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URINARY STONE DENSITY MEASURED ON NON-CONTRAST COMPUTED TOMOGRAPHY CORRELATED WITH SUCCESS RATE BY EXTRACORPOREAL SHOCKWAVE LITHOTRIPSY TREATMENT

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Abstract

Measurements of urinary calculi density in Hounsfield Unit, stone size, site by non-contrast computed tomography (NCCT), correlated with success rate by extracorporeal shock wave lithotripsy (ESWL) outcome in complete fragmentation, fragments less than 5 mm or incomplete fragmentation. Retrospective study comprising 40 patients with urinary calculus of 10-20 mm divided into two groups (10-15 mm and 16-20 mm), with defining stone location, site and attenuation measured in Hounsfield Unit (HU), divided into three groups:1- Soft stones <6500HU; 2- Medium stones 650-1200HU; 3- Hard stones >1200HU. All treated from 4000-4500 shock waves. Success in initial stone disintegration was defined with a plain film X-ray in 5-6 weeks.

Completely disintegrated calculus was confirmed in 31 (77.5%), up to 5 mm fragments in 3 (7.5%) and unsuccessful in 6 (15.0%) patients. The percentage difference between complete disintegration *versus* up to 5 mm fragments or failed disintegration was extremely statistically significant for $p<0.05$ (Difference test, $p=0.001$). High percentage calculated after one treatment in 2- Medium stone group 650-1200HU in 15 (60%) patients, in 6 (24%) of the 1-Soft stone group, and in 3-Hard stone group in 4 (16%).

Percentage difference between the 2-Medium stone group after one ESWL treatment *versus* the 1-Soft stone group and 3-Hard stone group was statistically significant for $p<0.05$ (Difference test, $p=0.0162$). Study findings show that the attenuation value of stones can predict successful outcome of ESWL treatment for the upper urinary tract, and it has a greater impact on ESWL outcome than the stone size and site.

Keywords: non-contrast computed tomography (NCCT), Hounsfield Unit (HU), extracorporeal shockwave lithotripsy (ESWL), disintegration, attenuation

Introduction

Urolithiasis is considered the third common urological problem worldwide [1].

Diagnostic modalities- computed tomography, plain film and ultrasound (US) have become investigations of choice for managing patients with urinary stones disease in order to determine the correct diagnosis and follow-up after medical therapy or urologic interventions.

Non-contrast computed tomography (NCCT) is a diagnostic modality of choice for urinary colic to distinguish urinary stones from tumors or other pathology of the urinary tract [2-4].

NCCT can detect differences in density as low as 0.5% and is used for predicting fragility and composition of urinary stones and outcome of extracorporeal shockwave lithotripsy(ESWL) [5,6].

For most renal calculi, especially with a diameter of 10-20mm, ESWL has become the most preferred treatment modality of choice, ever since its announcement in the 1980s [7-10].

The success rate of ESWL treatment is in the range of 60-90% in different series [7-9], but the outcome of ESWL treatment depends on so many factors which include stone site, localization, stone size, stone composition, obesity, and presence of infection or obstruction [11,12].

Compared to other treatment modalities, ESWL is a non-invasive and safe procedure, but it may also cause complications such as renal hematoma, infection, flank pain, and hemorrhage [13,14].

Gupta *et al*. successfully determined the outcome of ESWL in patients with urinary stones that had density <750HU [15].

The aim of this study was to evaluate the impact of renal stone density measured in Hounsfield Unit (HU), stone size, and site over ESWL outcome and stone fragmentation.

Materials and Methods

A retrospective study comprising 40 patients between January 2019 and November 2019 was performed. The study included both genders, 19 male and 21 female patients, age ranging from 50 to 75 years.

All incoming patients in Emergency Center of the General City Hospital "8th September" in Skopje, RN Macedonia with acute renal pain were included and those who came for a regular examination.

An informed consent was obtained from all participants in this study and it was approved by the institution's ethics committee.

