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ORIGINAL ARTICLE

Medicine Science International Medical Journal

Medicine Science 2025;14(1):169-72

The effect of skin-to-stone distance on success in renal pelvis stones treated with ESWL

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Received 05 December 2024; Accepted 31 December 2024
Available online 01 March 2025 with doi: 10.5455/medscience.2024.12.157

Abstract

Our study aimed to investigate the effect of stone load, skin-to-stone distance, and stone density Hounsfield Unit (HU) measured in unenhanced computed tomography on the success of ESWL in patients with renal pelvis stones. The data of 136 patients, who were admitted to the Urology Polyclinic of Malatya Training and Research Hospital between January 2016 and 31 December 2018 due to side pain and who underwent ESWL in the Urology Clinic after renal pelvis stone was detected as a result of radiological evaluation, were evaluated. In unenhanced abdominal CT performed on patients before ESWL, skin-to-stone distance and Hounsfield unit measurements of the stone were performed. In CT, the size of the stone was calculated by the product of its width and length in the sections where the stone appeared the largest. Hounsfield Unit was evaluated. In the post-ESWL follow-ups, stone-free rates were examined, and whether the skin-to-stone distance and HU were determinant factors were evaluated. For each ESWL session of the patients, the shock number was planned as 1500-2500 (mean=2123) and shock intensity as 14-20 (mean=17) kV. There were at least 7 days between two ESWL sessions. The mean age of the patients was calculated as 42.4±12.3 years and the mean BMI as 26.2±2.8 kg/m^2. The mean stone size was 118.4±62.3 mm^2, skin-to-stone distance was 10.2±1.6 cm, and stone density HU was 886.4±372.2. In 92 patients with a mean skin-to-stone distance below 9.2±0.9 cm and a mean stone density below 689±78.2 HU, stone-free success was achieved. In 44 patients who had residual stones following ESWL, the mean skin-to-stone distance was 11.6±1.6 cm and the stone density was 1217±218.4 HU. While 52.9% of the patients were male, 47.1% were female. BMI, stone diameter, skin-to-stone distance, and stone density were determined as parameters affecting treatment success in the treatment of renal pelvic stones with ESWL. A positive correlation was determined between skin-to-stone distance and BMI ($r=0.44$, $p<0.001$). Mean stone density HU was found to be a strong predictive value in stone treatment, and stone densities of the patients with residual stones following ESWL treatment were found to be statistically higher ($p<0.001$). The success of ESWL depends on stone density, skin-to-stone distance, BMI, and stone size. It is seen that rate of success is lower in cases with high stone density, long skin-to-stone distance, high BMI, and large stone size. Multicenter studies involving larger numbers of patients will contribute to the inclusion of these predictive values in guidelines.

Keywords: Kidney stone, extracorporeal shock wave lithotripsy, body mass index, hounsfield unit, stone-skin distance

Introduction

Extracorporeal Shock Wave Lithotripsy (ESWL) treatment was first introduced in 1980. This treatment modality, which has an important place in the treatment of urinary system stone disease, is a non-invasive procedure [1]. ESWL acts with a physical principle that focuses the energy obtained from an energy source on the stone to be broken. X-ray or ultrasonic imaging system is used to target this focus to the stone [2]. Generators that generate energy in ESWL are divided into three types as electrohydraulic, electromagnetic, and piezoelectric. Sound waves generated as a result of energy break up the stone [2,3]. Stone-free condition emerges when the broken stones are thrown from the ureters to the bladder and moved out of the body from there. Current studies report the general success rate of ESWL between 60% and 90% [4]. The European Association of Urology Guideline recommends ESWL with a strong degree in the treatment of kidney stones of 20 mm and below [5]. ESWL has an advantage compared to other treatment methods since it can be applied without anesthesia, can be applied as outpatient treatment, and is a non-invasive method [1,6]. Although ESWL is highly effective, its success depends on certain factors. These factors include the size and chemical composition of the stone, the anatomical position of the stone in the kidney, and the body structure of the

CITATION
Cimen S, Ozaydogdu Cimen A. The effect of skin-to-stone distance on success in renal pelvis stones treated with ESWL. Med Science. 2025;14(1):169-72.

OPEN ACCESS

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DOI: 10.5455/medscience.2024.12.157

patient. The use of ESWL is restricted in patients with a high Body Mass Index (BMI); therefore, treatment success is reduced. Overweight patients exceed the weight limit of the machine. In some devices, the focal distance, which is the distance from the skin to the stone, ranges between 11-17 cm. This short focal distance can be insufficient for patients with a high BMI. Another issue is that thick adipose tissue and muscle layer both cause a decrease in maximum shock wave pressure and hide the localization of the stone [7]. Another important issue affecting stone-free rates in patients undergoing ESWL is the chemical composition of the stone. Stones containing calcium oxalate monohydrate and cystine have a harder structure, while stones containing uric acid and calcium oxalate dihydrate have a softer structure. Since hard stones can be broken in ESWL, stone-free rates are high; however, this rate decreases in soft stones [8]. Unenhanced Computed Tomography is one of the parameters that negatively affect ESWL success since stones with a stone density of more than 800 HU have a harder structure in the Hounsfield Unit (HU) which is the indicator of the hardness of the stone [9]. Our study aimed to investigate the effect of stone load, skin-to-stone distance, and stone density HU measured in unenhanced computed tomography on the success of ESWL in patients with renal pelvis stones.

