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Predictive value of hounsfield unit in urinary system stones applied with eswl

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Abstract

This study claims to examine the relationship between the Housfield unit (HU) value and the success of Electro Shock Wave Lithotripsy (ESWL) treatment. Data of 142 patients were evaluated retrospectively in this cross-sectional observational study. The threshold value for stone density is calculated as 991.20 HU in the ROC analysis. The patients are seperated into two groups with respect to this value, and their demographic characteristics, stone characteristics and success rates after ESWL treatment are statistically compared. For the variables that are statistically crucial in the univariate analysis, logistic regression analysis are used as a multivariate analysis. The mean age of all patients were 45.25±11.72 years and the mean body mass index (BMI) is 28.42±3.98 kg/m². While our stone-free rate was 66.2% in our study, the mean stone size was 11.25±3.83mm, the Hounsfield unit value was 1007.55±337.75 HU, and the stone-skin distance was 108.02±20.02mm, respectively. We observed a crucial difference in between the Housfield unit value and stone size in univariate and multivariate analyzes between the two groups, and the stone-free rate after ESWL. The Hounsfield unit value, measured by the non-contrast computed tomography method, is a parameter for the prediction in success of patients undergoing Electro Shock Wave Lithotripsy treatment. Also, stone density above 991.20 HU in patients having urinary system stone disease requires the evaluation of alternative treatments as a condition that reduces the success of the treatment.

Keywords: Urinary stone disease, ESWL, Hounsfield unit

Introduction

Upper urinary tract stones are among the most common and recurrent diseases in current urological practices. Urinary tract stones stand out as an important health and economic problem because of their high prevalence and recurrence rates. The prevalence rate of kidney stones is around 10~12% in men and 5~6% in women [1].

The treatment method is specified by the location, size and density of the stones. The optimal goal in treatment is higher stone-free rates with fewer complications. Extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), semirigid or flexible ureterorenoscopic lithotripsy (URSL/RIRC), and open/laparoscopic nephrolithotomy options are available in the treatment of urinary system stone disease [2,3].

ESWL is an outpatient, simple, anesthesia-free and non-invasive treatment method that has been used since the 1980s. ESWL and RIRS are popular current treatments for kidney stones smaller than 2cm and proximal ureteral stones. While in asymptomatic lower pole stone cases are recommended to follow-up, ESWL is the primary treatment method in symptomatic patients [4]. The main goal in stone treatment is preferring the most appropriate method that will maintain the maximum stone-free rate. The European urology society guide states no significant difference between ESWL and RIRS in terms of success in the third month after surgery [1]. The success rates of ESWL vary between 35% and 89%, and these success rates are; stone density (HU), stone localization, female gender, diameter of the ureteropelvic junction, stone size, skin-to-stone distance and body mass index [4-6].

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Non-contrast computed tomography (CT) is an important diagnostic tool to identify urinary stone disease with high accuracy. The accuracy of non-contrast CT imaging for urolithiasis is 96-97%. Meanwhile, non-contrast CT is accepted as the gold standard in the diagnosis of patients with urolithiasis [7].

Sir Godfrey Newbold Hounsfield first developed the radiodensity scale by introducing the principle of determining the amount of X-rays that pass through are absorbed by tissues. CT images consist of pixels, each with a gray scale value between 1 (black) and 256 (white). This value showing the amount of X-rays passing through the structure can be measured and expressed in Hounsfield units (HU) [8]. There are studies that predict the result of ESWL of many factors, such as HU values measured with non-contrast CT [6,9-11].

In our study, we aimed to investigate the value of HU in predicting success rates in patients who underwent ESWL.

Material and Methods

Patient's Group

This retrospective cross-sectional observation study was conducted by including 142 patients diagnosed with kidney and proximal ureteral stones and treated with ESWL between January 2020 and December 2021. After approval of the study by the Non-Interventional Clinical Research Ethics Committee (Decision no: 445, Study no: 425, Date: 17.12.2021), demographic data of all patients, characteristics of the stones in non-contrast CT images, number of ESWL sessions applied, complications, residual stones after ESWL The presence and stone-free rate were recorded and examined. This retrospective study was not required a patient-informed consent form.

