Central stone density measured by computed tomography in Hounsfield units for predicting stone outcome after extracorporeal shockwave lithotripsy

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Received 17 November 2020
Revised 17 November 2020
Accepted 18 November 2020
Published 31 March 2022

Journal of Current Medical Research and Practice
2022, 7:80–84

Background
The density of the urinary stone is a determiner of extracorporeal shockwave lithotripsy (ESWL). It could be determined by computed tomographic (CT) measurement in Hounsfield units. In this study, we tried to establish an accurate way of stone density measurement by computed tomographic.

Patients and methods
In this prospective study, 18 patients with renal or upper ureteric stones were scheduled to perform ESWL. Stone densities were measured from different parts: central and peripheral measurements as well as stone size, location, and skin-to-stone distance.

Results
The patients' mean age was 40.4 ± 16.5 years. A total of 14 (77.8%) patients were male and four (22.2%) patients were female. The central density showed a statistically significant difference between the two groups with higher densities in the failed group ($P = 0.001$). The analysis proved that center density less than 935 HU predicts the successful outcome with a sensitivity of 71.4%, a specificity of 90.9%, a positive predictive value of 83.3%, a negative predictive value of 83.3%, and accuracy of 81.8%.

Conclusion
Central stone density is a significant predictor of the outcome of ESWL as higher density stone respond poorly to ESWL than low-density stone.

Keywords:
computed tomography, extracorporeal shockwave lithotripsy, Hounsfield units, stone density

J Curr Med Res Pract 7:80–84

2357-0121

Background

Urinary stones are a common disease affecting one in 11 people [1]. Their clinical presentation varies from being silent to severe loin pain owing to urinary obstruction. Bilateral ureteric obstruction may lead to chronic renal insufficiency if not promptly treated [2].

The management of urinary stones includes conservative medical treatment mainly for small stones and other treatment options including ureteroscopy, extracorporeal shockwave lithotripsy (ESWL), and percutaneous nephrolithotomy. ESWL has many advantages of being a noninvasive treatment [3]. Nonenhanced computed tomography (NECT) is the reference standard in the diagnosis of urinary stone and provides quantitative data about stone density that affects the outcome of ESWL [4].

The role of NECT in predicting ESWL outcome is widely investigated, including the following factors affecting stone outcome after ESWL session: size, mean density, and skin-to-stone distance (SSD) [4–6]. In this study, we aimed to investigate these factors and correlate them with a post-ESWL stone-free state.

Patients and methods

From January 2018 till April 2019, we prospectively examined 18 patients with renal pelvic or upper ureteric stones scheduled to perform ESWL. They had presented to the Urology Clinic at the Department of Urology with a history of renal colic, hematuria, and burning micturition, and then the patient was referred by the physician to the Radiology Department for performing CT kidney, ureter, and urinary bladder scan, as it is more accurate than plain radiograph and abdominal ultrasound. Patients signed informed consent. IRB of Assiut Faculty of Medicine approved the study (17101216).

We included adult patients older than 20 years, with stone size up to 25 mm for renal pelvic stones and up to 15 mm for upper ureteric stones. We excluded patients with febrile urinary tract infection, bleeding diathesis, pregnancy, severe skeletal malformation, and severe obesity.

They underwent NECT of the urinary system. CT kidney, ureter, and urinary bladders were done on supine patients by helical scan acquisition with a rotation time of 1 s, kV of 120, and mA of 300 on CT machine (Bright speed 16 slices; General Electric Company, [Milwaukee, Wisconsin, USA]). Axial images were acquired with 1.2-mm slice thickness [to measure the highest mean stone density by Hounsfield unit (HU) and size of the stone] at a 2-mm continuous increment. The density was measured in crosshair (point) rather than a region of interest. The stone density was measured by different measurements taken from the center and the peripheral one-third at anterior, posterior, medial, lateral, superior, and inferior aspects of each stone, considering more than 1 mm from the stone edge for peripheral densities to avoid partial volume effect. We reported the highest values for each measurement. Moreover, the average density of the whole measurements was calculated from the previous measurements (Fig. 1).

Patients were prepared the day before ESWL by enema, fasting about 8 h to avoid gaseous distention, and by laboratory coagulation tests. ESWL sessions were performed without sedatives on an outpatient basis with a Dornier MedTech lithotripter. Patients were laid at a supine position and delivered 3000 shocks at the session through one hour by a rate of 60–90 shocks per minute to each stone using ultrasound waves for radiolucent stones and plain radiograph for radio-opaque stones.

