The Respiratory Induced Kidney Motion: Does It Really Effect the Shock Wave Lithotripsy?

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Purpose: To investigate the effect of respiratory induced kidney mobility on success of shock wave lithotripsy (SWL) with an electrohydraulic lithotripter.

Materials and methods: Between May 2013 and April 2015, 158 patients underwent SWL treatment for kidney stones with an electrohydraulic lithotripter. The exclusion criteria were presence of a known metabolic disease (such as cystinuria), non-opaque stones, need for focusing with ultrasonography, abnormal habitus, urinary tract abnormalities, and inability to tolerate SWL until the end of the procedure. Stones greater than 20 mm, and lower pole stones were also excluded. The movement of the kidneys were measured with fluoroscopy guidance.

Results: The procedure was successful in 66.7% of the males, and 56.9% of the females. The mean stone size was 11 ± 3 mm in the successful group, and it was 14 ± 4 mm in the unsuccessful group. The mean stone mobility rate was 32 ± 10 in the successful group and 40 ± 11 in the unsuccessful group. Multivariate analysis showed that stone size and kidney mobility affected the success rate significantly, however Hounsfield Unit (HU) did not.

Conclusion: The current study shows the significant effect of kidney motion on the success of SWL. Further studies with different lithotripters are needed to determine the significance of kidney mobility.

Keywords: kidney motion; kidney stone; shockwave lithotripsy; urolithiasis.

INTRODUCTION

Shock wave lithotripsy (SWL) was first described in 1980s, and it has become the milestone in the treatment of upper urinary tract stone disease[(1)]. Its use increased gradually, and currently it has been used even in the treatment of complex stones.

A number of factors affect the success rates of SWL. They include stone-related factors including the type and localization of the stone, and its density on computerized tomography (CT); and patient-related factors including body habitus, the skin-stone distance (SSD), hydronephrosis and renal functions[(2-4)]. One of the most important problems in SWL is the difficulty to focus on the stone. Focusing is particularly difficult in kidneys that are hypermobile with respiration. A number of factors including anesthesia, pain, respiratory disorders, and body habitus affect respiration-related mobility of the kidneys.

In this study, we aimed to investigate the effect of the kidney motion on success of SWL in a lithotripter with an ellipsoid focus, and a focal zone of 7.5x22 mm.

PATIENTS AND METHODS

Study design

After obtaining approval of the Ankara Training and Research Hospital local ethics committee, 158 patients that had SWL between May 2013 and April 2015 were prospectively included in the study. Preoperative imaging included kidney, ureter, and bladder (KUB) X-ray and non-contrast enhanced computerized tomography (NCCT).

SWL procedure was employed while the patient was in supine position, using Elmed Multimed Classic (Elmed Medical Systems, Ankara, Turkey) electrohydrolic device. This device has an ellipsoid focus, the size of its focus is 7.5x22 mm, and its focus length is 135 mm (**Table 1**). Focusing was done by an experienced urologist, under fluoroscopy and continuous monitoring (Flouroscopy targeting and monitoring every 250 pulses). The procedure was done under intramuscular analgesia (Diclofenac sodium). The patients were administered 2000 shocks in every session, at 14-18 kv with stepwise voltage ramping, and 60 pulses/min.

The patients' body was fixed to the tables with markers to avoid body movement during sessions.

The patients were examined with KUB and ultrasonography to determine stone disintegration, and the degree of hydronephrosis one week after every session. SWL was done up to 3 sessions if there was no progression in hydronephrosis, and the patient was willing to keep up with SWL. None of the patients had more than 3 SWL sessions. The procedure ended when stone disintegration was achieved, ant the patient was stone free on follow up.

Both KUB and ultrasonography were obtained on follows up visits of the patients performed 1 and 3 months after the last successful SWL session, and NCCT was obtained when needed. The patients with insignificant residual stone fragments (< 3 mm residual fragments)

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Table 1. Descriptive analysis of patients and treatment parameters

Age* (year)	42 ± 1.5 (22-73)
Mean stone HU*	662 ± 14.7 (369-1453)
Stone size* (mm)	12.2 ± 0.2 (6-20)
Mean kidney mobility* (mm)	35 ± 0.8 (10-67)
Success Rate % (N)	%62.7 (99)
Size of focal area (mm)	7.5x22
Mean shockwaves number	1752 ± 321 (412-2000)
Mean energy (kV) *	15.01 ± 0.3(12-18)
Shock wave rate (per minute)	60
Mean shockwave session	2.68

Abbreviations: HU, Hounsfield unit
* Mean ± SD (Range)

were regarded as stone free.

Study population

Patients with stone size less than 20 mm were included in the study. The exclusion criteria were presence of a known metabolic disease (such as cystinuria), non-opaque stones, need for focusing with ultrasonography, abnormal habitus, urinary tract abnormalities, previous renal surgery and inability to tolerate SWL until the end of the procedure. The stones greater than 20 mm and lower pole stones were also excluded. Lower pole stones excluded due to its high SWL failure.