Renal calcified masses, lymph node calcifications, metallic thoracolumbar instrumentation, pregnancy, congenital renal anomalies, coagulopathies, patients younger than 18 years of age, patients receiving psychiatric and neurological treatment, patients undergoing urinary diversion, and patients with active urinary system infection were excluded from the study.

Imaging Method, Analysis and ESWL Criteria

All non-contrast tomography images were performed with a multi-detector serial CT device with 1.25mm sections, radiation dose adjusted to 120kV and 100mA.

All ESWL lithotripsy procedures were performed by the same electromagnetic lithotripter (ARGEMED A1000, Ankara, Turkey) under the supervision of the same senior urologist, after standard oral/im-iv non-steroidal anti-inflammatory (diclofenac sodium) treatment was administered half an hour before the procedure. ESWL energy protocol: lowest energy setting (0.1 Joule, J) 0-100 shock wave, then gradually increasing 0.2 J energy at additional face shock, so maximum with 1.0 J corresponding energy when 500 shock waves are delivered 3000 shock waves were applied with a frequency range of 60-70/min and a power of 15-20 kV. Fragmentation control of the stone was performed with intermittent serial fluoroscopic exposure at the beginning, middle and end of the ESWL procedure. All patients were kept under medical observation for approximately 2 hours as standard after the procedure.

The symptoms (pain, macroscopic hematuria, UTI) of all patients were evaluated routinely 1 week after ESWL, and the success of ESWL was evaluated by direct urinary system radiography and/or non-contrast CT taken 4 weeks later [12]. With the radiological evaluation performed after ESWL, stone-free and stones <=5mm were accepted as the success of ESWL (13).

Statistical analysis

All statistical analyzes in the study were performed by using the SPSS 26.0 (IBM Inc., Armonk, NY, US) package program. After evaluating the distribution of the variables with the Kolmogorov-Smirnov test, the Student-t test was used as a parametric test for the variables with normal distribution, and the Mann-Whitney-U test was used as a nonparametric test for the variables with non-normal distribution. The difference between independent categorical variables was evaluated with the Pearson chi-square test. The arithmetic mean for the normally distributed continuous variables and the percentage and frequency values for the standard deviation categorical variables are given. ROC analysis method was used for the Hounsfield unit threshold value. Pearson correlation test was used to evaluate independent variables. A value of $p<0.05$ was considered statistically significant.

Results

The mean age of the 142 patients included the study was 45.25±11.72 years and the mean body mass index (BMI) was 28.42±3.98 kg/m². Of the patients, 98 (69%) were male and 44 (31%) were female. Hydronephrosis accompanying the stone was not observed in 119 (83.8%) patients. Grade 1 hydronephrosis was observed in 6 (4.2%) patients, grade 2 in 12 (8.5%) patients, grade 3 in 4 (2.1%) patients, and grade 4 in 1 (0.7%) patient, respectively. The stone was located on the right side in 58 (40.8%) patients,, while it was located on the left kidney in 84 (54.2%). Ureteral DJ catheter placement was required before ESWL treatment in only 6 (4.2%) patients. While 97 (68.3%) patients had a single stone, 45 (31.7%) patients had more than one stone. The mean stone size of all patients was 11.25±3.83mm and the mean Hounsfield unit value was calculated as 1007.55±337.75 HU. The mean stone-skin distance was calculated as 108.02±20.02mm. In the study, the stone-free rate was calculated 66.2%. Stone-free status was maintained 33 (34.7%) patients in 1 session, 32 (33.7%) 2 sessions, and 30 (31.6%) 3 sessions. As a result of the ROC analysis, the threshold value for the Housfield unit was calculated 991.20 HU (AUC=0.474; p=0.040) with 59.1% sensitivity and 51% specificity (Figure-1). According to this threshold value, the patients were divided into 2 groups, group 1 ≤991.20 HU and group 2 >991.20 HU. The characteristic features of the patients are summarized in Table-1. A statistically significant difference was observed between the Housfield unit and stone size and stone-free rate after ESWL (Table-1). By the way, a weak correlation was provided between Housfield unit value and stone size (r=0.313; p<0.001) and stone-free rate after ESWL (r=-0.202; p=0.031). In the multivariate analysis, a significant correlation was found between stone-free rate and stone size and HU (p=0.013) (Table-2).

Table 1. General characteristics of the patients

	Group 1HU≤9912 n=66 (%46.5)	Group 2HU>9912 n=76 (%53.5)	p value
Age	43.48±12.19	46.79±11.16	0.101¹
Gender			
Male	48 (%72.7)	50 (%65.8)	0.374³
Woman	18 (%27.3)	26 (%34.2)	
BMI	28.17±4.46	28.64±3.52	0.204¹
Stone size	10.14±3.48	12.21±13.89	0.001¹
Stone side			
Right Kidney	25 (%37.9)	33 (%43.4)	0.504³
Left Kidney	41 (%62.1)	43 (%56.6)	
Stone localization			
Upper ureter	20 (%30.3)	27 (%35.5)	0.865³
Pelvis	31 (%47)	40 (%52.6)	
Lower calyx	6 (%9.1)	4 (%5.3)	
Middle calyx	5 (%7.6)	4 (%5.3)	
Upper calyx	4 (%6.1)	1 (%1.3)	
Number of the stone	1.44±0.80	1.46±0.70	0.573¹
Stone free patient	50 (%75.8)	45 (%59.2)	0.012¹
Hydronephrosis			
None	56 (%84.8)	63 (%82.9)	0.646³
Grade 1	5 (%6.1)	2 (%2.6)	
Grade 2	4 (%7.6)	7 (%9.2)	
Grade 3	1 (%1.5)	3 (%3.9)	
Grade 4	0 (%0)	1 (%1.3)	
Ureter DJ catheter before ESWL			
None	62 (%93.9)	74 (%97.4)	0.313³
Yes	4 (%6.1)	2 (%2.6)	
Stone-skin distance	106.44±21.76	109.39±18.41	0.457¹

BMI: Body mass index, ESWL: Electro shock wave lithotripsy, DJ: Double J catheter,
¹Student-t test, ²ROC analysis method, ³Pearson ki-Kare test

Table 2. Univariate and multivariate analysis results

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P **value**	OR (95% CI	P **value**
Age	1.02(0.99-1.05)	0.096¹		
Gender	**0.72(0.35-1.48)**	**0.373²**		
BMI	1.03(0.94-1.12)	0.479¹		
Stone size	**1.16(1.05-1.28)**	**0.002¹**	**1.12(1.00-1.24)**	**0.033³**
Stone side	0.79(0.40-1.55)	0.503²		
Stone localization	1.15 (0.94-1.40)	0.157²		
Number of stones	**1.03(0.66-1.61)**	**0.866¹**		
Stone free	**0.26(0.12-0.56)**	**0.001²**	**0.35(0.15-0.80)**	**0.013³**
Hydronephrosis	1.22(0.79-1.87)	0.362²		
Ureter DJ catheter before ESWL	**0.41(0.07-2.36)**	**0.324²**		
Stone-skin distance	1.00(0.99-1.02)	0.380¹		

BMI: Body mass index, ESWL: Electro shock wave lithotripsy, DJ: Double J catheter,
¹Student-t test, ²Pearson ki-Kare test, ³Binary Logistic Regression Analysis