Follow-up was done at 3 weeks after the session with abdominal radiograph film and ultrasound. If there were significant fragments, the second session of ESWL would be done. If only insignificant fragments were found, the patient received medical treatment and then evaluated after 4 weeks. The end point was the complete passage of all stone fragments or after 3 months from the last ESWL session. ESWL success was defined as no residual stones or remaining stone fragments of less than 4 mm (clinically insignificant residuals). We reported patient age, sex, stone size, location, and density in HU, as well as SSD (Fig. 2).

Statistical analysis

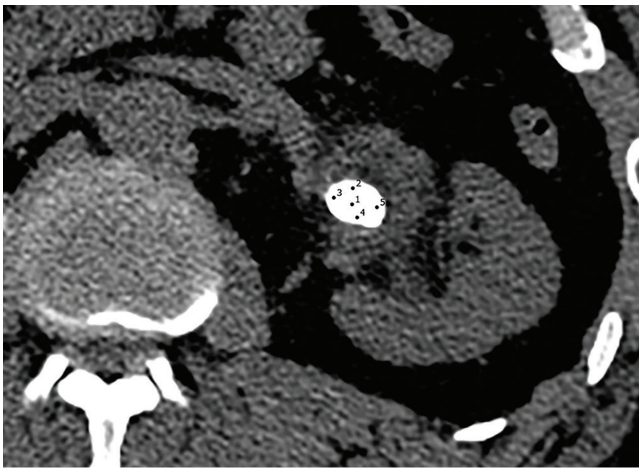
All statistical tests were performed using IBM-SPSS 23.0 (IBM-SPSS Inc., Chicago, Illinois, USA) and MedCalc, version 18.2.1 ((MedCalc Software, Mariakerke, Belgium). Continuous data were expressed in mean and SD, whereas categorical data were expressed in count and percentage. The χ^2 test compared the frequencies among categorical groups. For continuous variables, independent *t* test analysis was carried out if data were normally distributed, whereas the Mann–Whitney *U* test was calculated if data were not normally distributed. Univariate analyses were used to test significant predictors. Receiver operating characteristic curve was used to depict the diagnostic performance of significant predictors, analyzed as the area under the curve. A significant *P* value was considered when it is equal to or less than 0.05.

Results

Study population

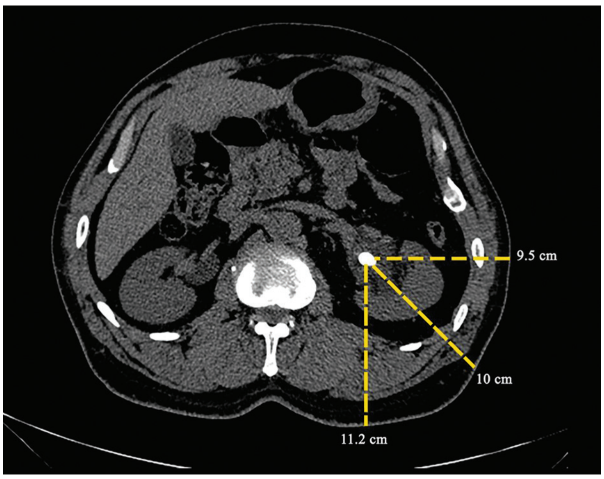
A total of 18 patients who presented with renal pelvic or upper ureteric stones were included in the statistical analysis in the prospective study. The mean age of the recruited patients was 40.4 ± 16.5 years. A total of 14 (77.8%) patients were males and four (22.2%) patients were females.

Figure 1



Multiple measurements were taken: (a) central density (1094 HU), (b) anterior density (787 HU), (c) medial density (821 HU), (d) posterior density (782 HU), (e) lateral density (842 HU).

Figure 2



Skin-stone distance was measured as an average of three measurements from skin-to-stone; at 0°, 45°, and 90° on axial non-contrast CT. CT, computed tomographic.

Stone characteristics

As shown in Table 1, there was no statistically significant difference between both groups regarding the stone size or location. Regarding the multiple CT density measurements, the central density showed a statistically significant difference between the two groups with higher densities in the failed group (P = 0.001), and to a lesser extent, the average density (P = 0.046) (Figs. 3 and 4).

