1110-5712 *Vol. 22, No. 3, 2016*
Egyptian Journal of Urology *96-102*

ROLE OF NON-ENHANCED CT AS A PREDICTIVE METHOD FOR SUCCESSFUL ESWL OUTCOME FOR URINARY CALCULI

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Objectives: To evaluate the role of different stones criteria in non-contrast multi-detector computed tomography (MDCT) in predicting successful outcome following extracorporeal shock wave lithotripsy (ESWL) for urinary calculi.

Methods: 120 patients who underwent ESWL as a primary treatment for renal or ureteric calculi were included from May 2014 to July 2015. Different criteria of stones were assessed by MDCT before ESWL including location, size, Hounsfield unit density, skin-to-stone distance. Patients were followed up for 3 months to assess stone clearance. The effect of different Ct criteria on stone clearance was analysed using Chi-Square test or Fisher-Exact tests. ROC (receiver operating characteristic) curve was used to determine the cut-off for stone density.

Results: Stone size was a statistically significant factor for ESWL success with a stone free rate > 95% for renal stones < 2 cm ($p < 0.001$). The mean stone density for cases with ESWL success was 662.56 ± 281.3 HU while it was 1097.54 ± 186.3 HU for cases with failed ESWL. The efficiency of ESWL was reduced when SSD was more than 10 cm with a stone free rate < 82%.

Conclusion: Stone size, density, site and SSD affect ESWL outcome which is improved with shorter SSD, stones < 2 cm and density below 1059 HU. MDCT provides accurate estimation of these factors.

Keywords: Non-contrast computed tomography, Shock wave lithotripsy, Urinary calculi.

INTRODUCTION

The prevalence of urinary stones has increased around the world in the last years. Many people are affected by urolithiasis throughout their life with estimated recurrence rate 50% within 5-10 years and 75% within 20 years. Since its introduction by Chaussy et al 1980, Extracorporeal schockwave lithotripsy (ESWL) has improved dramatically the management of urolithiasis with continually developing new devices with higher technology and low cost.[1] ESWL has become the preferred treatment for renal calculi of less than 2 cm in diameter and the first-line treatment for upper ureteric stones for the past 20 years.[2] ESWL has many advantages over other modalities of stone treatment. It is a minimally invasive outpatient procedure mostly not requiring deep anaesthesia.

The outcome of stone clearance after ESWL is strongly related to stone disintegration and clearance of the fragments. Stone disintegration is affected by several factors, such as stone related factors including the size, composition and number, patient-related factors including the age and obesity, the operator's experience and the type of lithotripter.[3,4]

Non-contrast multi-detector computed tomography (MDCT) has become the investigation of choice for the assessment of acute loin pain. It is recognized as the most accurate method for detection of calculi in the urinary tract with a reported sensitivity of 94% and a specificity of 97%.[5,6] MDCT obtains thin collimated data of the urinary tract during single breath hold and provides higher spatial resolution compared with single detector computed tomography. Its ability to provide reconstructions in the coronal, sagittal and oblique planes makes it accurate in the localization of calculi and various urinary tract pathologies.[7] Our study rationale was to evaluate the different stones criteria in MDCT for prediction of the successful ESWL outcome for urinary calculi.

PATIENTS AND METHODS

This study included 120 patients between May 2014 and July 2015 in the ESWL unit, Benha University Hospital. All eligible patients signed an informed consent and the study was approved by the Research Ethics Committee, Faculty of Medicine, Benha University.

Inclusion criteria:

Patients with solitary renal or ureteric stones who were managed with ESWL as an initial treatment or after unsuccessful medical expulsive therapy were included. We included these patients if the maximal stone diameter was 0.5-2.5 cm for renal stones and 0.5-1.5 cm for ureteric stones. We excluded children (< 18 years old) and patients with lower ureteric stones, active urinary tract infection (UTI), renal or ureteric anomalies, renal insufficiency, previously failed ESWL, distal urinary tract obstruction, uncorrected coagulopathies, pregnancy, renal artery or aortic aneurysms, severe skeletal malformations and morbid obesity.

