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The Factors That Affecting Shockwave Lithotripsy Treatment Outcome of Kidney Stones

Mehmet Vehbi Kayra, Mehmet Reşit Gören, Cevahir Özer, Ferhat Kılınç

Başkent University Adana Dr. Turgut Noyan Research and Medical Center, Department of Urology, Adana, Turkiye

What's known on the subject? and What does the study add?

Shockwave lithotripsy (SWL) is still one of the essential treatment options in the treatment of kidney stones with lower complication rates compared to other treatment methods. In this study, factors and markers that determine SWL success and activity were evaluated.

Abstract

Objective: We analyzed the relation of shockwave lithotripsy (SWL) success and the combination of success predictors.

Materials and Methods: In this retrospective study, the outcomes of 1.880 patients with kidney stones treated with SWL were analyzed. A total of 124 adult patients with complete records with non-contrast computed tomography, stone analysis, laboratory data were involved in the study. Patients who were with urinary system anomalies, who were receiving alpha-blocker and/or calcium channel blockers and whom with impaired kidney function were excluded. The effect of stone density, skin-to-stone distance (SSD), perirenal tissue density (PTD), subcutaneous tissue density (STD), stone size, stone burden, stone localization, infundibulopelvic angle (IA), body mass index (BMI) and stone analysis results on the success of the treatment was evaluated.

Results: SSD, PTD, STD, stone localization, IA and BMI did not have any significant effect on SWL success. Stone size and stone burden had a significant association with treatment success (p=0.0001), and the cut-off values determined for stone size and stone burden were 12.95 mm (p=0.0006) and 121.38 mm^2 (p=0.004) respectively. Stone density also had a significant association with treatment success (p=0.0001), and the cut-off value determined for stone density was 739 Hounsfield Unit (p=0.001). Treatment success was significantly lower in cystine and calcium oxalate monohydrate stones compared to other stone types (p=0.019).

Conclusion: Significant markers that determine SWL effectiveness are stone size, stone burden, stone density and stone type.

Keywords: Shockwave lithotripsy, kidney stone, stone type

Introduction

Shock wave lithotripsy (SWL) is a very advantageous treatment option with a shorter hospital stay and recovery time compared to other surgical treatments (1). Endourological methods such as percutaneous nephrolithotomy (PNL) and retrograde intrarenal surgery, which have progressed with the latest technology, have made notable developments in stone treatment approaches. However, the popularity of SWL has not decreased because PNL and retrograde intrarenal surgery should be performed in the operating room conditions and anesthesia is required for these treatments (2). But prediction of SWL outcome is still challenging. Thus, some parameters have been established in predicting the success of the SWL process. Stone volume, stone density, the chemical composition of stone, the location of the stone in the kidney, skin-to-stone distance (SSD), and infundibulopelvic angle (IA) are essential factors that determine the outcome of treatment (3,4). However, one or more of these factors were separately analyzed but not all of them were analyzed for the patients treated with the same lithotripter.

Correspondence: Mehmet Vehbi Kayra MD, Başkent University Adana Dr. Turgut Noyan Research and Medical Center, Department of Urology, Adana, Turkiye
Phone: +90 322 327 27 27 **E-mail:** vehbikayra@hotmail.com **ORCID-ID:** orcid.org/0000-0002-7349-9952
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In this study, it was aimed to estimate the predictability of the lithotripsy treatment success before the treatment with the data examined, and all the factors affecting the lithotripsy success were studied to be more beneficial in clinical practice.

Materials and Methods

Patients

In the retrospective study, 1.880 patients who underwent SWL treatment according to the current European Association of Urology guidelines at the time of treatment in our clinic between January 2011 and December 2015 were analyzed (5). A total of 124 adult patients (≥18 years old) who had uncontrasted computed tomography (NCCT), stone analysis, laboratory data, complete patient records and had a radiopaque single kidney stone was included in the study. Patients who were with urinary system anomaly, who were receiving alpha-blocker and/or calcium channel blockers that may affect the stone-free rate and who had kidney dysfunction were excluded from the study. This study was approved by Baskent University Institutional Review Board (project no: KA16/227) and supported by Baskent University Research Fund.

Age, gender, body mass index (BMI) and stone analysis results were obtained from the patient records. From the NCCT images, stone localization, stone density, SSD, perirenal tissue density (PTD), subcutaneous tissue density (STD), stone size, stone burden and IA were determined.

On NCCT images, the longest diameter of stone that could be measured on the axial and coronal plane was accepted as stone size (Figure 1). The stone burden was calculated by the combination of maximal axial and coronal diameters on NCCT. SSD was defined as the distance between the center of the stone at 45° and 90° angles to the skin in axial sections on NCCT images. Stone density was obtained by calculating the mean density of the largest elliptical area drawn in the stone on the basis of the Hounsfield Unit (HU) at the level where the stone had the largest diameter in axial sections (Figure 2). The PTD was defined as the mean density of the area between kidney and abdominal wall in HU. STD was determined as the mean density of adipose tissue between the skin and the abdominal wall in HU. IA was calculated by obtaining the angle of the renal lower pole calyx to the ureteropelvic junction on NCCT coronal section or intravenous pyelography (IVP) images.

SWL Procedure

The procedure was performed to all patients under sedoanalgesia. For sedoanalgesia, midazolam (0.03-0.07 mg/kg) and fentanyl (0.5-1 mcg/kg) or ketamine (0.5-1 mg/kg) were administered

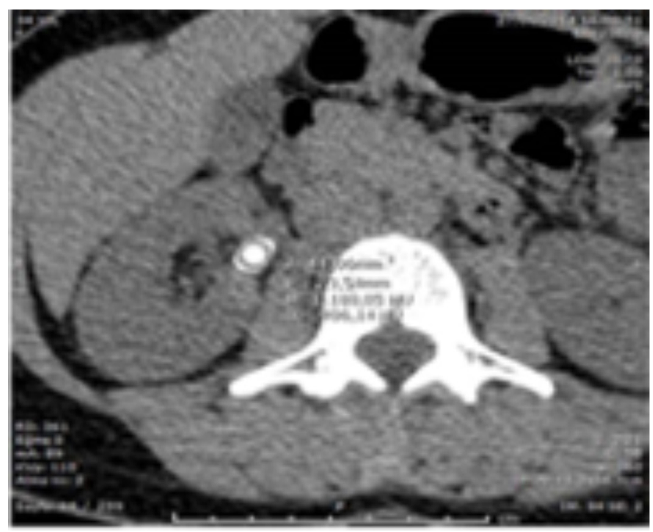

Figure 2. Measurement of stone density on NCCT

Figure 1. Measurement of the widest diameter of the stone in two planes on NCCT

intravenously (IV) under the control of an anesthesiologist. Lithostar Modularis Uro-plus (Siemens Medical Systems©, Erlangen, Germany) was used for SWL. During the SWL session, the opaque stones were treated with fluoroscopy guidance. The process began with a 0.1 power setting (9.506 kV) and the voltage was increased sequentially in the first 1.000 shocks and reached a maximum of 3.5-4 power settings (47.65-52.03 kV). Between 3.500 and 5.000 shock waves were applied in total by giving 60 shock waves per minute. All procedures were done by the same SWL technician.

Follow-up

In all patients, stone fragmentation was checked by a kidney-ureter-bladder X-ray (KUB), NCCT or ultrasonography (USG) after 24-48 hours of the SWL session. If the stone was not fragmented, the second session SWL was planned. The interval between additional SWL sessions was at least three days. No more than three sessions of SWL treatment was applied. The patients were followed up with NCCT, USG, or IVP after three months of the last SWL session. The treatment success was defined as stone-free status or clinically insignificant residual fragments (≤3 mm) after 3 months of the last SWL session. To collect stone specimens, patients were asked to urinate into a clean container to collect stone fragments after SWL sessions. Stone analysis was done with Fourier Transform Infrared Spectroscopy.

The records of the patients were reviewed for post-SWL treatments such as PNL, ureteroscopy which were used to calculate efficacy coefficient (EQ). The EQ is the percent of the patients who are stone free X 100 ÷ (100% + percent re-treatment rate + percent having auxiliary procedures).

Statistical Analysis

For the comparison of the continuous measurements between successful and unsuccessful groups, the distributions were checked. Since the parametric distribution prerequisite was not satisfactory, non-parametric Kruskal-Wallis test and Mann-Whitney U tests were applied, and chi-square tests were employed to evaluate the success rates. In the study, a cut-off value was determined for the values that were statistically significant between the groups and the area under the receiver operating characteristic curve (ROC) was evaluated by ROC Analysis, by calculating the sensitivity and specificity values. The statistical significance level was determined as p<0.05 in all tests.

Results

The overall success rate was 90/124 (72.5%). There was no statistically significant difference between age, gender, BMI and treatment success. (respectively p=0.079, p=0.632, p=0.557). It was determined that the side and localization of the kidney stone did not affect the success of the treatment (respectively p=0.119, p=0.225). Lower calyx stones were compared with all stones in other localizations, and there was no significant difference (p=0.089). It was also found that SSD, PTD, STD and IA did not affect the success of treatment (respectively p=0.778, p=0.985, p=0.488, p=0.549). Patient variables, stone features, SWL characteristics and success rates of the two groups are summarized in Table 1.

There was a statistically significant association between the size of the stone and the success of treatment (p=0.0001). The cut-off value for the stone size was 12.95 mm (p=0.0006, sensitivity=70.6%, specificity=72.2%) It was determined that the success of treatment was higher for the stone sizes below this value. The association between stone burden and treatment success was also statistically significant (p=0.0001). The cut-off value of the stone burden for treatment success was 121.38 mm^2 (p=0.004, sensitivity=70.6%, specificity=72.2%). It was determined that the treatment success rate was higher below this value. There was statistical significance between stone density and treatment success (p=0.0001). The cut-off value determined for stone density was 739 HU (p=0.001, sensitivity=70.6%, specificity=60%) (Table 2). It was seen that the stone type was an influential factor affecting the success of treatment (p=0.019) (Table 2).

The overall complication rate was 13.7%. Double J stent placement and ureterorenoscopy were performed for ureteral obstruction and steinstrasse. PNL was applied to complicated kidney stones in the unsuccessful group and postoperative stone-free status was achieved. Complications classified according to Clavien and auxiliary procedures performed are shown in Table 1. The EQ of the device used in this study was 60.1%.

Discussion

Although SWL has been one of the essential treatment option for kidney stone treatment for many years, its place in the list of kidney stone treatment preferences may change due to technological developments in endoscopic devices (6,7). SWL is a non-invasive treatment option with lower complication rates compared to other treatment modalities of kidney stones, but it has lower success rates (2). Hence, the predicted factors for the SWL result should be defined and the proper treatment option should be chosen for patients with upper urinary tract stones.

Habib et al. (8) analyzed the association between stone size and treatment success and reported that the rate of success was 80% for stone diameter <13.5 mm, while this rate reduced to 52.3% for >13.5 mm. In a study where 2.954 cases were analyzed, Abdel-Khalek et al. (9) reported 89.7% stone-freeness for kidney stones of 15 mm and below, while this rate reduced to 78% in stones above 15 mm. Kanao et al. (10) developed

Table 1. Demographic data and treatment outcomes

	Success	Failure	Total	p-value
Gender				
Male	59 (69%)	27 (31%)	86 (69%)	p=0.632
Female	31 (82%)	7 (18%)	38 (31%)	
Age	43.7±13.3	48.7±15.6	45.1±14.1	p=0.079
Body mass index, (kg/m²)	26.4±4.0	26.5±4.2	26.4±4.0	p=0.557
Side				
Right	51 (80%)	13 (20%)	84 (68%)	p=0.119
Left	39 (65%)	21 (35%)	60 (32%)	
Stone-localization				
Lower calyx	29 (66%)	15 (34%)	44 (36%)	p=0.225
Middle calyx	14 (70%)	6 (30%)	20 (16%)	
Upper calyx	15 (75%)	5 (25%)	20 (16%)	
The renal pelvis	32 (80%)	8 (20%)	40 (32%)	
Stone size (mm)	11.3±3.6	14.7±4.9	12.2±4.3	p=0.0001
Stone burden (mm²)	102.9±65.6	205±131.7	130.9±99.3	p=0.0001
Stone density (HU)*	682.9±254.4	890.6±310.4	739.9±285.2	p=0.0001
Skin to stone distance (mm)	90.6±22.0	91.8±22.8	90.9±22.1	p=0.778
Perirenal tissue density (HU)	-101.7±16.3	-101.6±41	-101.7±25.4	p=0.985
Subcutaneous tissue density (HU)	-104.3±11.2	-106±14.6	-104.7±12.2	p=0.488
Infundibulopelvic angle (°)	43.8±8.4	42.8±8.3	43.5±8.4	p=0.549
Composition				
Calcium oxalate monohydrate (COM)	5 (50%)	5 (50%)	10 (8%)	p=0.019
Calcium oxalate dihydrate (COD)	5 (71%)	2 (29%)	7 (6%)	
COM+COD	59 (79%)	17 (23%)	76 (61%)	
Uric acid	14 (82%)	3 (18%)	17 (14%)	
Struvite	1 (100%)	0 (0%)	1 (1%)	
Brushite	2 (67%)	1 (33%)	3 (2%)	
Cystine	0 (0%)	4 (100%)	4 (3%)	
Carbonate apatite	5 (83%)	1 (17%)	6 (5%)	
Complication (Clavien classification)				
Grade 2				-
UTI*	1 (50%)	1 (50%)	2 (1.6%)	
Grade 3				
UP* obstruction	0 (0%)	2 (100%)	2 (1.6%)	
Steinstrasse	7 (70%)	3 (30%)	10 (8%)	
Auxiliary procedures				
DJ* stent placement	1 (100%)	0 (0%)	1 (0.8%)	-
URS*	7 (70%)	3 (30%)	10 (8%)	
PNL*	0 (0%)	2 (100%)	2 (1.6%)	
Count of session				
1	52 (85%)	9 (15%)	61 (49%)	p=0.001
Multiple	38 (60%)	25 (40%)	63 (51%)	