Regression analysis to detect predictors of poor outcome

The regression test was performed to find predictors of successful ESWL. Only central density was significantly associated with a higher probability of successful ESWL (odds ratio = 0.995, P = 0.021) (Table 2). None of the other factors showed statistically significant predictive value.

Receiver operator characteristics curve of significant predictors

The analysis proved that center density less than 935 HU predicts the successful outcome with sensitivity of 71.4%, specificity of 90.9%, positive predictive value of 83.3%, negative predictive value of 83.3%, and accuracy of 81.8% (Figs. 5 and 6 and Table 3).

Discussion

ESWL is an emerging minimally invasive treatment modality for renal pelvic and ureteric stones, beginning since 1980 used in selected cases [7]. ESWL needs to be carefully selected in the background of favorable outcome criteria, otherwise unnecessarily exposing to the complication of the technique [8]. In this study, we stated the failed outcome of ESWL as the presence of significant residual fragments larger than 4 mm, as used by other authors [9].

In this study, we aimed at investigating the different predictors of ESWL success using CT findings. We studied stone size, site, density, and SSD. Regarding the stone size, we found nearly equal sizes in both groups, with no statistically significant difference. However, many other previous works encountered the size relevance on the ESWL outcome, and the smaller stones had better outcomes [3,4]. Our study failed to demonstrate that this may be attributed to the small sample size. Regarding the stone renal pelvic or ureteric location, we did not find any statistical

Table 1 Comparison between successful and failed cases

Variables	Successful (n=11)	Failed (n=7)	P
Stone size	11.83±4.3	10.4±5.6	0.548
Stone site			
Renal pelvic	9 (81.8)	6 (85.7)	0.674
Ureteric	2 (18.2)	1 (14.3)	
Anterior density	524.2±163.8	735.6±312.7	0.077
Posterior density	602.64±268.8	662.86±159.3	0.602
Lateral density	529.8±306.1	591.0±248.4	0.664
Medial density	513.6±212.6	684.1±244.8	0.137
Superior density	465.0±167.7	673.6±289.6	0.069
Inferior density	601.6±263.4	665.71±132.4	0.561
Central density	545.0±281.4	1102.3±323.9	0.001
Average density	537.7±178.3	730.7±195.5	0.046
Skin-to-stone distance	10.47±1.6	9.1±1.6	0.258

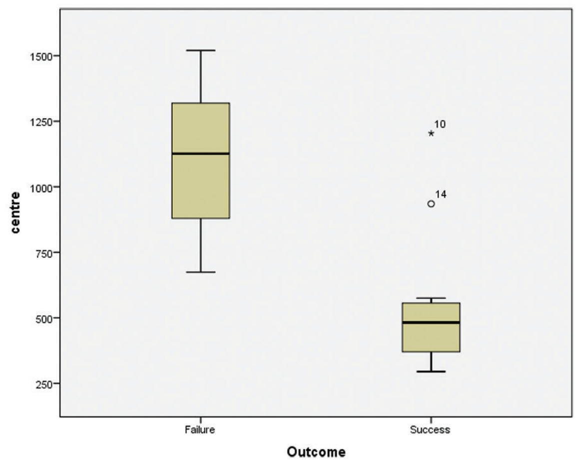
Data are presented as mean±SD and n (%).

Table 2 Predictors of successful extracorporeal shockwave lithotripsy: univariate regression analysis

	Odds ratio	95% CI	P
Central density	0.995	0.990-0.999	0.021
Average density	0.994	0.989-1.000	0.065

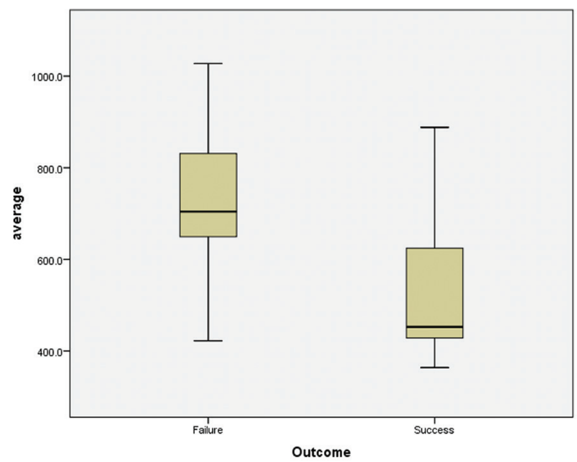
CI, confidence interval.