Every patient had renal calculi with stone size between 10-20mm, divided into two groups (from 10-15mm and 16-20mm), with the definition of stone site.

Exclusion criteria for this study were congenital renal anomalies, pregnancy, bleeding disorders, and renal failure.

All patients from the study had from one to three ESWL treatments.

Prior to ESWL treatment, NCCT scans were performed using one-point five-section slices through renal stone, viewed on soft tissue window.

NCCT was performed on Siemens Emotion 16 CT Scanner using a high-quality mode at 130kV, 85mAs, and 5mm collimation reconstructed at 1.5mm, and drawing region of interest(ROI) measuring size and mean density of stones.

Stones diameter was measured in millimeters (mm) in axial and coronal planes and they were divided into two groups: 1-Small size (10-15mm) and 2-Large size (16-20mm).

According to the site definition, renal stones were divided into 21 renal calculi in the left kidney and 19 renal calculi in the right kidney.

Attenuation of the stones was measured in Hounsfield Unit (HU) and all patients in this study were divided into three categories: 1-Soft stones <650HU; 2-Medium stones 650-1200HU; 3-Hard stones >1200HU.

All ESWL treatments were performed on a Third-generation Electromagnetic Shock Wave Siemens Lithotripter observing stone fragmentation during the treatment by fluoroscopy. In each ESWL treatment between 4000-4500 shock waves were given per patient.

For initial assessment outcome from the treatment, a plain film X-ray was performed after 5-6 weeks.

According to the outcomes of ESWL treatment, all 40 patients in this study were divided into three groups: 1-completely disintegrated calculus; 2-fragments of less than 5mm (considered clinically not significant); 3-"failure group" -stone fragmentation did not occur at all or with a significant residual fragment of 5mm or larger in size.

Unsuccessful ESWL treatment was considered after 4 months of the initial treatment on non-contrast computed tomography if there was: 1-incomplete fragmentation of renal calculus (fragment size 5mm or larger); 2-failure of fragmentation on plain film X-ray.

Chi-square test was used for statistical significance of stone-free rates and a p-value of 0.05 or less was taken as significant.

Results

In a period of eleven months 40 patients were examined in the Department of Radiology with the collaboration of the Department of Urology at the General City Hospital "8th September" in Skopje, RNM.

Most of the calculi were localized in the left kidney - in 21(52.5%)patients and in 19(47.5%)patients they were in the right kidney.

The calculi size ranged from 10-20mm.The highest number of patients had stone size between 10-15mm(small stone size) i.e. 25(62.5%) and 15 patients (37.5%) had stone size between 16-20mm(large stone size).

One treatment session with ESWL was performed in 25(62.5%) patients with calculi, two ESWL treatments were performed in 7(17.5%) patients and three ESWL treatments were performed in 8(20.0%) patients. The percentage difference between one ESWL *versus* two and three ESWL treatments wasextremely statistically significant for $p<0.05$(Difference test, $p=0.00051$).

Completely disintegrated calculus was confirmed in 31(77.5%), up to 5mm fragments in 3(7.5%) and unsuccessful in 6(15.0%)patients. The percentage difference between complete disintegration *versus* calculi disintegrated up to 5mm fragments or incomplete calculi disintegration wasextremely statistically significant for $p<0.05$(Difference test, $p=0.001$).

Table 1. Characteristics of calculi registered in the examined patients

Calculus size	
10-15 mm, N(%)	25(62.5)
16-20 mm, N(%)	15(37.5)
Calculus site	
left kidney, N(%)	21(52.5)
right kidney, N(%)	19(47.5)
Number of ESWL treatments	
one, N(%)	25(62.5)
two, N(%)	7(17.5)
three, N(%)	8(20.0)
Division by Hounsfield Unit (HU)	
<650 HU, N(%)	9(22.5)
650-1200 HU, N(%)	22(55)
>1200 HU, N(%)	9(22.5)
Disintegration	
complete	31(77.5)
fragments of less than 5mm	3(7.5)
incomplete- failure group	6(15)

The renal stone density range was between 487 HU and 1400 HU.
The results showed that out of 40 patients, in 9(22.5%) the stone density was less than 650 Hounsfield Unit(Soft stone) on non-contrast computed tomography, in 22(55%) it was between 650-1200 Hounsfield Unit(Medium Stone) and9 (22.5%) patients had density of more than 1200 Hounsfield Unit(Hard Stone).