Pre ESWL evaluation:

All patients were subjected to clinical, laboratory and radiological evaluation preoperatively. ***CT* protocol:**

All patients underwent MDCT for assessment of stone size, density and skin to stone distance (SSD) using 16-channel multi-detector CT scanner (Toshiba Activion™ 16 Multislice CT, Tokyo, Japan). The imaging data were reviewed with 2-D and 3-D capability. Reconstructed axial images were generated from the volumetric source data in the different phases. Reformatted coronal images (2 mm thickness, 2 mm increment with no overlaps) were created from the isotropic imaging data. Three-dimensional reformation was generated using maximum intensity projection, average intensity projection and volume-rendering technique. SSD was calculated by measuring three distances from the stone to the skin measuring the average of these values at 0 º, 45 º and 90 º (**Fig. 1**).

ESWL Technique:

Patients were prepared by fasting the night before the procedure. Intestine was prepared by enemas. Light anaesthesia (Midazolam, propofol infusion and fentanyl) was used for all patients. ESWL was done using mobile electro hydraulic spark gap lithotripter (MT-2 RX, BMA for design and industry, Giza, Egypt) using fluoroscopy for stone localization. Localization of radiolucent stones was achieved after a bolus IV injection of a contrast medium 1 mL/kg.

The focus phantom was adjusted to be in the cross hair on the imaging in vertical position and oblique position of C-arm (+ 15º and -15º). We started by low energy (6 Kv) then gradually increased the power until reaching (22 Kv). The stone localization and focus was ensured by frequent images. The upper limit of applied shock waves per session was 3000 for renal stones and 4000 for ureteric stones. The rate was 120 shocks per minute. The patients were discharged in the same day.

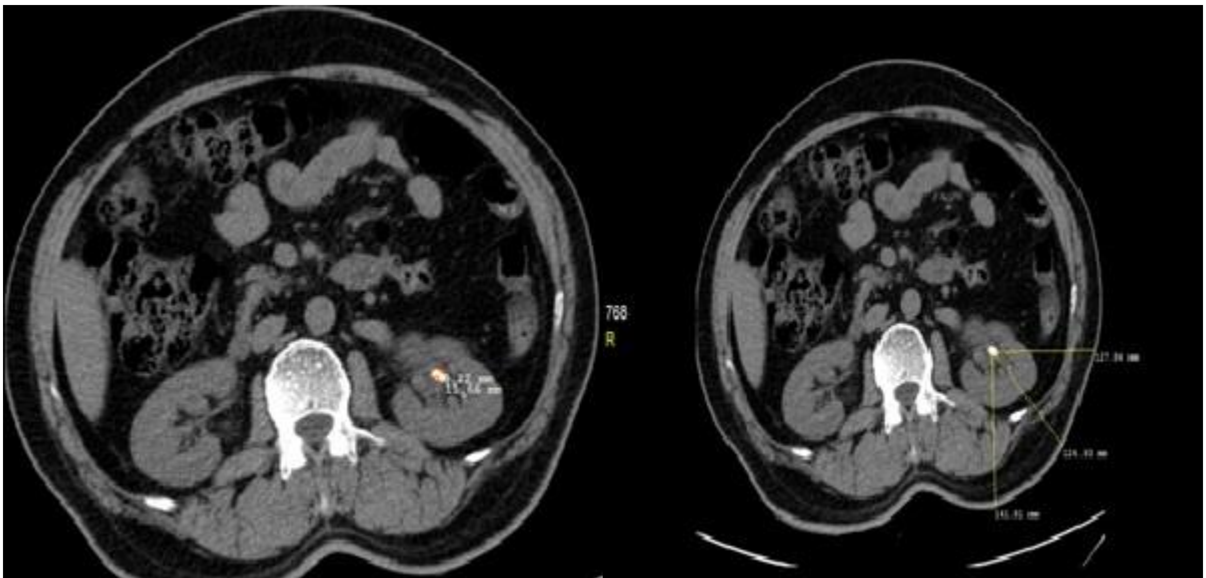


Fig. 1: Non contrast MDCT of the abdomen & pelvis showing (a) Hyper-dense stone in middle calyx measuring 11 mm with 768 HU and average SSD of 13.3cm.

Post ESWL follow up:

All patients were followed up in the outpatient clinic by KUB two weeks after ESWL. MDCT was used for radiolucent stones. The ESWL sessions were repeated if required up to 3 sessions. The final outcome was assessed after 3 months after all ESWL sessions. Success was defined as the absence of significant residual fragments ≥ 4 mm. Patients with asymptomatic residual gravels < 4 mm were scheduled for regular follow-up every 6 months.

