The factors that affecting shockwave lithotripsy treatment outcome of kidney stones

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Abstract

Bacground: We aimed to analyze combination of the schockwave lithotripy (SWL) success predictors. Methods: In this retrospective study, the outcomes of the patients with kidney stones treated with SWL were analyzed. Adult patients ([?]18 years) with complete records with non-contrast computed tomography (NCCT), 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), as well as body mass index (BMI) and stone analysis results on the success of the treatment was evaluated. Results: SSD, PTD, STD, stone localization, IA, as well as body-mass index, did not have any association with 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 mm2 (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 HU (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, besides, stone type.

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

Conflict of Interest

Nothing to declare.

Keywords: Shock wave lithotripsy, kidney stone, stone type, non-contrast computed tomography

What's already known about this topic?

The prediction of shockwave lithotripsy treatment still has limitations. Various researches have reported associations between SWL success and stone density, stone to skin distance, stone composition, infundibulopelvic angle etc, however, these parameters have not been evaluated on the same lithotripter.

What does this article add?

A complete comparison between these factors with the same lithotripter have not been reported. Thus, we reviewed our records and compared the SWL success with stone density, skin-to-stone distance (SSD), perirenal tissue density (PTD), subcutaneous tissue density (STD), stone size, stone burden, stone localization, infundibulopelvic angle (IA), as well as body mass index (BMI) and stone analysis of our lithotripter.

BACKGROUND

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 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 percutaneous nephrolithotomy 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]

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.

METHODS

In the retrospective study, patients who underwent SWL treatment according to at the treatment time's current EAU guidelines in our clinic between January 2011 and December 2015 were analyzed.[3] Adult age group ([?]18 years) having complete records concerning non-contrast computed tomography (NCCT), stone analysis, laboratory data, and patient records were included in the study. Patients who are with urinary system anomaly, who were receiving alpha-blocker and/or calcium channel blockers that may affect the stone-free rate and who are with kidney dysfunction were excluded.

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 can be measured on the axial and coronal plane was accepted as stone size (Figure 1a-1b). The stone burden was calculated by with the combination of maximal axial and coronal diameters on noncontrast computer tomography. 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 defined as the mean density of the area between kidney and abdominal wall in HU. STD 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.

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 intravenously (IV) under the control of an anesthesiologist. Lithostar Modularis Uro-plus (Siemens Medical Systems ©, Erlangen, Germany) used for SWL. During the SWL session, the opaque stones were treated with fluoroscopy guidance. In non-opaque stones, opaque administration was performed through nephrostomy (if present) or intravenously to visualize the stone for fluoroscopic guidance. Also, there were non-opaque stones which has been treated under ultrasonographic guidance. The process began with a 0.1 power setting (9.506 kV), and the voltage was increased sequentially in the first 1000 shocks and reached a maximum of 3.5-4 power settings (47.65-52.03 kV). Between 3500 and 5000 shock waves were applied in total by giving 60 shock waves per minute.

In all patients, stone fragmentation was checked by a kidney-ureter-bladder x-ray (KUB), NCCT, and ultrasonography (USG) after 24-48 of 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 followed-up with NCCT, USG, or IVP after three months of the last SWL session. The treatment success defined as stone-free status or clinically insignificant residual fragments ([?]3 mm) after 3 months of the last SWL session.

Statistical Analyses

In comparing the continuous measurements between the groups, the distributions were checked. Since the parametric distribution precondition was not satisfied, nonparametric 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. Logistic Regression Analysis was performed to define independent risk factors affecting the success rate. The statistical significance level was determined as $p < 0.05$ in all tests.

RESULTS

The mean age of the patients whose data were analyzed was 45 +- 14.11 and there was no association between age and stone fragmentation success ($p = 0.079$). Eighty-six (69.3%) of the patients were male, and 38 (30.7%) were female. The success rate was 68.6% in male patients and 81.5% in women. No significant association was seen between gender and treatment success ($p = 0.632$). The overall success rate was 90 (72.5%).