Measurements

The size of the stone was calculated taking the longest axis of the stone on KUB into consideration. The ratio of the size of the stone measured on KUB and the size of the stone measured on fluoroscopy was calculated. The center of the stone and the center of the fluoroscopy were marked when the patient was monitored with fluoroscopy. Then, cranial and caudal motion of the stone was marked on fluoroscopy, and the motion of the kidney on fluoroscopy was calculated by comparing it with the stone size (**Figure 1**). The size of the stone was not measured between the sessions. Only the motion values measured at the first measurement were taken into consideration in the study. The movements of the kidney were measured three times at the beginning, middle and end of the procedure. In the next SWL sessions measurement was not done considering the disintegration of the stones.

Statistical analysis

Statistical analysis of data was performed with SPSS IBM PASW 18. Descriptive statistics were given as mean, standard deviation, frequency, and percent. The normality of distribution was tested with Shapiro Wilks Test for continuous variables. Student T test was used if the distribution was normal, and Mann Whitney U Test was employed if the distribution was not normal. Categorical variables were analyzed with Fisher's Exact Test. Univariate and multivariate regression analysis models were used to analyze the effects of different factors on the success rate of SWL. The results that were significant (p value < 0.05 statistically significant) and near significant variables on univariate analysis were analyzed with multivariate logistic regression test.

RESULTS

The patient characteristics and demographic data are presented in **Table 2**. The success rate of SWL was analyzed statistically in relation with the mean age, sex, side of the kidney with stone, localization of the stone, (Hounsfield Unit) HU of stone, and kidney motion. The mean age was 39 ± 11 years in the patients with a successful result, and 46 ± 13 years in the ones with an unsuccessful result. The procedure was successful in 66.7% of the males, and 56.9% of the females. Presence of the stone in the right or the left kidneys, in the upper or renal pelvis were not found as significant factors for the success of treatment. The successful and unsuccessful groups were similar for age and gender as well as the side and localization of the stone.

Univariate analysis showed that size of the stone, HU of the stone, and kidney motion affected the success of SWL significantly. Multivariate analysis showed that stone size and kidney motion affected the success rate significantly, however HU did not.

DISCUSSION

Advances in endourological procedures such as retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PNL), and high success rates obtained with those procedures make one ask whether SWL loses its value as a gold standard treatment modality[5-7]. Therefore, it is important to know the success rate of SWL in different patient groups. Stone parameters, patient characteristics, and types of lithotripters have been investigated for their effects on the success of SWL[8-10]. Some of the most important factors that affect the success of SWL are correct focusing on the stone, and monitoring the stone with fluoroscopy. The kidney motion

Table 2. Patients demographics and analysis of SWL success rate.

	Univariate Analysis			Multivariate Analysis			
	Success	**Failure**	***p* value**	**OR**	**95%CI**	***p* value**	
Age* (year)	39 ± 11	46 ± 13	0.057	1.03	0.98-1.09	0.234	
Gender (%)			0.463	-	-	-	
Female, N(%)	37 (56,92%)	28 (43,08%)		-	-	-	
Male, N(%)	62 (66,66%)	31(33,34%)		-	-	-	
Side (%)			0.711	-	-	-	
Right, N(%)	49 (49,5%)	31 (52,5%)		-	-	-	
Left, N(%)	50 (50,5%)	28 (47,5%)		-		-	-
Stone size* (mm)	11 ± 3 (6-20)	14 ± 4 (8-20)	< 0.001	1.62	1.19-2.21	0.002	
Mean stone HU*	771 ± 194 (369-1453)	829 ± 141(418-981)	0.012	1.01	0.99-1.01	0.534	
Mean kidney mobility* (mm)	32 ±10 (10-67)	40 ±11(15-60)	< 0.001	1.12	1.04-1.21	0.003	
Stone location (%)			0.064	0.24	0.05-1.16	0.077	
Upper/mid calyceal, N(%)	42 (42,4%)	34 (57,7%)					
Renal pelvis/UPJ, N(%)	57 (57,6%)	25 (42,3%)					

Abbreviations: SWL, shock wave lithotripsy; HU, Hounsfield unit;
* Mean ± SD (Range)