Material and Methods

The data of 136 patients, who were admitted to the Urology Polyclinic of Malatya Training and Research Hospital between January 2016 and 31 December 2018 due to side pain and who underwent ESWL in the Urology Clinic after renal pelvis stone was detected as a result of radiological evaluation, were evaluated. For the study, approval was obtained from Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Ethics Committee Decision No: 2018/16-29). In unenhanced abdominal CT performed on patients before ESWL, skin-to-stone distance and Hounsfield unit measurements of the stone were performed. In CT, the size of the stone was calculated by the product of its width and length in the sections where the stone appeared the largest. Hounsfield Unit was evaluated. In the post-ESWL follow-ups, stone-free rates were examined, and whether the skin-to-stone distance and HU were determinant factors were evaluated.The study inclusion criteria were as follows: a stone located in the renal pelvis, a stone size not smaller than 10 mm and not larger than 15 mm, a maximum of 3 sessions of ESWL, being radio-opaque stones, and having no anatomical and congenital variation that could affect the success of ESWL alone. Following the ESWL treatment of the patients, KUB (direct urinary system graphy) was performed and stone-free rates were determined. The effect of skin-to-stone distance factors on the stone-free rate of the Hounsfield unit, which was investigated as an independent factor, was evaluated. ELMED brand ESWL device was used in the process. This device is used with membrane coupling, spark-gap dry system, and X-ray fluoroscopic focusing system. For each ESWL session of the patients, the shock number was planned as 1500-2500 (mean=2123) and shock intensity as 14-20 (mean=17) kV. There were at least 7 days between two ESWL sessions. Urine culture was examined in all patients before the procedure. The patients without growth in urine culture were included in the study. Moreover, analgesia was provided to the patients by routine intramuscular administration of 75 mg diclofenac sodium before ESWL. Following ESWL, the patients were called for follow-up on Day 2, Day 15, and Day 30. In the follow-up, KUB and Unenhanced CT were performed. The fragmentation of the stone, removal of the stone fragments, disappearance of symptoms, presence of clinically insignificant residual stone, and absence of additional treatment methods were considered successful. Logistic regression analysis, Mann Whitney-U test, and Chi-Square test were used to compare the demographic data, stone density, stone diameter, and skin-to-stone distance of the patients, and $p<0.05$ was considered statistically significant.

Results

The demographic data of the patients and stone parameters such as skin-to-stone distance, stone density, and stone size are shown in Table 1. The mean age of the patients was calculated as 42.4±12.3 years and the mean BMI as 26.2±2.8 kg/m^2. The mean stone size was 118.4±62.3 mm^2, skin-to-stone distance was 10.2±1.6 cm, and stone density HU was 886.4±372.2. In 92 patients with a mean skin-to-stone distance below 9.2±0.9 cm and a mean stone density below 689±78.2 HU, stone-free success was achieved. In 44 patients who had residual stones following ESWL, the mean skin-to-stone distance was 11.6±1.6 cm and the stone density was 1217±218.4 HU. While 52.9% of the patients were male, 47.1% were female. BMI, stone diameter, skin-to-stone distance, and stone density were determined as parameters affecting treatment success in the treatment of renal pelvic stones with ESWL (Table 2). A positive correlation was determined between skin-to-stone distance and BMI ($r=0.44$, $p<0.001$). Mean stone density HU was found to be a strong predictive value in stone treatment, and stone densities of the patients with residual stones following ESWL treatment were found to be statistically higher ($p<0.001$). Urosepsis and hematoma in the renal pelvis were not observed in any patient as major complications following ESWL. Eleven patients had petechiae and ecchymosis on the skin on the side where ESWL was performed, and 6 patients had macroscopic haematuria that lasted for 2 days and resolved spontaneously with oral hydration.

Table 1. Demographic data and stone parameters of patients treated with ESWL

	Patients treated with ESWL (n=136)
Age	42.4±12.3
Gender	
Male	72 (52.9%)
Female	64 (47.1%)
BMI (kg/m^2)	26.2±2.8
Stone-skin distance (cm)	10.2±1.6
Stone density (HU)	886.4±372.2
Stone size (mm^2)	118.4±62.3
The side with the stone	
Right	70 (51.4%)
Left	66 (48.6%)

 DOI: 10.5455/medscience.2024.12.157

Table 2. Factors affecting success in patients with complete stone-free and residual stones

	All patients	Stone-free patients (n=92)	Patients with residual calculi (n=44)	p
Age	42.4±12.3	38.4±10.6	43.1±11.2	NS
BMI	26.2±2.8	25.1±8.2	28.8±3.8	0.003
Stone size (mm²)	118.4±62.3	98.1±57.1	151.1±52.8	0.002
Stone density (HU)	886.4±372.2	689±78.2	1217±218.4	0.001
Stone-skin distance (cm)	10.2±1.6	9.2±0.9	11.6±1.6	0.001