The success rate in the right kidney was calculated as 79.6%, while the success rate in the left kidney as 65%. The fact that the stone was on the right or left kidney was not observed to affect the success of treatment ($p = 0.119$). According to stone-localization; treatment success rates were 65.9%, 70%, 75%, 80% in the lower calyx, middle calyx, upper calyx, and the renal pelvis stones respectively. No significant association between the localization of the stone in the kidney and the success of treatment was detected ($p = 0.225$). The mean BMI of the patients was calculated as 29.8 +- 4.2. It was concluded that BMI was not a factor affecting stone fragmentation success ($p = 0.557$).

The mean size of the treated stones was 12.2 +- 4.25 mm. 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%) (Table 1). It was determined that the success of treatment increased in the stone sizes below this value. The average stone burden of the patients was calculated as 130.9 +- 99.25 mm^2. 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%) (Table 1). It was determined that treatment success increased below this value. ROC curves displaying the cut-off values of stone size and stone burden were presented in Figure 3.

In the study, the average SSD was calculated as 90.9 +- 22.1 mm .SSD did not affect treatment success ($p = 0.778$). The average IA was 43.5 +- 8.3 deg. There were no association between IA and treatment success ($p = 0.549$). The mean PTD was -101.7 +- 25.3 HU and it was not a factor affecting treatment success ($p = 0.985$). STD was determined to be -104.2 +- 12.2 HU, and the density had no association with treatment success ($p = 0.488$).

The mean density of the treated stones was calculated as 739 +- 285 HU, and 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). Figure 4 presented the ROC curve of stone density.

Among the treated stones, calcium oxalate monohydrate (COM) was observed in 10 patients, calcium oxalate dihydrate (COD) in 7 patients, combined COM and COD in 76 patients, uric acid in 17 patients, carbonate apatite in 6 patients, cystine in 4 patients, brushite in 3 patients, struvite in 1 patient. It was seen that the stone type was an influential factor affecting the success of treatment ($p = 0.019$) (Table 3).

DISCUSSION

Although SWL has been an essential treatment option for kidney stone treatment for many years, its role in kidney stone treatment has diminished with technological advances in endoscopic devices.[5,6] 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.[7] 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.

Al-Ansari et al. analyzed the association between stone size and treatment success and reported that the rate of success was 90% for stone diameter <10 mm, while this rate reduced to 70% for > 10 mm.[8] In a study where 2,954 cases were analyzed, Abdel-Khalek et al. reported 89.7% stone-freeness for kidney stones of 15 mm and below, while this rate reduced to 78% in stones above 15 mm.[9] Kanao et al. developed a nomogram to predict SWL success and reported that stone size, the location of the stone, and the number of stones were efficient in success rates.[10] Lalak et al. analyzed the SWL treatment results for 500 kidney stones and reported that success rates at three months after the operation were 76% for stone size <10 mm, 66% for 10-20 mm, and 47% for >20 mm.[11]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%).

In the meta-analysis conducted by Lingeman et al., the overall stone-free rate was reported to be 59% for lower calyx stones.[12] Kupeli et al. reported that the stone-free rate was 53.3% in 165 patients who were applied SWL to the lower calyx stones.[13] Similarly, in this study, it was observed that the stone had various treatment success rates in different localizations in the kidney. Although the success rates were 65.9% in the lower calyx, 70% in the middle calyx, 75% in the upper calyx, and 80% for the renal pelvis, no statistically significant association between stone localization and treatment success was observed.

In the study conducted by Obek et al., 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.[14] It was observed that the success rates of patients with a stone burden more than 2 cm^2reduced 49%, 53%, and

60%, respectively. In the study, Obek et al. concluded that SWL treatment should be the basic treatment option in stones, with a stone burden less than 200 mm^2, independent of localization.[14] 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%).