Statistical analysis:

Data were analysed using the computer program SPSS (Statistical package for social science) version 17.0 using Chi-Square and Fisher-Exact tests. ROC (receiver operating characteristic) curve was used to determine the cut-off for stone density.

RESULTS

This study included 120 (80 males; 40 females) patients. Twelve patients had ureteral stones more than 1 cm while 10 patients had renal stones more than 2 cm. These patients with relatively larger stone size were non-obese with a low density for their stones which increased their chance for stone fragmentation. The mean age was 39.29 ± 11.44 (range 19 - 65) years old. Patients with BMI 30 or less accounted for the majority (69.2%). **Table (1)** demonstrates different stones criteria.

No major complications were encountered. The reported complications were mild hematuria (9 cases), skin ecchymosis (5 cases), acute pyelonephritis (2 cases) and steinstrasse (3 cases). The steinstrasse occurred in 3 patients with renal stones. It was managed with ureteroscopy and double-J ureteric insertion.

The overall success rate of ESWL was 89.2%. The best success was reported in the renal pelvis (95.5%; $p = 0.005$). Stone size was statistically significant factor for ESWL success. The smaller stone size was found to increase the success rate while the large stone size required more ESWL sessions with more failure (60% of stones > 2 cm). The mean stone density was 587.77 ± 264.91 HU for renal stones and 899.04 ± 262.85 HU for ureteric stones.

Decreased stone density was found to increase the success rate and to decrease the number of sessions. The mean stone density was 662.56 ± 281.36 for successful ESWL cases and 1097.54 ± 186.30 for failed ESWL cases ($p < 0.001$). SSD had a major influence on ESWL success as 94.4% of cases with SSD less than 10 cm were successful after 3 sessions (43.7% after the first session) (**Table 2**).

ROC (receiver operating characteristic) curve showed that a stone density of 1059 would predict the successful outcome with 88.8% specificity, 76.9% sensitivity, 96.9% positive predictive value and 45.5% negative predictive value with an accuracy of 87.5 % (**Fig. 2**).

Table (1): Stone criteria in the whole series

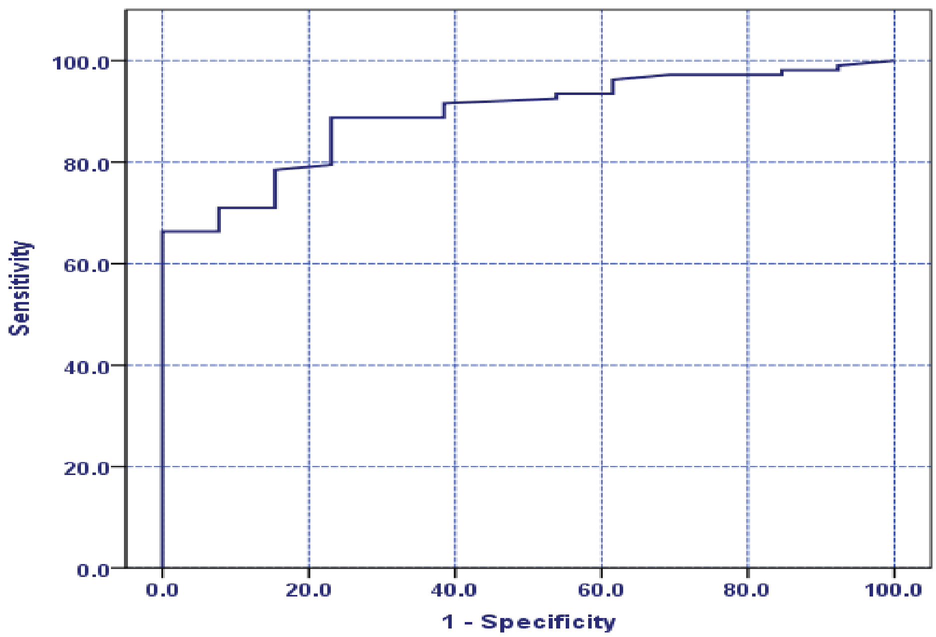
Variable	NO of patients (%)
Stone Site	
Kidney	
Upper calyx	8 (6.7%)
Middle calyx	15 (12.5%)
Lower calyx	28 (23.3%)
Renal pelvis	22 (18.3%)
Ureter	
Upper third	25 (20.8%)
Middle third	22 (18.3%)
Stone Size (mm)	
Kidney	
5-10	18 (15%)
11-20	45 (37.5%)
21-25	10 (8.3%)
Ureter	
5-10	35 (29.2%)
11-15	12 (10%)
Stone Density (HU)	
< 500	35 (29.2%)
501-1000	60 (50%)
> 1000	25 (20.8%)
SSD (cm)	
< 10	71 (59.2%)
> 10	49 (40.8%)

