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Effect of Tissue Densities at the Skin-to-Stone Distance on the Success of Shockwave Lithotripsy

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

Skin stone distance is one of the many factors affecting the success of extracorporeal shock wave lithotripsy. The shock waves pass through different tissues from skin to stone. In this study, we investigated the effect of the thickness and density of the tissues on the path of shock waves from the skin to the stone.

Abstract

Objective: There are several factors affecting the success of shockwave lithotripsy (SWL), which is still one of the first-line treatments for renal stones smaller than 2 cm. The aim of this study was to evaluate the effect of thickness and density measurements obtained by computed tomography (CT) for various tissues within the route of shockwaves on the outcome of SWL treatment success.

Materials and Methods: The data of 89 patients who underwent SWL for renal pelvic stones smaller than 2 cm between July 2020 and September 2021 were prospectively evaluated. Age, sex, body mass index, stone volume, stone density, skin-to-stone distance, tissue thickness and density, hydronephrosis, number of shockwaves, and SWL success were recorded. Patients were divided into two groups according to SWL success: SWL success and SWL failure groups. Demographic data and CT parameters were compared between the groups.

Results: Stone-free status (<4 mm residual stone) was achieved in 70 patients. Mean subcutaneous adipose tissue density was -97 Hounsfield unit (HU) in group 1 and -101 HU in group 2 (p=0.575). Mean muscle tissue density was 32 HU in group 1 and 31 HU in group 2 (p=0.843). Perinephric adipose tissue density was calculated as -93 HU in group 1 and -98 HU in group 2 (p=0.621). Skin-to-stone distance, tissue thickness, and tissue density findings failed to effect stone-free status.

Conclusion: According to the results obtained in this study, tissue thickness and density in a CT scan did not affect treatment success. Only stone density and size in a CT scan can help to decide SWL treatment success, as suggested in previous studies.

Keywords: Hounsfield unit, extracorporeal shockwave lithotripsy, renal stone, non-contrast computed tomography

Introduction

First introduced by Chaussy et al., shockwave lithotripsy (SWL) still maintains its place as a non-invasive method for treating renal stones smaller than 2 cm (1). SWL is frequently used around the world, and the treatment success rate is reported to be between 47-91%. Various features of a stone, such as density, size, and location, its skin-to-stone distance; and the device used, can affect success rates (2). Non-contrast computed tomography (CT) is the most used radiologic imaging modality in the evaluation of urinary tract stones. CT is the preferred radiological evaluation method because it provides more information about stone-related data such as stone location, density, size and skin-to-stone distance; and information about renal anatomy such as infundibulopelvic angle and hydronephrosis (3).

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In addition, the subcutaneous adipose tissue, muscle tissue, perinephric adipose tissue, and renal parenchymal thickness and density can be measured by CT. To date, there is no study in the literature evaluating the effect of tissue density on SWL success. The aim of this study was to evaluate the effect of thickness and density measurements obtained by CT for various tissues within the route of shockwaves on the outcome of SWL treatment success.

Materials and Methods

This was a single-center prospective study that was approved by the Institutional Ethics Review Board and was conducted in accordance with the good clinical practice guidelines (decision no: 2020/514/182/5, date: 22.07.2020 - Kartal Dr. Lütfi Kırdar City Hospital). Between July 2020 and September 2021, a total of 94 patients who underwent SWL for renal pelvic stones were included in the study. Five patients were excluded from the study; three could not tolerate the procedure, two were lost during follow-up. A total of 89 patients who underwent SWL treatment for renal pelvic stones smaller than 2 cm in diameter were included in the study. Abdominal non-contrast CT, urinalysis, urine culture, complete blood count, and coagulation tests were performed on all patients before the procedure. The same Dornier Compact Sigma (Med Tech, Munich, Germany) device in our institution was used for the SWL treatment of all patients. Exclusion criteria were anatomical disorders, coagulation disorders, active urinary infection, and distal obstruction and a treatment of more than three sessions. All SWL procedures were performed without anesthesia by the same doctor and technician. During 1 extra SWL session, a maximum of 3000 shocks were delivered at the energy level of 2 to 4, corresponding to 14 to 15 kV. All of them had radiopaque stones. One month after the end of treatment, patients with ≥4 mm stones confirmed by CT or direct urinary tract radiography were considered unsuccessfully treated (4).

Skin-to-stone distance was measured at 0°, 45° and 90° in the axial section of a non-contrast CT scan and then averaged (5). Parenchymal thickness at the skin-to-stone distance, perinephric adipose tissue, muscle tissue, and subcutaneous adipose tissue were also calculated (Figure 1). Tissue densities were marked as region of interest in a circular pattern with a 1 cm diameter on CT and calculated as mean Hounsfield unit (HU) [Infinitt Pacs 3.0.11.4 (BN11)] (Figure 2). Stone volume was calculated using the formula (0.523 × length × width × height) (6). Stone density, the number of shockwaves, body mass index (BMI), degree of hydronephrosis, side, and patients' age and sex were included in the analysis. Patients were divided into two groups as SWL success and SWL failure groups, and their demographic data and CT findings were compared.

Statistical Analysis

Statistical analyzes were performed using the software SPSS version 20.0. The conformity of the variables to a normal distribution was examined visually (histogram) and analytically (Kolmogorov-Smirnov and Shapiro-Wilk tests). All continuous variables are presented as mean and standard deviation. Student's t-test was used to compare continuous variables between groups. Continuous variables with abnormal distribution were evaluated with the Mann-Whitney U test. Chi-square test was used to compare categorical variables. P-values <0.05 were interpreted as statistically significant.

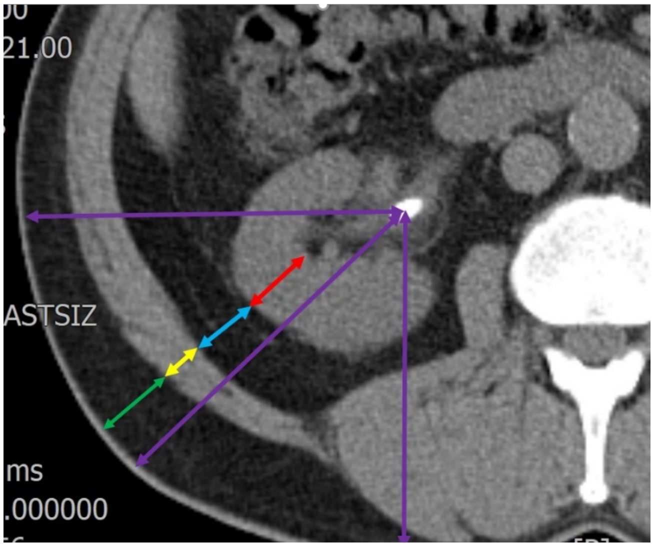

Figure 1. Skin-to-stone distance and tissue thicknesses. Purple arrow: skin-to-stone distance, red arrow: Renal parenchyma thickness, blue arrow: Perinephric adipose tissue thickness, yellow arrow: Muscle tissue thickness, green arrow: Subcutaneous adipose tissue thickness

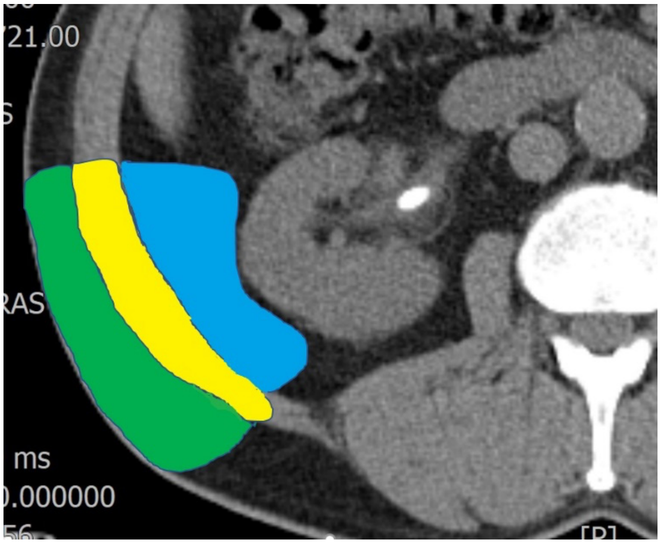

Figure 2. Measurement of tissue densities. Blue area: Perinephric adipose tissue, yellow area: Muscle tissue, green area: Subcutaneous adipose tissue

Results

A total of 89 patients who underwent SWL for renal pelvic stones were included in the study. Patients defined as stone-free were included in group 1 (n=70) and patients with residual stones were included in group 2 (n=19). Of the 89 patients, 60 were male and 29 were female (group 1: 48/22, group 2: 12/7). BMI (kg/m^2) was 26.41 for group 1 and 25.02 for group 2. There was no statistically significant difference between the groups in terms of age, sex, side and BMI (Table 1). The mean stone volume was 500 mm^3 in group 1 and 694 mm^3 in group 2. Stone volume was significantly higher in group 2 (p=0.041). Stone density was significantly higher in group 2 (732 HU in group 1 vs. 888 HU in group 2, p=0.005). The total number of shockwaves was 5797 in group 1 and 7142 in group 2. The number of shockwaves was significantly higher in group 2 (p=0.032). Mean subcutaneous adipose tissue density was -97 HU in group 1 and -101 HU in group 2. Mean muscle tissue density was 32 HU in group 1 and 31 HU in group 2. Perinephric adipose tissue density was calculated as -93 HU in group 1 and -98 HU in group 2. There was no statistically significant difference between the groups in terms of skin-to-stone distance, tissue thickness, and tissue density (Table 2). Multivariate analysis revealed that none of the variables were predictive for stone-free rate (Table 3).

Discussion

The effect of shockwaves may decrease as they cross through different tissue types, and this may affect SWL success. At this point, SWL success may be affected as the thickness and density of the tissues between the stone and skin vary. In vitro studies in the literature reported no significant difference in the transmission of shockwaves in different tissues, however, only animal tissues were used in these studies (2,7). Ng et al. (8) reported that thicker renal parenchyma increased SWL success, whereas success decreased in thinner or scarred parenchyma. In this study, although renal parenchymal thickness was high in the successful SWL group, no statistically significant difference was observed. Juan et al. (9) reported that the rate of failure was high in patients with more visceral and perirenal adipose tissue. Another study reported that abdominal adipose tissue

Table 1. Demographic data

	Group 1 (n=70)	Group 2 (n=19)	p-value
Gender (male/female)	48/22	12/7	0.783
Age (years)	43.43 (±13.15)	43.32 (±13.06)	0.974
BMI (kg/m^2)	26.41 (±4.23)	25.02 (±3.48)	0.192
Side (right/left)	37/33	12/7	0.450

BMI: Body mass index

Table 2. Computed tomography and extracorporeal shockwave lithotripsy data

		Group 1	Group 2	p-value
Stone volume (mm^3)		500 (±345)	694 (±416)	0.041
Stone density (HU)		732 (±222)	888 (±151)	0.005
Skin-to-stone distance (mm ± SD)		98.60 (±20.81)	98.95 (±18.28)	0.948
Muscle tissue (mm ± SD)		13.26 (±3.55)	13.05 (±4.02)	0.829
Subcutaneous adipose tissue (mm ± SD)		24.11 (±15.04)	26.26 (±13.67)	0.575
Perinephric adipose tissue (mm ± SD)		15.13 (±8.0)	13.11 (±5.34)	0.302
Parenchymal thickness (mm ± SD)		26.2 (±4.19)	24.58 (±6.57)	0.194
Subcutaneous adipose tissue density (HU)		-97 (±37)	-101 (±16)	0.644
Muscle tissue density (HU)		32 (±13)	31 (±15)	0.843
Perinephric adipose tissue density (HU)		-93 (±45)	-98 (±16)	0.621
Number of shockwaves		5797 (±2495)	7142 (±1922)	**0.032**
Degree of hydronephrosis	Grade 0	3 (4.3%)	1	0.068
	Grade 1	22 (31.4%)	3	
	Grade 2	34	10	
	Grade 3	11	3	
	Grade 4	0	2	

SD: Standard deviation, HU: Hounsfield unit

Table 3. Evaluation of predictive variables for stone free status on multivariate analysis

	Odds ratio (95% CI)	p-value
Skin-to-stone distance (mm ± SD)	1.023 (0.963-1.087)	0.464
Muscle tissue (mm ± SD)	1.007 (0.851-1.192)	0.936
Subcutaneous adipose tissue (mm ± SD)	0.993 (0.927-1.065)	0.853
Perinephric adipose tissue (mm ± SD)	0.929 (0.831-1.038)	0.191
Parenchymal thickness (mm ± SD)	0.917 (0.817-1.030)	0.143
Subcutaneous adipose tissue density (HU)	0.995 (0.962-1.028)	0.750
Muscle tissue density (HU)	0.995 (0.957-1.034)	0.786
Perinephric adipose tissue density (HU)	0.998 (0.971-1.026)	0.893

SD: Standard deviation, HU: Hounsfield unit, CI: Confidence interval areas had no effect on stone-free status (10). In this study, subcutaneous adipose tissue, muscle tissue, and perinephric adipose tissue thickness had no effect on stone-free status. To the best of our knowledge, there are no previous studies on the effect of tissue density in the literature. We calculated and analyzed the average density of tissues at the skin-to-stone axis. Accordingly, subcutaneous adipose tissue, muscle tissue, and perinephric adipose tissue densities had no effect on stone-free status. Furthermore, we evaluated the association of skin to stone distance, tissue density and tissue thickness with stone - free status using multivariate analysis and found that none of these variables were predictive of stone-free status.

CT is a rapid and reliable imaging modality for the diagnosis of urinary tract stones. Furthermore, CT is critical to treatment planning by revealing the location, size, and density of the stone; obstruction status; and presence of urinary anomalies. There are many factors affecting the success of SWL; and various findings on CT may be useful in predicting the success of SWL treatment (11).

Previous studies evaluated the association between patent characteristics and SWL outcome. Graversen et al. (12) found that BMI had an effect on SWL success in their study. BMI was thought to be influential at two points: skin-to-stone distance and adipose tissue thickness. It was concluded that the increased adipose tissue may be an obstacle in the transmission of shockwaves. In another study conducted by Pareek et al. (5), BMI was found to be an important parameter in predicting stone-free status in SWL. However, skin-to-stone distance and stone density were reported to be more important parameters. In this study, BMI was not identified as an effective parameter in predicting stone-free status. This may be due to the small sample size and the fact that only patients with renal pelvic stones were included in the study.

There are studies reporting both positive and negative results of the effect of skin-to-stone distance on SWL success. Jacobs et al. (13) found that skin-to-stone distance had no effect on SWL success, whereas El-Nahas et al. (14) found that skin-to-stone distance was associated with SWL success. Similarly, Patel et al. (15) identified skin-to-stone distance as an independent predictor on multivariate analyzes in their study. Interstingly, Weld et al. (16) found that skin-to-stone distance only had an effect on SWL success in calcium stones when renal pelvic stones were excluded from analysis. There are studies in the literature reporting cut-off values of 9-11 cm for skin-to-stone distance. Pareek et al. (5) reported a cut-off value of 10 cm. These authors concluded that a more than 10 cm distance was related to lower SWL success rates. In this study, the mean skin-to-stone distances was similar for both groups. Mean skin-to-stone distance was lower than 10 cm for both groups, so we think that skin-to-skin distance was less importantin our study. SWL success decreases as stone size increases. Therefore, SWL is not recommended for stones larger than 2 cm (17). Some studies have reported that stone volume is more important than the maximum length of the stone (18). Concordant with the literature, in our study, a higher mean stone volume rate was determined in "unsuccessfully" treated patients.

Stone density is an important predictor of SWL success. Gupta et al. (19) reported that patients with stone density >750 HU had more residues and required more sessions. In another study, El-Nahas et al. (14) found that SWL failure increased when stone density was more than 1000 HU. These authors concluded that stone density is an independent predictor of stone fragmentation. Different from these studies, a high failure rate with increasing stone size was demonstrated in patients with stone density above 1000 HU (20). Although no cut-off value was calculated in this study, stone density was found to be higher in the unsuccessful SWL group than in the other.

In this study, a maximum of 3000 shockwaves per session was administered, and patients received a maximum of three sessions. Patients in whom fragmentation could not be achieved or those who had residual stones were rescheduled for the treatment. The number of shockwaves was higher in the unsuccessful SWL group than in the other. Joseph et al. (21) reported that the number of shockwaves was high in patients with residual stones or in patients in whom fragmentation was not achieved.

Study Limitations

There are certain limitations to this study. First, the small patient number is a weakness of the study. More reliable results could be achieved with a larger patient cohort. The results of stone analysis and metabolic evaluations of patients were not included. In addition, only patients with renal pelvic stones were included. Therefore, the results cannot be generalized and may differ in other renal stones.

Conclusion

CT parameters before SWL can predict stone-free status. Stone density and volume are important parameters to be considered in patient selection. Based on the results obtained in the present study, no effect of skin-to-stone distance and the thickness and density of the tissues at this distance on stone-free status could be determined. Further studies should be conducted to evaluate these parameters in larger patient groups.

Ethics

Ethics Committee Approval: This was a single-center prospective study that was approved by the Institutional Ethics Review Board and was conducted in accordance with the good clinical practice guidelines (decision no: 2020/514/182/5, 22.07.2020 - Kartal Dr. Lütfi Kırdar City Hospital).

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Authorship Contributions

Surgical and Medical Practices: C.Ç., B.Ş., O.Ö., Concept: C.Ç., Y.T., Design: U.C., Y.T., Data Collection or Processing: C.Ç., E.D., A.C., Analysis or Interpretation: O.Ö., Y.T., Literature Search: C.Ç., E.D., U.C., Writing: C.Ç., B.Ş.

Conflict of Interest: No conflict of interest was declared by the authors.

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