Figure 3



Boxplot of central density in successful and failed cases.

Figure 4



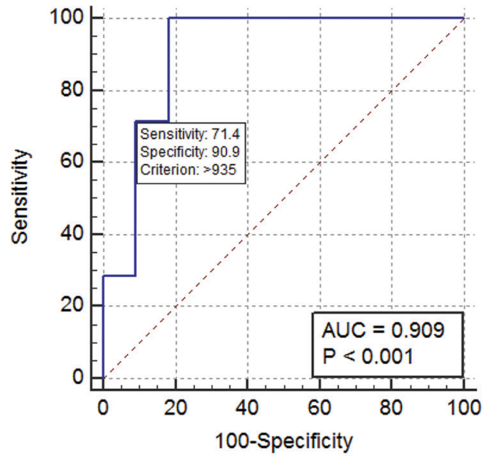
Boxplot of average density in successful and failed cases.

Table 3 Goodness criteria of computed tomographic predictors of successful extracorporeal shockwave lithotripsy

	Cut-off value	Sensitivity (%)	Specificity (%)	PPV	NPV	Accuracy	AUC
Central density	<935	71.4	90.9	83.3	83.3	81.8	90.9
Average density	<704	42.9	72.7	50	66.7	58.4	75.3

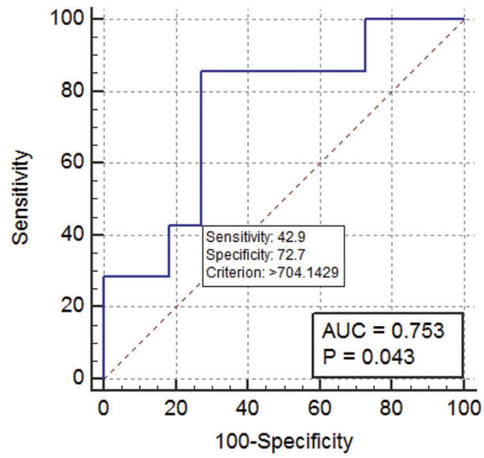
AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive values.

Figure 5



ROC curve of central density. ROC, receiver operating characteristic.

Figure 6



ROC curve of average density. ROC, receiver operating characteristic.

difference between both groups. A study by Shinde *et al.*[10] concluded the same finding, whereas another study by Weld *et al.*[11] showed the importance of the intrarenal location of the stone, as they included only intrarenal stone and found that stones at the renal pelvis or pelvi-ureteric junction are passed better than calyceal stones. Upper and middle calyceal stones are cleared better than lower ones. Further studies should investigate renal and ureteric locations separately.

The primary study's purpose is to study the relation between stone density and ESWL results. This issue is widely investigated through literature, and there is still no consensus.

Many previous studies show the prognostic value of stone density with a better outcome for smaller stones [6,10,12,13]. This discrepancy between our results and the literature may be attributed to the small sample size, nonhomogenous sample, and the way of measuring stone density.

The only significant variable was the central density, where density in the successful ESWL group was 545 HU, whereas in the failed ESWL group was 1102 HU, with a *P* value of 0.001. Moreover, the average densities were 537 and 730 HU in success and failure groups, respectively, with a *P* value of 0.046. The ROC analysis suggested cutoff values above it, failed ESWL would be predicted, that is, 935 HU for central density and 704 HU for average density, with higher sensitivity, specificity, predictive values, and accuracy for central density. This can be supported by the evidence that the center of the stone is formed first as a nucleus upon which the peripheral parts are deposited, thus having a higher density, and better-predicting stone response to ESWL.

Our cutoff values were near those of previous studies. Wang *et al.*[5] found that stone density more than 900 HU was a significant predictor of poor ESWL outcome. Other authors recommended different stone density thresholds, namely more than 1000 HU[14] and more than 750 HU [15].

We found no difference between the groups regarding SSD, with *P* value of 0.258. Previous studies conducted by Gonulalan *et al.* [16] and Cho *et al.* [6] agreed with our results. However, many other studies revealed the opposite [10,17]. This difference may be related to different patient demographics.

A strength of this study is the development of a stone density method to refine the way of density measurement using crosshair (point), thus avoiding partial volume effect encountered when using region of interest. Moreover, our study was prospective; thus, we could collect enough clinical, radiological data, as well as follow-up results.