*: Hounsfield unit, ± mean and standard deviation, UTI: Urinary tract enfection, UP: Ureteropelvic, DJ: Double J, URS: Ureterorenoscopy, PNL: Percutaneous nephrolithotomy

Table 2. Determined cut-off values for stone size, burden and density					
	AUC*	Sensitivity	Specifity	Cut-off	p
Stone size	0.718	64.75%	67.8%	12.95 mm	0.0006
Stone burden	0.786	70.6%	72.2%	121.38 mm^2	0.004
Stone density	0.706	70.6%	60%	739 HU	0.001

AUC: Area under curve, HU: Hounsfield unit

a nomogram to predict SWL success and reported that stone size, the location of the stone, and the number of stones were the factors affectingthe success rates. Azal Neto et al. (11) published a prospective study investigating the relationship between stone size and SWL success involving 1.902 patients. They reported that the success of treatment decreases for any localization of the kidney in stones larger than 15 mm. In the lower pole, they found that the success of the treatment decreased in stones larger than 10 mm. In this study, similar to the literature, we determined that SWL treatment success reduced with increasing stone size. In the study, the cut-off value determined for stone size was calculated as 12.95 mm (sensitivity=70.6%, specificity=72.2%).

Soliman et al. (12) investigated the results of lower pole kidney stone treatment of different treatment modalities in a prospective study. They reported that the success rate of SWL in lower pole kidney stones was lower. ElSheemy et al. (13) showed in their study that mini-PNL operation is a more effective treatment than SWL for stones of 10-25 mm in the lower calyx of the kidney. Kupeli et al. (14) reported that the stone-free rate was 53.3% in 165 patients who underwent SWL to the lower calyx stones. In our study, although the treatment rate in lower calyceal stones was lower compared to other localizations, statistically significant results could not be obtained due to the small number of patients.

In the study by Obek et al. (15), the SWL success in the isolated lower calyx, middle calyx and upper calyx were analyzed and the success rate was determined to be 63%, 73%, and 71%, respectively. We observed that the success rates of patients with a stone burden more than 2 cm^2 reduced further to 49%, 53%, and 60%, respectively. In the study, Obek et al. (15) concluded that SWL treatment should be the basic treatment option in stones, with a stone burden less than 200 mm^2, independent of localization. Torricelli et al. (3), in a prospective study of 125 patients, determined that stone burden was an important factor for the success of SWL treatment, regardless of localization. Similarly, in this study, it was observed that the stone burden was an essential factor in SWL success and treatment success decreased as the stone burden increased. The cut-off value for stone burden was calculated as 121.38 mm^2 (sensitivity=70.6%, specificity=72.2%).

In the study by El-Nahas et al. (16), where 120 kidney stones were analyzed, the mean BMI of the patients was measured as 28.6±5.3 kg/m^2. It was determined that BMI was a factor influencing the stone fragmentation success and was suggested that alternative treatments should be applied in obese patients (16). In this study, the mean BMI value of the patients was measured as 29.8±4.2 and there was no statistically significant difference between the BMI and the stone fragmentation success. At this point, we have a limitation that should be considered. SWL treatment wasn't applied to the patients weighing more than 130 kg due to technical limitations of our SWL device.

There is contradictory data in the literature concerning the association between IA and SWL success. In the study by Talas et al. (17) on 198 patients, the IA was reported to be one of the essential factors for the passage of residual stone fragments after SWL in lower calyx kidney stones. In the prospective study by Toricelli et al. (3) on 120 patients, it was revealed that the IA did not have a significant relationship with the success of treatment in the lower calyx stones. Similarly, our results yielded that the IA did not affect SWL success.

In a study on 30 patients, Joseph et al. (18) analyzed the association between NCCT attenuation value and stone fragmentation and determined that the SWL success of stones >1000 HU decreased. In the study by Nakasato et al. (19), it was found that the treatment success of stones with >815 HU decreased. Similarly, in our study, it was reported that treatment success decreased as stone density increased. The cut-off value for stone density was determined as 739 HU (sensitivity=70.6% specificity=60%). Although stone density was determined to be an essential factor that predicted SWL success in various studies, the cut-off values were reported in a wide range. One of the most significant reasons for this situation may be that the stone density measurement methods differ. There is no consensus for the stone density calculation. We calculated the stone density from the longest section of the stone that may have affected our results. Studies have shown that ultraslow and full-power SWL are more effective in the shock wave treatment of urinary tract stones with high stone density (20,21). However, the potential negative impact of this approach on the parenchyma and its associated device-dependent factors, such as generator type and focal area size, should not be ignored.

The association between stone composition and stone fragmentation was firstly defined by Dretler in 1988 (22). In some studies, it was determined that the type of stone could be defined according to the heterogeneity of the stone in NCCT images and the success of SWL could be predicted according to the stone heterogeneity (23,24). Higher energy levels and more sessions were required during SWL treatment in chemically resistant stones. While the fragility of calcium oxalate monohydrate (COM) and cystine stones was low, the fragility of calcium oxalate dihydrate, struvite, and uric acid stones was high (25). In this study, it was concluded that the stone composition was an essential factor affecting the success of treatment. The treatment success of the study was lower in cystine and COM stones.

There are different results in the literature concerning the effect of SSD on SWL success. In the study by Abdelhamid et al. (26), it was determined that treatment success decreased as SSD increased. In the study by Lee et al. (27), it was observed that a factor determining the treatment success was SSD and that the area of the perirenal and pararenal fat tissue and the abdominal circumference was not influential on the treatment success. In the study by Nakasato et al. (19), no significant result was observed between SSD and treatment success. Although El-Nahas et al. (16) determined that obesity was a factor that decreased the success of treatment, SSD was not a factor effecting for treatment success. In our study, the mean BMI value of the patients was measured as 29.8±4.2 and there was no statistically significant difference between the BMI and the stone fragmentation success and between SSD and treatment success. Besides, PTD was also not an effective factor in terms of the success of treatment. To define the effectiveness of SSD in predicting SWL treatment success, extensive prospective studies are needed.

Study Limitations

The study had some limitations. It was a retrospective and non-randomized study. Additionally, the number of patients whose data could be totally accessed was not very high.

Conclusion

In the study, it was determined that stone size, stone burden, and stone density were the essential factors in the success of SWL and the type of stone is an essential marker determining SWL activity. By defining these parameters before treatment, SWL treatment success can become more predictable. Hence, SWL can be recommended for suitable patients as an alternative to the minimally invasive surgery options that have developed recently.

Ethics

Ethics Committee Approval: This study was approved by Baskent University Institutional Review Board (project no: KA16/227) and supported by Baskent University Research Fund.

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: M.V.K., M.R.G., C.Ö., F.K., Concept: M.V.K., M.R.G., C.Ö., F.K., Design: M.V.K., M.R.G., C.Ö., F.K., Data Collection or Processing: M.V.K., M.R.G., C.Ö., F.K., Analysis or Interpretation: M.V.K., M.R.G., C.Ö., F.K., Literature Search: M.V.K., M.R.G., C.Ö., F.K., Writing: M.V.K., M.R.G., C.Ö., F.K.

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