Discussion

The first objective in the treatment of urinary system stones is to ensure complete stone-freeness in the patient. Today, various medical and surgical treatments are used in the treatment of urinary system stones. Non-invasive and invasive treatments include ESWL, percutaneous nephrolithotripsy (PCNL), rigid or flexible ureteroscopy, laparoscopic ureterolithotomy, retrograde intrarenal interventions, and open surgical interventions [3,10]. In the guidelines, ESWL is still considered as the first treatment option for a renal pelvic stone of 20 mm or below in an adult patient [5]. Compared to other treatment methods, ESWL is non-invasive, its application is easier for the patient and the physician, the length of hospital stay is short, kidney damage is low, and complications are less [11].

The stone density determined in unenhanced computed tomography, that is, the HU value, is an important parameter in achieving complete stone-free condition in patients undergoing ESWL. As the HU of the stone increases, stone-free rates decrease. Similarly, studies have shown that stone-free rates decrease as the size of the stones in high HU increases, and stone-free rates increase as the stone size decreases [12,13]. In another study, the content of the stone was tried to be determined by HU measurement, and it was revealed that it could separate calcium and uric acid stones [14]. HU of uric acid stones was found to be lower than calcium stones. When the literature was examined, the common idea in almost all studies was that the stone with 800 HU or above contributed positively to stone-free rates [15]. In our study, it was aimed to predict the complete stone-free rate of skin-to-stone distance and HU value in patients with renal pelvis stones. In the analyses, it was found that both skin-to-stone distance and HU were predictive values in predicting the stone removal rate in patients who underwent ESWL. It was revealed that stone-free rate was statistically significantly higher in our patients with low HU measurement.

Obesity is an increasing health issue of our age. Obesity is calculated with body mass index measurement. It is obtained by dividing the weight (kg) of a person by the square of his height [14,16]. In our study, while stone-free rate decreased after ESWL in patients with high BMI, that is, obese category, this rate increased as BMI decreased. The reason for this may be that it is difficult to focus the stone in patients with high BMI or that shock waves are absorbed by fat tissue and skin and reach the stone.

When the literature is examined, it is seen that another factor affecting ESWL success is skin-to-stone distance [17]. It is thought that as the distance traveled by the shock wave in the body increases, the power of shock wave may decrease. There are different studies in the literature on skin-to-stone distance measurement. Some researchers determined this distance as 3-dimensional by measuring 0o,45o, and 90o and then averaging them [18]. Pace et al. measured the odds ratios at a distance of only 450[19]. In our study, the skin-to-stone distance was calculated by measuring only at 45o. In the studies conducted to predict the success of ESWL in the literature, this distance is between 9 cm and 11 cm in studies where skin-to-stone distance estimation values are given [20]. Some studies reported that the correlation between skin-to-stone distance and BMI affects ESWL success, but gender and racial fat distribution have no contribution to this success [21]. In a different study, body fat distance was added or removed from the skin-to-stone distance and it was found that treatment success was associated with adipose tissue. In this study, it was determined that both the skin-to-stone distance and the fat and muscle tissue ratio affecting this distance were significantly lower in the successful group [22]. In addition to skin-to-stone distance, the size of the stone is among the factors that affect success. In a study, as well as skin-to-stone, stone size and stone localization were evaluated. In this study, it was observed that a HU density below 900 and a skin-to-stone distance of less than 9 cm affected ESWL success regardless of BMI [19,21].

In another study, it was reported that the stone-free rate was low in one group (patients with a skin-to-stone distance of 11.5 cm) and completely stone-free in the other group (patients with a skin-to-stone distance of 8.1 cm). The authors emphasized that a skin-to-stone distance greater than 10 cm negatively affects ESWL success and stone localization is not important in this success. They emphasized that skin-to-stone distance should be measured before ESWL in predicting ESWL success [23,24].

Our study found that ESWL success increased significantly, especially in patients with a skin-to-stone distance of 9.5 cm and a stone density value HU below 700. Furthermore, in the 67.6% ESWL success obtained in our study, it was found that skin-to-stone distance, BMI, stone diameter, and stone density were the parameters affecting ESWL stone-free rates. The main limiting factors of our study were the limited sample size and the small number of cases.

 DOI: 10.5455/medscience.2024.12.157

Conclusion

Kidney stones can be treated with ESWL. The success of ESWL depends on stone density, skin-to-stone distance, BMI, and stone size. It is seen that rate of success is lower in cases with high stone density, long skin-to-stone distance, high BMI, and large stone size. BMI, stone load, stone density, and skin-to-stone distance measurements before ESWL can be used to predict the success rate in patients with renal pelvic stones. Multicenter studies involving larger numbers of patients will contribute to the inclusion of these predictive values in guidelines.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
For the study, approval was obtained from Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee (Ethics Committee Decision No: 2018/16-29).

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