The study conducted by Pareek et al. showed that BMI had a statistical association with SWL success.[15] In the study conducted by El-Nahas et al., where 120 kidney stones were analyzed, the mean BMI of the patients was measured as 28.6 +- 5.3 kg.[16] 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 association between the BMI and the stone fragmentation success. At this point, we have a limitation that should be considered. Since the SWL device, used in the study, could not carry patients weighing more than 130 kg technically, SWL treatment cannot be applied for 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 conducted by Talas et al. on 198 patients, the IA was reported to be one of the essential factors in the removal of residual stone fragments after SWL in lower calyx kidney stones.[17] In the retrospective study conducted by Viswaroop et al. on 148 patients, it was revealed that the IA did not have a significant relationship with the success of treatment in the lower calyx stones 10 mm and above.[18] Similarly, our results yielded that the IA did not affect SWL success.

In a study on 30 patients, Joseph et al. analyzed the association between NCCT attenuation value and stone fragmentation and determined that the SWL success of stones >1000 HU decreased.[19] In the study conducted by Nakasato et al., it was found that the treatment success of stones with >815 HU decreased.[20] Similarly, in this 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 detected 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 which may affected our results.

The association between stone composition and stone fragmentation was firstly defined by Dretler in 1988.[21] 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.[22,23] Higher energy levels and more sessions were required during SWL treatment in chemical resistant stones . While the fragility of COM and cystine stones was low, the fragility of COD, struvite, and uric acid stones was high.[24] In this study, it was concluded that stone composition was an essential factor affecting the success of treatment. The treatment success of the study was lower in cystine stones and COM stones.

There are different results in the literature concerning the effect of SSD on SWL success. In the study conducted by Abdelhamid et al., it was determined that treatment success decreased as SSD increased.[25] In the study conducted by Lee et al., it was observed that one of the factors 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.[26] In the study conducted by Nakasato et al., no significant result was observed between SSD and treatment success.[20] Although El-Nahas et al. determined that obesity was a factor that decreased the success of treatment, SSD was not an efficient factor for treatment success.[16]Similarly, in this study, there was no association between SSD and treatment success. Besides, PTD were also not an essential factor in terms of the success of treatment. In order to define the effectiveness of SSD in predicting SWL treatment success, extensive prospective studies for different variables such as obesity degree, stone location, and lithotripter type are necessitated.

The study had some limitations. It was a retrospective study, and the number of patients whose data can be totally accessed was not very high. However, one of its most essential advantages was the evaluation of various factors affecting SWL success.

CONCLUSION

NCCT is a useful method in the diagnosis of kidney stones. This method is frequently employed only to detect the stone and determine its localization. In the study, it was determined that stone size, stone burden, and stone density found in NCCT were the essential factors in the success of SWL. Besides, 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.

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Conflict of Interest

Nothing to declare.

Acknowledgements

Nothing to declare.

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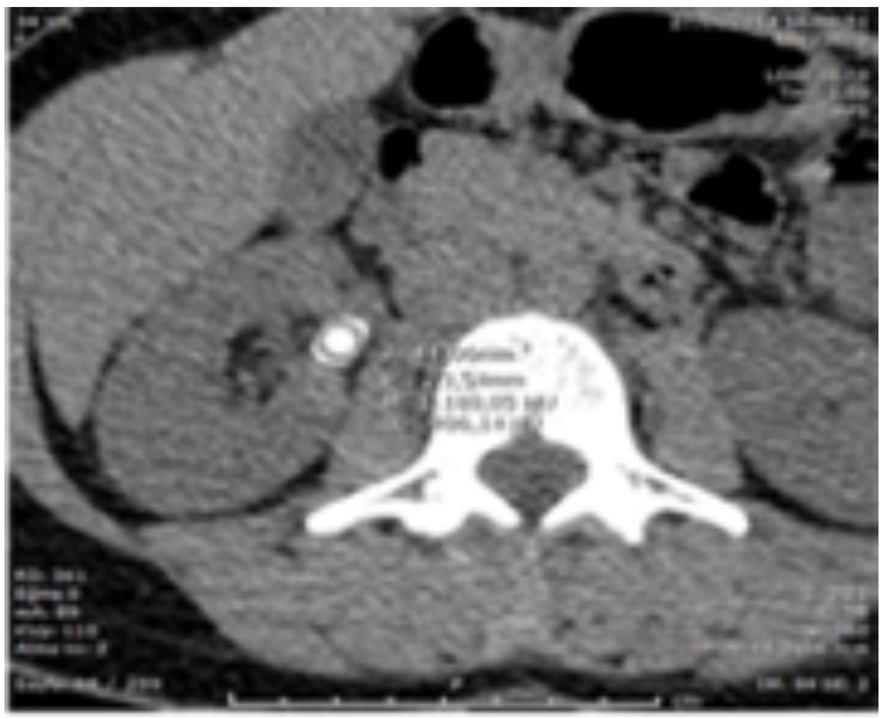

