Effect of Shock Wave Frequency on Treatment Outcomes in Patients with Renal Stone Treated by Extracorporeal Shock Wave Lithotripsy

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ABSTRACT:
BACKGROUND:
since the introduction of ESWL in treatment of renal stones, it remained the first option for most renal and ureteric stones, with a success rate ranging from 60% to 90%. Multiple variables can affect treatment outcome, including those related to the machine, dose administered, and factors related to the patient; the exact role of most of these factors is still under study.
OBJECTIVE:
We investigated the effect of shock wave frequency on treatment outcomes in terms of success and complication rates.
PATIENTS AND METHOD:
139 patients with radio-opaque renal stones, presented to the Urology consultancy clinic during the period June 2010 through January 2012 and decided to undergo ESWL treatment were randomized into three groups, the first group (46 patients) received shock waves at a frequency of 120 waves per minute, the second (47 patients) at 90 w/m, and the third group (46 patients) at 60 w/m. Patients were followed for treatment outcome and appearance of complications at 1 week, 3 weeks, and 6 weeks. Stone free status or insignificant asymptomatic residual gravels of 5mm or less are considered as success. Durations of hematuria and analgesic requirement were the main complications looked for during follow up, while subcapsular and retroperitoneal hematomas were looked.
RESULTS:
All patients received 3500-4000 shock waves per session at 17-18 KV energy. Success rate was significantly higher in the second and third groups, while the durations of hematuria and analgesic requirement were significantly shorter in groups 2 and 3. There was no significant difference between groups 2 and 3 in all outcome and complication parameters; however, the duration of treatment was significantly longer in groups 2 and 3.
CONCLUSION:
ESWL efficacy in fragmenting renal stones is significantly improved by decreasing frequency from the standard 120 sw/min to slower rates (90 and 60 sw/min), with significantly decreased analgesic requirement and hematuria durations. There were no significant differences between the 60 and 90 sw/min frequencies. Taking in account the longer treatment duration for the 60 sw/min frequency; the 90 sw/min frequency would be optimal in terms of stone disintegration, complications, and duration of treatment.
KEY WORDS: ESWL, renal stone.

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INTRODUCTION:
Shockwave lithotripsy has revolutionized the management of renal stones since its introduction early in 1980's. It remains the first option for most renal and ureteric stones [(1)], with a success rate ranging from 60% to 90% [(2)]. There are a number of variables that can affect the efficiency of shock wave lithotripsy, including stone factors, patient related factor, and lithotripsy related factors, the latter includes lithotripter design, energy setting,

shock wave electrode consumption level and the rate at which shock waves are administered[3].

While shock wave lithotripsy is considered safe and noninvasive, it can cause renal injury with intraparenchymal hemorrhage in the shock wave line. Subcapsular and retroperitoneal hemorrhages are well known and established complications, while long term issues such as hypertension are of concern. The above mentioned complication result from damage to renal parenchyma , the degree of which is related to many factors like the number of shock wave and the maximum voltage used[4] as well as the rate of voltage escalation[5]. The reduced effectiveness of the newer generation lithotripters has encouraged investigators to identify factors that affect positively or negatively the treatment outcome, and modify treatment strategies aiming at minimizing damage to surrounding tissues[2].

The effect of shock wave frequency on treatment outcome has been studied both in-vitro and in several randomized clinical trials [6-10], in our unit it was routine standard to use 120 shocks per minute in attempt to save time and treat more patient per day, however, recent publications has shown that decreasing the shock wave frequency may improve the stone disintegration rates [3,11,12].

If the stone fragmentation can be improved using shock waves at a slower rate and a fewer total number of waves delivered , patients could have a higher success rate with a fewer side effects of their stone treatment and spared from new ESWL sessions and more invasive treatment options [3].

In this study we compared stone disintegration and complications rates of shock waves at 60, 90, and 120 waves per minute.

PATIENTS AND METHODS:

Study design: double blinded, prospective, randomized controlled clinical trial.

Patients' grouping: 139 patients with 10-20mm, radio-opaque renal stones who were presented to the Urology consultancy clinic in Surgical Specialties Hospital at the Medical City Complex in Baghdad during the period June 2010 through January 2012 and were decided to undergo ESWL treatment for their renal stones were systematically randomized into three groups, the first group (46 patients) received ESWL at a frequency of 120 sw/min, the second group (47 patients) received the treatment at 90 sw/min, and the third group (46 patients) at 60 sw/min.

Exclusion criteria were: patients younger than 18 years, bilateral stones, recurrent stone, use of ureteric stents, anatomical or metabolic anomalies, and obese patients with body weight more than 100 kg.

In our unit, the standard treatment rate is 120 shocks per minute, so to decrease the impact on the daily schedule of treatment, only one patient was treated with 60sw/m, and one with 90sw/m each day.

The study was approved by the ethical committee and all patients were asked to give a written consent before being enrolled in the study.

Patients were investigated by routine blood and urine analysis, CT scan used to determine the stone size (measured as the greatest dimension) and location.

Patients were treated with Storz Modulith® SLX-F2 0109, all received 3500-4000 SW's started at 15 kv and increased gradually every 100 shocks to a maximum of 20kv, and the stone was monitored by fluoroscopy each 200 SW's. Tramadol intramuscular injection was given 15 minutes before commencing treatment were used for analgesia. The duration of treatment was recorded from the first to the last shock wave administered including the fluoroscopy time. The time needed to reposition the patient was omitted form calculation.

The patients were followed in terms of treatment outcome and appearance of complications at 1 week, 3 weeks, and 6 weeks after treatment by a blinded urologist and a radiologist using ultrasound and KUB films when needed as the ethical committee refused to justify the use of repeated CT scans in the follow up to document stone free rates.

Stone free status or insignificant asymptomatic residual gravels of 5mm or less after the first treatment session, were considered success.

Durations of hematuria and analgesic requirement are the main complications asked for in follow up, while subcapsular and retroperitoneal hematomas were looked for specifically using ultrasound performed by the same ultrasonographist in patients with long duration of pain or acute abdomen.

Ureteric obstruction was also given a special attention during follow up.

Data collected and analyzed statistically using SPSS 15, chi square, and student's t-tests were used as appropriate.

RESULTS:

Patients in all the three groups showed no significant difference in age, gender, and stone parameters (size, side, and location) as shown in table 1. They all received 3500-4000 shock waves per session at 15-20 KV energy.

Table 1: Demographic characteristics of patients in the three groups (success/total).

Parameter	Group 1 (120 sw/m)	Group 2 (90 sw/m)	Group 3 (60 sw/m)	P value
No.	46	47	46	0.71
Males	33	36	34	
Females	13	11	12	
Age	39.45∓9.7	41.93∓11.2	43.20∓11.7	0.19
Stone size	16.20∓2.8	14.80∓4.1	15.21∓4.8	0.29
Side				0.91
Right	25	23	25	
Left	21	24	21	
Location				0.78
Pelvic	8	10	9	
UC	13	12	13	
MC	12	12	11	
LC	13	13	14	

Sw/m : shock wave /minute, UC : upper calyx, MC : middle calyx, LC : lower calyx

Success rate was higher in the second and third groups than in the first group, and the difference was statistically significant (P=0.031 between groups 1 and 2, and P=0.028 between groups 1 and 3), see table 2.

Table 2: Treatment success rates in the groups in relation to stone location.

Stone site	Pelvic	Upper calyx	Middle calyx	Lower calyx	Total
Group 1	6/8 (75%)	10/13 (76%)	9/12 (75%)	6/13 (46%)	31/46 (67%)
Group 2	9/10 (90%)	10/12 (83%)	10/12 (83%)	11/13 (84%)	40/47 (85%)
Group 3	8/9 (88%)	11/13 (84%)	10/11 (90%)	12/14 (85%)	41/47 (87%)

Treatment time was significantly different between all the three groups, it was 33.1∓2.6 minutes, 49.4∓3.2 minutes, 66.2∓3.8 minutes in groups 1, 2, and 3 respectively.

The durations of hematuria and analgesic requirement were significantly shorter in groups 2 and 3 than in group 1 (for hematuria P=0.028 between groups 1and 2, and P=0.030 between groups 1 and 3, while for duration of analgesic requirement P=0.036 between groups 1 and 2, and P=0.040 between groups 1 and 3). Figure 1.

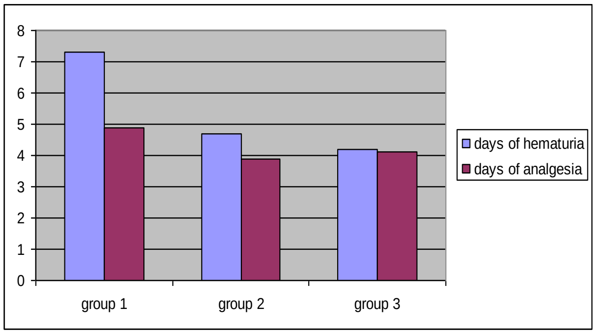

Fig.1: The duration of hematuria and analgesia requirement in the three groups.

There was no significant difference between groups 2 and 3 in all outcome and complication parameters; however, the duration of treatment was significantly longer in group2, and 3. No patient in all the three groups developed subcapsular, retroperitoneal hematomas, or ureteric obstruction.

DISCUSSION:

Since the invention of shock wave lithotripters early in 1980's, it has revolutionized the treatment of renal stones, and was believed to be a panacea for renal stones by many urologists [13]. However, the newer generations of lithotripters are associated with lower success rates [2], for this reasons, scientists started to investigate various factors that may limit the effectiveness of SW in disintegrating stones, including stone related, machine related, and treatment strategies related factors.

