stone between 5 and 20 mm which allowed for the evaluation of a homogeneous group of stones commonly treated with ESWL. Inclusion of all stones of various sizes would have diluted the data, making it uninterpretable. Because of fairly uniform groups, there was no significant difference in stone size between two groups with different HU values.

In the present study, when patients were categorized by calculus density, 56.66% with calculi of < 750HU had complete clearance with 100% success rate. Conversely, of patients with calculi of ≥750HU (43.34% subjects), only 15.4% could clear the stones completely, leaving rest as partially fragmented or un-fragmented. Analysis indicated that the attenuation value (calculus density) had an inverse relation with outcome. In the study of Omer et al,[14] the rate of stone clearance in upper urinary system using ESWL was 100% with stones of <500HU value while those with >1000HU had only 10% clearance rate. While in the study of Naik et al,[4] the success rate was 100% with stones of <500HU value and about 33% for >1000HU stones. In the study of Joseph et al,[16] the success rate was 100% with stones of <500HU value and about 55% for >1000HU stones. Therefore, all these studies demonstrate 100% success rate with stones of <500HU, while the success rate was low for stones more than 1000HU. In our study, the success rate was 100% for stones even upto 750HU value with markedly decreased success rate of ESWL above this value. In the study of Gupta et al,[16] the success rate was 88% for stones more than 750HU while it was 65% for stones more than 750HU. There was significant difference in mean attenuation value in stone-free and residual stone groups (514.10 versus 970.36 HU). Pareek et al[17] observed similar findings. In their study, the mean HU value of stone free group was significantly lower than that with residual stone group (551HU vs 926HU). Ouzaid et al[18] suggested a threshold of 970Hu for predicting success of ESWL in stone clearance. Thus, results of present study are in agreement with previous studies and in reiterates the fact that stone attenuation value has an inverse relation with success rate of ESWL.

In present study, there is no statistically significant difference in size of stones in groups with treatment success and failure. Similar observations have been made by other authors.[4,18]

Mean number of ESWL sessions required was significant higher in group with stones of >750HU value (1.47 vs 2.46), which means that stones with higher attenuation value require more number of ESWL sessions. Similar observations have been made in other studies.[4,19]

CONCLUSION

In conclusion, Patients with HU < 750 have higher significantly stone fragmentation rate (100%) versus patients with HU > 750 (15.4%), which suggests that the HU measurement of upper urinary calculi (renal or upper ureteric) on pre-treatment non-contrast CT predicts the stone-free rate after ESWL. HU determination on non-contrast CT as well as stone size may be beneficial for selecting the preferred treatment option, that is ESWL, ureteroscopy or percutaneous nephro-lithotomy for patients with urinary calculi.

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