SSD: skin to stone distance

Table (2): Relation between Stone parameters and ESWL outcome

		1st Session	2nd session	3rd session	Over all Success	Failed	*P*
Size (mm)	Kidney						
	5-10	13 (72.2%)	5 (27.8%)	-	18 (100 %)	-	< 0.001 *
	11-20	15 (33.3%)	19 (42.2%)	9 (20%)	43 (95.5%)	2 (4.5%)	
	21-25	-	2 (20%)	2 (20%)	4 (40 %)	6 (60 %)	
	Ureter						
	5-10	17 (48.6%)	12 (34.3%)	4 (11.4%)	33(94.3 %)	2 (5.7%)	0.005 *
	11-15	2 (16.7%)	6 (50 %)	1 (8.3 %)	9 (75 %)	3 (25 %)	
	Total	47 (39.2%)	44 (36.7%)	16 (13.3%)	107 (89.2%)	13 (10.8%)	
Site	Kidney						
	Renal pelvis	15	5	1	21 (95.5%)	1 (4.5%)	0.005 *
	Upper calyx	6	1	-	7 (87.5%)	1 (12.5%)	
	Middle calyx	10	3	-	13 (86.6%)	2 (13.4%)	
	Lower calyx	13	7	4	24 (85%)	4 (15%)	
	Ureter						
	Upper ureter	18	4	1	23 (92%)	2 (8%)	
	Middle ureter	14	3	2	19 (86.3%)	3 (13.7%)	
Density (HU)	≤ 500	30 (85.7%)	5 (14.3%)	-	35 (100%)	-	< 0.001 *
	501-1000	17 (28.3%)	30 (50%)	10 (16.7%)	57 (95%)	3 (5%)	
	> 1000	-	9 (36 %)	6 (24%)	15 (60%)	10 (40%)	
	Total	47 (39.2%)	44 (36.7%)	16 (13.3%)	107 (89.2 %)	13 (10.8%)	
SSD (cm)	≤ 10	31 (43.7 %)	27 (38%)	9 (12.7%)	67 (94.4%)	4 (5.6 %)	0.027 *
	> 10	16 (32.6 %)	17 (34.7%)	7 (14.3%)	40 (81.6%)	9 (18.4 %)	
	Total	47 (39.2%)	44 (36.7%)	16 (13.3%)	107 (89.2 %)	13 (10.8%)	

* Significant. SSD: skin to stone distance



	Area under the curve (95%CI)	Cutoff value	Sensitivity	Specificity	PPV	NPV	Accuracy
Density	**87.3% (82.4% -96.1%)**	**1059.50**	**88.8%**	**76.9%**	**96.9%**	**45.5%**	**87.5%**

Fig. 2: ROC curve for HU predicting success and failure

DISCUSSION

Management of urinary calculi have changed in recent decades towards less invasive interventions including ESWL, with clearance rate ranging from 45% to 95%. Stone disintegration is strongly affected by many factors including stone composition, stone burden, type of lithotripter, operator experience and patient factors including BMI.[8]

MDCT has been proven to be the gold standard for diagnosing patients with upper tract calculi due to its high sensitivity and specificity with delineating the number, size, site, density and SSD of any urinary calculi with overall accuracy of 96%-97%.[8] These factors affect treatment selection. Proper patient selection is very important to improve SWL outcomes. Dretler and Spencer were the first who suggested that outcome of ESWL is affected by CT attenuation values of calculi. Several investigators have shown that SWL is more likely to fail in patients with renal calculi more than 750-1000 HU and those patients should be considered for other treatment modalities.[9]