Our study had several limitations, given that the sample size is small, especially for subgroup analysis. Moreover, we did not assess the interobserver and intraobserver variability in measuring stone diameters and densities.

CT is considered a precise method for urinary stone detection and ESWL outcome prediction. Central stone density is a promising characterizing parameter that may help in filtering unsuitable patients for ESWL.

Conclusion

ESWL is an important minimally invasive therapeutic tool used in the treatment of renal stones. ESWL needs to be carefully selected in the background of favorable outcome criteria, otherwise unnecessarily exposing exposure to the complication of the technique. CT is a beneficial tool in filtering patients and predicting stone-free state after ESWL by assessing the central stone density.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Alelign T, Petros B. Kidney stone disease: an update on current concepts. Adv Urol 2018; 2018:3068365.

2 Rule AD, Krambeck AE, Lieske JC. Chronic kidney disease in kidney stone formers. Clin J Am Soc Nephrol 2011; 6:2069–2075.

3 Lim KH, Jung JH, Kwon JH, Lee YS, Bae J, Cho MC, *et al.* Can stone density on plain radiography predict the outcome of extracorporeal shockwave lithotripsy for ureteral stones?. Korean J Urol 2015; 56:56–62.

4 Lee HY, Yang YHH, Lee YLL, Shen JTT, Jang MYY, Shih PMC, *et al.* Noncontrast computed tomography factors that predict the renal stone outcome after shock wave lithotripsy. Clin Imaging 2015; 39:845–850.

5 Wang LJ, Wong YC, Chuang CK, Chu SH, Chen CS, See LC, *et al.* Predictions of outcomes of renal stones after extracorporeal shock wave lithotripsy from stone characteristics determined by unenhanced helical computed tomography: a multivariate analysis. Eur Radiol 2005; 15:2238–2243.

6 Cho KS, Jung HD, Ham WS, Chung DY, Kang YJ, Jang WS, *et al.* Optimal skin-to-stone distance is a positive predictor for successful outcomes in upper ureter calculi following extracorporeal shock wave lithotripsy: a bayesian model averaging approach. PLoS One 2015; 10:e0144912.

7 Shrestha D, Adhikari DB, Shrestha A. Extracorporeal shock wave lithotripsy in the management of upper urinary tract stone: a single institute experience. Med J Pokhara Acad Health Sci 2018; 1:3.

8 Reynolds LF, Kroczak T, Pace KT. Indications and contraindications for shock wave lithotripsy and how to improve outcomes. Asian J Urol 2018; 5:256–263.

9 Joseph P, Mandal AK, Singh SK, Mandal P, Sankhwar SN, Sharma SK. Computerized tomography attenuation value of renal calculus: Can it predict successful fragmentation of the calculus by extracorporeal shock wave lithotripsy? A preliminary study. J Urol 2002; 167:1968–1971.

10 Shinde S, Al Balushi Y, Hossny M, Jose S, Al Busaidy S. Factors affecting the outcome of extracorporeal shockwave lithotripsy in urinary stone treatment. Oman Med J 2018; 33:209–217.

11 Weld KJ, Montiglio C, Morris MS, Bush AC, Cespedes RD. Shock wave lithotripsy success for renal stones based on patient and stone computed tomography characteristics. Urology 2007; 70:1043–1047.

12 Ouzaid I, Al-qahtani S, Dominique S, Hupertan V, Fernandez P, Hermieu JF, *et al.* A 970 Hounsfield units (HU) threshold of kidney stone density on non-contrast computed tomography (NCCT) improves patients' selection for extracorporeal shockwave lithotripsy (ESWL): evidence from a prospective study. BJU Int 2012; 110 (11 Part B):E438–E442.

13 Abdelaziz H, Elabiad Y, Aderrouj I, Janane A, Ghadouane M, Ameur A, *et al.* The usefulness of stone density and patient stoutness in predicting extracorporeal shock wave efficiency: results in a North African ethnic group. Can Urol Assoc J 2014; 8:E567–E569.

14 El-Nahas AR, El-Assmy AM, Madbouly K, Sheir KZ. Predictors of clinical significance of residual fragments after extracorporeal shockwave lithotripsy for renal stones. J Endourol 2006; 20:870–874.

15 Gupta NP, