Original Article

Evaluation of effectiveness of extracorporeal shock wave lithotripsy (ESWL) on the basis of stone density as measured by computed tomography (CT) in patients with renal stone

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Abstract

Renal stone or urolithiasis is the third most common disease of the urinary tract. ESWL has become the preferred treatment for renal calculi of <2 cm in diameter except in lower calyx. CT with non enhancement by contrast medium has long been used clinically to evaluate substance density in Hounsfield units (HU) to distinguish calculi from calcifications, tumors and blood clots. Present study was conducted to evaluate effectiveness of ESWL on the basis of stone density as measured by CT scan in patients with renal stone. This hospital based cross sectional study was conducted from April, 2014 to September, 2015 in the Department of Radiology & Imaging and Department of Urology, BSMMU. Sixty patients presented with renal stone with an age group of 18 years and above in both sexes who were attended in the OPD were included as study population. Patients were divided into two groups based on HU: patients having HU<900 were belonged to Group-A and HU≥900 were belonged to Group-B. Mean (SD) stone density among the respondents in Group A was 717 (76) HU and in Group B was 1091 (99) HU. Mean (SD) shockwaves needed in Group A and Group B were 2590 (223) and 3000 (132) respectively. In group A, 10 (38.5%), 13 (50.0%) and 3 (11.5%) patients needed 1, 2 and 3 session respectively for complete clearance of stone whereas in group B, 1 (11.1%), 3 (33.3%) and 5 (55.6%) patients needed 1, 2 and 3 session respectively for complete clearance of stone. This study concluded that Hounsfield units (HUs) measurement of urinary calculi on pre-treatment non-contrast CT predicts the stone fragmentation rate after extracorporeal shockwave lithotripsy (ESWL).

Key Words: Renal stone, extracorporeal shock wave lithotripsy,, stone density

Introduction

Renal stone or urolithiasis is increasing day by day due to different life style and as well food habits.[1] It is interesting that this increase is seen regardless of sex, race and age.[2] Plain film radiography, excretory urography, retrograde pyelography and ultrasonography have been used in various combinations for diagnosis of urinary tract stones in patients presenting with flank pain.[3] Non-contrast helical computerized tomography has become the radiographic modality of choice by providing rapid and accurate determination of stone parameters when evaluating urinary lithiasis.[3] The ability to assess urinary tract calculi characteristics and to determine susceptibility to fragmentation is not a new phenomenon.[4]

ESWL is introduced in the early 1980s which has dramatically changed the management of urinary tract stones. Many investigators have studied the usefulness of non-contrast CT for evaluating urinary calculi and observed that it provides greater density discrimination than conventional plain abdominal film or excretory urography.[3] Non-contrast CT scan can provide an abundance of information on urinary tract calculi, including size, shape, number and location.[5] By evaluating patients undergoing ESWL for upper urinary tract calculi it will be determined

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the success of this procedure which will be predicted by pretreatment HU values measured on non contrast CT scan.[5] The ability of non Contrast CT (NCCT) scan to detect density difference as low as 0.5% has been used to determine the composition which ultimately governs the clinical outcome in ESWL and reduce the number of hospital visit as well as cost.

Methods

From April 2014 to September 2015, total 60 patients were participated in this prospective study. Patients with a symptomatic solitary stone, 0.5 to 2 cm in the largest dimension in satisfactorily functioning and unobstructed renal units, located in renal pelvis upper and middle calyx were included in this study.

Patients age between 23 to 57 years, sex was randomly selected and the patients with BMI of around 23 was selected in all the cases for this study. Patients with stone at any other anatomic location like lower calyceal and calyceal diverticular stone, stone size more than 2 cm, less than 0.5 cm, previous unsuccessful attempt at ESWL, radiolucent stone, multiple stones, active urinary tract infection, distal urinary tract obstruction, bleeding diathesis, severe skeletal malformation, pregnancy, congenital urinary tract anomalies or elevated serum creatinine level (>2mg/dl) were excluded from this study. Preprocedural radiological evaluation included plain x-ray of the kidneys, ureters and bladder and non contrast CT of KUB on a multi-slice CT scanner**.**

Stone size, stone location (upper calyceal, middle calyceal and renal pelvic), stone attenuation values (Hounsfield units, HUs) and skin to stone distance were recorded. The lowest, highest and most common attenuation values were recorded and the mean calculus attenuation value was calculated. Patients were divided into two groups based on calculus attenuation value i.e. group 1: calculus attenuation value <900 HU, group 2: calculus attenuation value value >900 HU.

Pre-procedural consultation, operative procedure and follow up were performed by one surgeon. All treatment was done by an electromagnetic Lithostar Multiline lithotripter (Siemens, Germany) as an outpatient basis. All patients received analgesia in the form of parenteral tramadol hydrochloride just before the procedure. Calculus was localized and monitored under fluoroscopic guidance. In supine position, patients were delivered approximately 3000 shocks at 90shocks/min to each stone. The treatment began with a low voltage (3-3.5 KV), then increased gradually that could be tolerated by the patients and in this study all patients finally received the treatment with a shock intensity of 16 KV. The numbers of shock impulses to be delivered to the stone were not predetermined and were decided by the operator during the session depending upon the ongoing fragmentation as observed through fluoroscopy. After the procedure, patients were prescribed analgesics, antibiotics for one week and advised to take adequate amount of water.

Plain x-ray of kidneys, ureters and bladder was performed in all patients as a scheduled follow up 4 weeks after the procedure for assessing the outcome. ESWL success was defined as patients being stone free (SF) or with remaining stone fragments of <3mm, which were considered as clinically insignificant residual fragments (CIRF). Remaining fragments of >3mm or non-fragmented stones after 3 sessions of ESWL were considered as treatment failure.

Hounsfield units (HUs) of every fragmented and non-fragmented stones and the number of shockwaves received for fragmentation of stone were observed and compared in the stone free and residual stone groups. The fragmentation rate in all three groups (based on calculus attenuation value) as well as the mean number of shockwaves received for fragmentation of stone in each group was also observed and compared.

Result

In our study Mean (SD) age was 42.9 (8.6%) and 43.1 (6.1%) years in group A and group B respectively. Difference between these two groups in age was not statistically significant. Total 34 patients were male and 26 patients were female. Out of them, 16 (53.3%) male patients were in group A and 18 (60%) male patients were in group B. Among the female, 14 (46.7%) patients were in group A and 12 (40%) were in group B. Difference was not statistically significant. Total 39 patients had stones in the right side, among them 21 (70%) were in group A and 18 (60 %) were in group B. Total 21 patients had stones in left side, among them 9 (30 %) were in group A and 12 (40 %) were in group B. Difference was not statistically significant. The mean BMI, SDD, density of stones and shockwaves received for fragmentation were relatively lower in group A than group B and were 22.5 (2.) kg/m^2, 83.7 (4.2) mm, 717 (76) HU, 2590 (223) and 24.9 (1.3) kg/m^2, 100.4 (6.3) mm, 1091 (99) HU, 3000 (132) respectively and these values were statistically significant (*p <0.001).* (Table-I).

Table-I: Values according to Hounsfield Unit groups after ESWL

	Attenuation value		
	Group A HU<900	Group B HU>900	*p*
n (%)	30(100.0%)	30(100.0%)	
Age (years) [Mean (SD)]	42.9 (8.6)	43.1 (6.1)	0.905*
Sex, *n(%)*			0.602#
Male	16(53.3%)	18(60.0%)	
Female	14(46.7%)	12(40.0%)	
Side, *n(%)*			0.417#
Right	21(70.0%)	18(60.0%)	
Left	9(30.0%)	12(40.0%)	
BMI, kg/m^2 [Mean (SD)]	22.5(2.0)	24.9(1.3)	<0.001*
SSD, mm [Mean (SD)]	83.7(4.2)	100.4(6.3)	<0.001*
Stone density, HU [Mean (SD)]	717(76)	1091(99)	<0.001*
Shock waves [Mean (SD)]	2590(223)	3000(132)	<0.001*

*Unpaired t test was done to measure the level of significance

#Chi-square test was done to measure the level of significance

In group A (HU ≤900) success rate is 86.7% (26 cases out of 30) and failure rate is 13.3% (4 cases out of 30) and in group B (HU >900) success rate is 30% (9 cases out of 30) and failure rate is 70% (21 cases out of 30). Success rate is high in group A with lower calculus attenuation value (≤900 HU) and success rate is lower in group B with higher calculus attenuation value (>900 HU) (Table -II).

In success group, the mean number of shockwaves received for fragmentation of stones in group A, and group B were 2545 (203) and 2916 (221) respectively and the mean calculus attenuation value were 704 (64) HU and 986 (40) HU respectively. Significantly lower number of shockwaves was required in group A with lesser calculus attenuation value than in group B with relatively higher calculus attenuation value (Table - III).

Table-II: The fragmentation rate of stones in two groups (based on calculus attenuation value)

	Attenuation value		p value
	Group A HU≤900	Group B HU>900	
Success	26 (86.7%)	9 (30.0%)	0.001
Failure	4 (13.3%)	21 (70.0%)	
Total	30 (100.0)	30 (100.0)	

Chi-square test was done to measure the level of significance

Table -III: Analysis of HU and shockwaves in different groups.