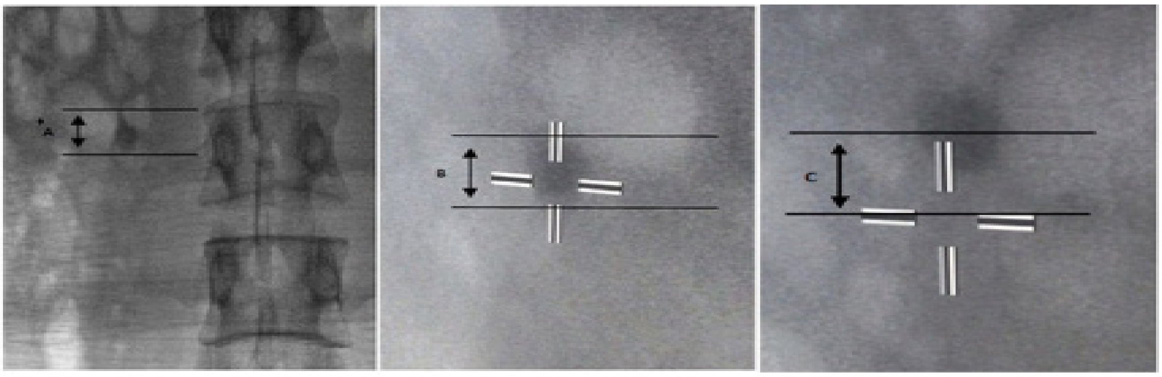

Figure 1. The method used to measure the actual mobility (M). A: Craniocaudal size of the stone on kidney-ureter-bladder X-ray, B: The size of the stone under fluoroscopy, C: The mobility of the stone with respiration. M=AxC/B (Calculation of actual mobility by calculating the ratio of the actual size of the stone on kidney-ureter-bladder X-ray and its size on fluoroscopy).

due to respiration usually makes difficult to keep the stone in the focal zone of the lithotripter. Kidney motion due to respiration may be up to 5-50 mm, and this shows that more than 50% of the shock waves remain out of the focal zone of the lithotripter[11-15]. An in vitro study made with a lithotripter with a focal zone of 4.5 mm showed that fragmentation effect decreased significantly when motion was more than 10 mm[16]. A recent magnetic resonance imaging (MRI) study showed that the motion was 8.9 mm for the right, and 8.48 mm for the left kidneys in awake individuals, and those values were greater in the individuals under general anesthesia .[14] Correct focusing of the SWL shock waves on the stone is important both for SWL success and prevention of parenchymal injury[17]. In these studies, kidney mobility was measured by ultrasound, MRI and CT which is dissimilar to our study. Although the measurement used in our study is an analytical measurement, the greatest advantage is that the measurements are made during the process.

Various systems have been developed for continuous localization before shock wave firing, such as ultrasonography and tracking algorithms to solve respiration-related focusing problems[17,18].

Performing SWL under general anesthesia, and controlling and coordinating the respiratory movements of the patient with the SWL sequences are the main measure to prevent respiratory movements which impair success of SWL. A number of studies showed better results with general anesthesia compared to sedation[19-22]. The success rates under sedoanalgesia were reported as 52-72% in those studies.

Other parameters that affect the success of SWL are SSD, type of the stone, and stone HU. Various studies showed the effects of SSD on the success of SWL on kidney stones. Studies reported that the success of SWL decreased when SSD was >10 cm[23,24]. Another mechanism that affects the success of SWL is the focal zone of the device. In vitro studies showed that the lithotripters with broader focal zones had higher capacities to break the stones[25,26]. However, it must be kept in mind that injury to neighboring tissues increases as the focal zone gets broader. Two different zones may be used in MODULITH SLX-F2 urologic workstation (Storz-Medical, Kreuzlingen, Switzerland). The broader focal zone (50x9 mm) is used in kidney stones, and the narrow focal zone (28x6 mm) is used in the ureteral stones. However, the clinical results did not show any improvement in the effectivity[26]. In a very recent study, Harrogate et al. investigated kidney motion, and found stone motion secondary to respiration as 7.7±2.9 mm for kidney stones, and 3.6 ± 2.1 mm for ureteric stones in patients who were not under anesthesia[27]. Different from other studies, in that study it was suggested that respiration-related motion was less in conscious patients without any anesthesia. Another study that investigated SWL success in relation with respiration-associated movement in 10 patients reported mean motion as 1.5 ± 0.3 cm with ultrasonography, and it was seen that approximately 40% of the shock waves missed the stone[28]. We found a greater mean motion in this study. This difference may be related to different measurement methods of movements among studies, including ultrasonography, MRI and CT instead of fluoroscopy in other studies. In addition, in our study we calculated the sum of cranial and caudal movements.

A number of hypotheses have been proposed for stone disintegration. Broader focal zone, slower pulse rate, adequate coupling of shock wave head, and active monitoring increase success of SWL[25].

The main limitations of our study are use of a single lithotripter, and absence of SSD data and stone analysis. Another limitation is making measurements under fluoroscopy without any electronic measurement, chasing the movements visually, and manual measurement of the points and distances with maximum movement. However, there are only scarce reports in the literature that have investigated respiration-related motion on the success of SWL. To our knowledge, this is one of the first studies that included the highest number of patients, and analyzed a number of parameters in relation with motion.

CONCLUSIONS

In our study, we observed a statistically significant relationship between kidney motion and success of SWL. Further comparative studies using lithotripters with different focal zones are needed to determine the significance of kidney motion on different focal zones and different devices.

CONFLICT OF INTEREST

The authors report no conflict on interest.

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