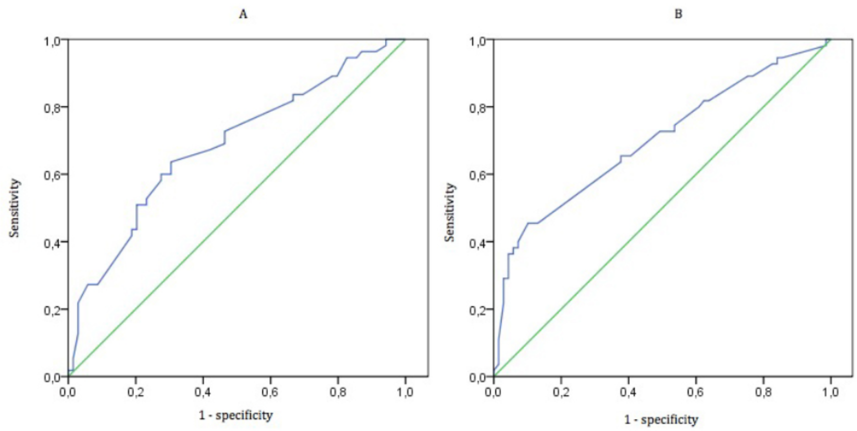
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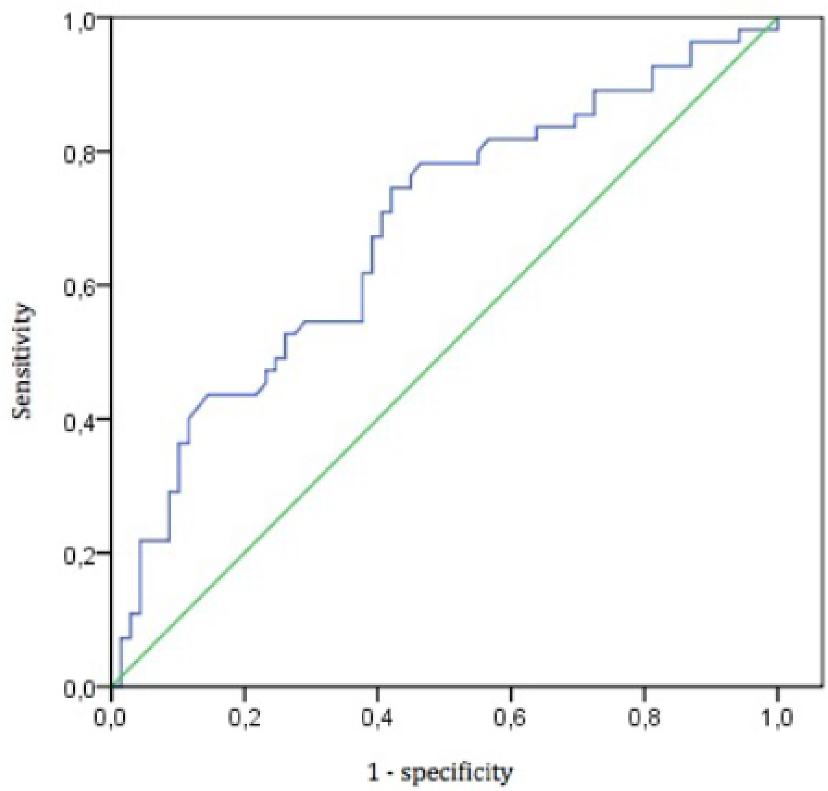
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