A high percentage was calculated with one treatment and success in the 2-Medium stone group 650-1200HU in 15(60%) patients, in 6(24%) in the 1-Soft stone group, and in the 3-Hard stone group in 4(16%).The percentage difference between the 2-Medium stone group with one ESWL treatment *versus* the 1-Soft stone group and 3-Hard stone group was statistically significant for $p<0.05$(Difference test, p=0. 0162) (Table2).

In the 2-Medium stone group of density measured in Hounsfield Unit(HU)between 650-1200HU was observed in 15(68.1%) patients after one ESWL treatment, in 2(9.1%) patients after two ESWL treatments and after three treatments in 2(9.1%) patients the calculus was completely disintegrated, and in 3(13.62%) patients there was incomplete disintegration.

There was a weak correlation between calculus size and site *versus* disintegration (Pearson Chi-square: p=.243741; p=.420350).
There was a strong positive correlation between the number of ESWL treatments and the disintegration of the calculus.

The average value of HU in successful disintegration was 933.0HU, in calculus with fragments less than 5mm 925.0HU(considered clinically not significant).

The average value of an attenuation of the stone measured in the Hounsfield Unit (HU) after one successful ESWL treatment was 903.0HU.

Table2. Number of session and HU

number of sessions treatment / HU	<650	650-1200	>1200	in total
1	6	15	4	25
2	1	2	4	7
3	2	5	1	8
in total	9	22	9	40

Discussion

As the stone density on NCCT has been reported to be correlated with ESWL outcome [16], the measurement of the mean stone density by NCCT plays an important role in predicting stone disintegration.
Stones with a density >1000HU are less likely to be disintegrated [16].

CT is a non-invasive diagnostic investigation for upper urinary tract calculus, has a high sensitivity, and can be used in diagnosing of other pathologies of the urinary tract.
ESWL treatment is the most used non-invasive modality for treating renal calculi[17].
ESWL treatment outcome is measured in terms of stone fragmentation and clearance.
In this study, we proved that the calculi with density of 650HU-1200HU from 2-Medium stone category had the biggest success rate after ESWL treatment in 22(55%) patients, where in 15 patients calculi were completely disintegrated after 1 ESWL treatment, in 2 patients after two ESWL treatments calculi were completely disintegrated, in 1 patient calculi were completely disintegrated after three ESWL treatments,

in 1 patient calculi were fragmented in less than 5mm (considered clinically not significant) after 3 ESWL treatments and in 3 patients calculi were not at all fragmented after three ESWL treatments.

There was a weak correlation between calculus size and side *versus* disintegration.

The average value of HU in successful disintegration was 933.0HU.

Pareek *et al*. correlated stone clearance with calculus density in their study of 100 patients [18],and concluded that patients with residual calculi had a mean calculus density of more than 900 HU. However, they did not correlate the calculus density with fragmentation.

These results are in agreement with those of Joseph *et al*. [7] showing that the stone density has an inverse relation with ESWL success rate, and CT stone density has a positive correlation with the number of shockwaves and the number of treatments for successful fragmentation.

Our results have shown that the success of ESWL treatment is almost always guaranteed when the CT attenuation value is less than 925HU.

Conclusion

The findings of this study have shown that stone density measured on CT can predict the success rate of ESWL treatment for the upper urinary tract. There is a strong positive correlation between the number of ESWL treatments and the disintegration of the calculus.

Attenuation values of upper urinary tract stones are useful in defining the success in ESWL treatment outcome or defining an alternative treatment in patients with suspected poor outcome from ESWL.

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