This study showed that males were more affected for renal stones than women and this is in agreement with Tanaka and his colleagues.[10] Kidneys were more in risk for urinary stones than ureter; kidney stones represent about 60.8 % of all patients while ureteric stones represent about 39.2 % of all patients. This is almost due to ureteric peristalsis that helps in spontaneous passage of small ureteric stones. Papadoukakis and his colleagues reported that spontaneous passage of ureteric stones less than 4 mm occurs in about 80%.[11]

The univariate analysis showed that stone size is a statistically significant factor in ESWL success and this copes with the results of Wang and Weld and associates.[12,13] About 28 patients presented with lower calyceal stone. The reported success in these patients was the lowest. This may be due to effect of gravity that decreases spontaneous stone clearance. This is similar to the results reported in the literature. [14, 15]

To increase the success rate of ESWL, a proper selection of patients should be done. Larger size of renal or ureteric stones will increase the required sessions with more rate of failure. Renal stones less than 2 cm and ureteric stones less than 1 cm were more suitable for ESWL and gave good result. This is in agreement with many studies. [2,10,15-17]

A lower calyceal stone had the lowest stone free rate (85%) after ESWL compared to stones in other location with the highest success rate in renal pelvic stones group (95%). This makes an appreciable difference between stone fragmentation by ESWL and total elimination of the resultant fragments. The problem in lower pole stones is fragment retention rather than stone disintegration. One important factor that predicts the success of ESWL in lower pole stones is the calyceal anatomy. The lower pole infundibular (IF) length, infundibular width (IW) and the infundibulopelvic (IP) angle are determining factors.[18]

We noticed that a less density of the stone would increase the success rate of ESWL with less ESWL sessions. Our study reported that mean stone density was 662.56 ± 281.3 for successful cases and 1097.54 ± 186.3 for failed cases. A stone with a density less than 500 HU needs usually one session while a stone with a density ranging from 500 to 1000 HU needs usually two sessions. This finding was comparable to the findings in other studies. [2,14-16] On the other hand, density of the stone was not reported as a predictor for success on other studies. [19, 20] Patel and his colleagues reported that the mean density for patients with residual fragments was slightly higher than those of stone free patients (738 vs. 779 HU) without significant difference.[19] Other studies reported that stone attenuation values was ranging from 587 to 837 HU in successful cases and from 910 to 1225 HU in failed cases.[21,22]

The efficiency of ESWL was significantly reduced when SSD was more than 10 cm. A combination between SSD and other factors are useful to predict the outcome of ESWL.[19] Pareek et al reported that SSD greater than 10 cm on MDCT was a predictor of ESWL failure ($p < 0.01$).[19] Perks and his colleagues observed that a SSD of less than 9 cm and a stone density of less than 900 HU were good predictors of ESWL success ($p < 0.01$).[22] In 2012, Choi et al reported that BMI and SSD are certainly interrelated, but body fat distribution varies between gender and race.[3] BMI was found as a significant predictor of success.[19, 23] We think that the effect of BMI is related probably to the distance of the stone from the skin, which reflects the shockwave path in the body. Therefore, SSD is probably a more direct measurement of the effect of body build on ESWL outcome than BMI.

According to our study, different MDCT stones criteria can play an important role in predicting success of ESWL. However, the number of patients is relatively small especially in the subgroups. Our study was limited also by depending on only univariate analysis in evaluation of the stone free rate.

CONCLUSION

Stone size, density, site and SSD are significant predicting factors for ESWL success. A combination between these CT criteria will help in the proper treatment selection with a higher success especially with shorter SSD (< 10 cm), stones < 2 cm and density below 1059 HU. MDCT provides accurate estimation of these factors.

ACKNOWLEDGEMENTS

The authors are grateful to the residents in urology (Dr. Mohamed Kadry and Dr. Yehia El-Kerdasy) and radiology departments (Dr. Mohamed Yousef), Benha University Hospital, Benha, Egypt; for their help in patients' recruitment and follow up

ABBREVIATIONS

BMI: body mass index
ESWL: extracorporeal schockwave lithotripsy
KUB: Kidney, ureter and bladder X-ray
MDCT: multi-detector computed tomography
SSD: stone to skin distance

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