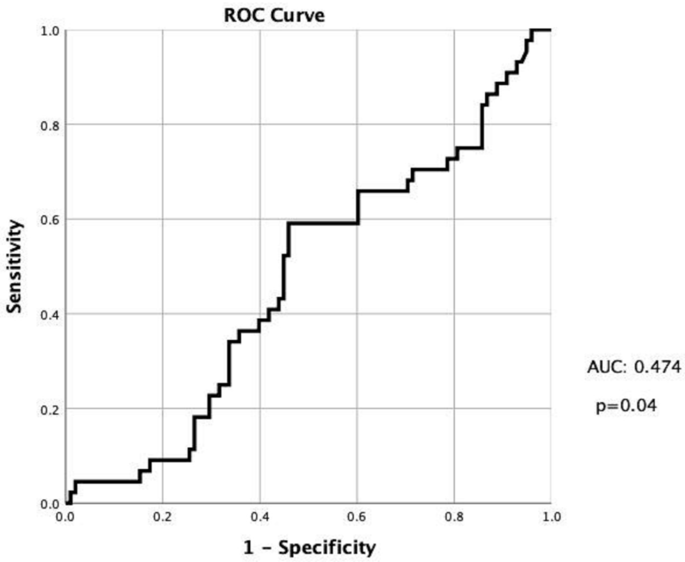

Figure.1 Univariate and Multivariate Analysis Results

Discussion

In our study, we demonstrated that there is a significant relationship between HU, showing density in urinary system stones on non-contrast CT, and the size of the stone and the stone-free rate after ESWL treatment. We found that there was a negative correlation between HU and ESWL success. It decreased in stones with a density above 991.20 HU, which we calculated as the threshold value.

ESWL has taken an important place in the treatment of urinary system stones by reducing the morbidity and mortality rates related to ESWL as a result of the development of equipment that provides new shock wave generation in parallel with the developments in technology since the 1980s. Factors affecting the success of ESWL include stone-related factors such as stone size, stone location, stone composition, degree of obstruction, skin-to-stone distance, and stone attenuation value; clinical factors such as solitary kidney, abnormal ureter anatomy and concomitant diseases, and technical factors such as lithotripter type and energy source [14]. Failure of ESWL; It occurs due to the need for more than one session, increased medical costs, and unknown complications such as acute kidney injury, bleeding and edema. In our study, we observed a negative correlation between HU, which is a stone-related factor, and ESWL success. We think that alternative treatment options should be evaluated in patients with high stone density.

In a study, the mean HU value (mean HU<857) was defined as an independent predictor of ESWL success. It has been stated that stone fragmentation is more difficult with high HU density and may require repetitive ESWL sessions [15]. In a similar study, it was shown that the success rate of ESWL is better when HU is <900 HU [16]. It has been stated that although the ESWL threshold values are different from each other, the mean HU value can be used to predict success [17]. They also revealed that the mean HU value may not be stable and causes some limitations in estimating the success of ESWL, by predicting that the differences between the curative effect of ESWL and the density components of the stones cannot be predicted [15]. In another study, it was concluded that the strongest predictive value was the localization of the stone, and the other significant variable was mean HU (mean HU <900) [18]. In another study in which a total of 50 patients were examined prospectively, it was reported that the 970 HU value was successful in predicting the success of ESWL with 100% sensitivity and 81% specificity [19]. In our study, we observed that the success of ESWL was better in stones with a density below 991.20 HU, similar to the studies in the literature.

In another study, it was shown that stone volume is the strongest predictor of ESWL outcome in urinary system stones [20]. It has been reported that ESWL treatment was successful with a rate of 90.2% for stone size <10mm and 68.6% for stone size >10 mm, also related to the number of shock waves and the number of sessions [21]. In our study, we found a statistically significant difference between the reduction in stone size and the success of ESWL. At the same time, we observed that the stone density increased in parallel with the increase in stone size, and this was a negative factor in the success of ESWL.

The most important limiting factor in our study is the lack of data on the stone component. The stone component is an important factor in the success of ESWL. Although many studies have reported that there is a relationship between HU and the stone component[18,22], there are studies [23,24] claiming the opposite. Due to the retrospective design of our study, we could not obtain data on the stone component.

Conclusion

In our study, we demonstrated that there is a relationship between ESWL, which is a very common treatment method in urinary system stone disease, and HU, which shows the density of the stone in non-contrast CT. It has been revealed that the stone size increases and the success of ESWL decreases with the increase of stone density, namely HU. Today, we recommend measuring the density of the stone in HU with non-contrast CT, which is accepted as the gold standard method in the diagnosis of urinary system stone disease. We think that the success of treatment will decrease in patients with HU>991 and alternative treatments to ESWL treatment should be kept in mind.

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
The study was approved by the Non-Interventional Clinical Research Ethics Committee (Deci-sion no: 445, Study no: 425, Date: 17.12.2021).

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