In the early lithotripters, the SW was delivered in synchronization with the patient's ECG, this resulted in a rate of 60-80 shocks per minutes that's not controlled by the operator [3], as new generations appeared, they used a rate of 120 sw/min, in no relation to the patient's ECG, and this was found safe, and shortened the treatment time [14], but treatment outcome was inferior to the first generation lithotripters, this have been at first attributed to the change in technology, but it may be partly due to the change in SW frequency [3]. In addition to improving the stone fragmentation rates, slower rates may also decrease the biological effect on renal tissue [15].

In this clinical trial we studied the impact of changing shock wave frequency on the outcome of treatment of renal stones; we compared 3 different frequencies, 60, 90, and 120 shocks per minute. To evaluate the independent effect of SW rate, we tried to fix all other parameters as stone size, number of SW delivered in one session, and energy level used, however; one parameter that can not be controlled is the stone type which is not known before treatment. We found that decreasing the frequency from the standard 120 sw/min to 90 and 60 sw/min was associated with a statistically significant improvement in the treatment outcome in terms of more efficient stone fragmentation and lesser pain and hematuria, however, there was no significant difference in the results between the 60and 90 sw/min groups. Taking in consideration the time factor, which is significantly longer between any tow of the three groups, we reached a conclusion that using the 90 sw/min frequency may be the best in terms of success, complications, and time of treatment.

Many in vitro and in vivo studies tried to find the SW frequency associated with the best treatment outcome. Vallancien et al tested SW frequencies of 75,150,300, and 600 sw/min for already analyzed retrieved human urinary stones, and found that the 75 and 150 sw/min frequencies were associated with the best stone disintegration rates specially in harder stones, but this was associated with significantly increased treatment time [18]. Later in vitro studies suggested even a slower rates as low as 30 and 60 sw/min, Greenstein et al found that a frequency of 60 sw/min was associated with the best outcome in fragmenting 118 standardized ceramic stones with a mean diameter of 9.5 mm using 30, 60, 90, 120, and 150 sw/min frequencies using an electrohydraulic lithotripter, with no significant difference between the 30 and 60 sw/min groups [19], a similar result was found by Weir et al later [20].

The first live animal study of the effect of changing SW frequency on stone fragmentation was conducted by Paterson et at 2002, they reported a better disintegration at 30 sw/ min in comparison with 120 sw/min, in fact they tried these frequencies because in an earlier in vitro study they failed to show any difference in stone fragmentation rates between 60 and 120 sw/min frequencies [(21)].

Later on, many clinical trials have been conducted to study the effect of changing SW frequency on stone fragmentation. In 2005, Madbouly et performed a randomized clinical trail on 156 patients treated for renal stones using 60 and 120 sw/min frequencies, they reported a significantly higher success rates in the 60 sw/min group, but they did not control for stone characteristics and the number of SW delivered in treatment sessions, in addition, the results were not based on a single SWL treatment [(22)]. In the same year, Kenneth et al in their prospective study comparing the 60 and 120 sw/min frequencies reported a higher stone free rates in the 60 sw/min group with lesser complications, more over, they stated that patients with larger initial stone area (more than 100 mm2) experienced a greater benefit with treatment at 60 sw/min [(3)]. One year later in 2006, Davenport et al reported no significant stone free rates in patients treated using 60 and 120 sw/min [(23)], many authors speculated that this may have been due to lack of larger stone sizes, and the use of an electromagnetic rather than electrohydraulic lithotripter [(2)].

Although the slower SW treatments were proved by many authors to be associated by better stone disintegration rates and less renal tissue damage, the mechanism behind this is not well known. In 1993, Choi and colleagues suggested that slowing the SW rate decreased the acoustic impedance mismatch, and improved cavitation bubble production on stone surface [(16)], on the other hand, Zhong and collegues suggested that slower rates cause less renal tissue damage by allowing more time for the bubble dissolution between shocks and avoiding capillary rupture [(17)], more over, decreasing the retreatment rate will also reduce the overall damage to the kidney.

The main disadvantage of slower frequencies in treatment is the significantly increased treatment time; this may be overlooked by the decreased retreatment rate and the improved patient satisfaction which is of significant importance in our community in which many false thoughts about the harmful effect of SW on kidneys predominate.

There are many limitations in our study, including the short time of follow up (3 weeks) because most of the patient would be lost if a longer duration to be adopted, we tested the effect using only one type of lithotripters, the electromagnetic, this effect needs to be reproduced using other lithotripter types, and finally, we need to investigate the long term effects on blood pressure and renal function.

CONCLUSION:

ESWL efficacy in fragmenting renal stones is significantly improved by decreasing frequency from the standard 120 sw/min to slower rates (90 and 60 sw/min), with significantly decreased analgesic requirement and hematuria durations. There were no significant differences between the 60 and 90 sw/min frequencies. Taking in account the longer treatment duration for the 60 sw/min frequency; the 90 sw/min frequency would be the most appropriate in terms of stone disintegration, complications, and time of treatment.

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