Variables	Group A (<900 HU)		p value	Group B (>900HU)		p value
	Success Mean (SD)	Failure Mean (SD)		Success Mean (SD)	Failure Mean (SD)	
HU	704 (64)	805 (101)	0.011	986 (40)	1136 (81)	0.001
Shockwaves	2545 (203)	2883 (77)	0.003	2916 (221)	3037 (31)	0.018

Unpaired t test was done to measure the level of significance

Table VI shows number of ESWL session required in success cases. In group A, 10 (38.5%), 13 (50.0%) and 3 (11.5%) patients needed 1, 2 and 3 session respectively. But in group B, 1 (11.1%), 3 (33.3%) and 5 (55.6%) patients needed 1, 2 and 3 session respectively. There was significant difference between these two groups.

Discussion

Shockwave lithotripsy is one of the preferred treatment modality for calculus in the upper urinary tract since its introduction by.[6] It can remove up to 90% of stone in adults.[7] However, shockwave lithotripsy monotherapy is not successful in 9.4% to 26.3% of renal and proximal ureteral stones. The outcome of ESWL depends on many factors, including stone size, location, composition and fragility, type of shockwave generator, and presence of obstruction as well as characteristics of the patient. Relatively greater number of shockwaves was used for stones with higher stone density. HUs is an independent factor; more the HUs attenuation value of stones, more the shockwaves received for fragmentation.

In group A, 10 (38.5%), 13 (50.0%) and 3 (11.5%) patients needed 1, 2 and 3 session respectively. But in group B, 1 (11.1%), 3 (33.3%) and 5 (55.6%) patients needed 1, 2 and 3 session respectively. There was significant difference between these two groups. The study demonstrated that 10 (38.5%), 13 (50.0%) and 3 (11.5%) patients needed 1, 2 and 3 session respectively with stone density ≤ 900 HU for complete clearance of stone whereas 1(11.1%), 3(33.3%) and 5 (55.6%) patients needed 1, 2 and 3 session respectively with stone density > 900 HU for complete clearance of stone. Gupta and associates in their study demonstrated a linear relationship between the calculus density and number of ESWL sessions required. Of patients with calculi of < or = 750 HU, 41 (80%) needed three or fewer ESWL sessions and 45 (88%) had complete clearance. Of patients with calculi of >750 HU, 41 (72%) required three or more ESWL sessions, and 37 (65%) had complete clearance.

the development in the technology of endourologic procedures and SWL increases the management options of renal stones, it also increases the need for more evaluation of their efficacy and indications. Patient, stone and radiographic parameters have been studied as potential predictors of SWL success. In particular HU attenuation value has been shown to be a potentially useful independent predictor of success. Average HU attenuation is a convenient measure that can be easily determined from NCCT using a web based viewing system. Although CT is associated with greater radiation exposure and costs than plain radiography, NCCT stone characteristics predict ESWL success for nephrolithiasis. Patient characteristics are not so much predictive. ESWL success defined as stone free or clinically insignificant residual fragments (<3mm) is influenced by stone size, attenuation value and SSD. Stones with lower attenuation value are fragmented and ultimately clearing more.

In this study, HU and shockwaves were particularly analyzed to determine the predictors of ESWL success. Considering all these factors, patients may be advised to elect a more invasive procedure such as ureteroscopy or PCNL as the first line treatment that will reduce the unnecessary sufferings and medical costs of the patients. Findings of this study suggest that the Hounsfield units (HUs) measurement of urinary calculi on pre-treatment non-contrast CT predicts the stone fragmentation rate after extracorporeal shockwave lithotripsy (ESWL). Stones with lower attenuation values on non contrast CT are fragmented more than stones with higher attenuation values.

References

1. John D and Fuller A. Epidemiology of stone disease in North America. Urol Clin North Am 2012; 13-17.
2. Dretler SP. Stone fragility – a new therapeutic distinction. J Urol 1988; 139 : 1124-7.
3. Hesse A , Brandle E , Wilbert D, Kohrmann KU , Alken P . Study on the prevalence and incidence of urolithiasis in Germany comparing the years 1979 vs. 2000. Eur Urol 2003 ; 44 : 709-13.
4. Raynal G, Merlet B , Traxer O, (), 'In-hospital Stays for Urolithiasis: Analysis of French National Data', Prog Urol. 2011;21: 459-62.
5. Trinchieri A , Coppi F , Montanari E , Del Nero A , Zanetti G, Pisani E. Increase in the prevalence of symptomatic upper urinary tract stones during the last ten years. Eur Urol 2000 ; 37 : 23-5.
6. Chaussy C, Brendel W, Schniedt E. Extracorporeally induced destruction of kidney stones by shock waves. Lancet 1980; 2: 1265–8.
7. Miller NL , Lingeman JE. 'Management of Kidney Stones', BMJ. 2007; 334: 468 – 72.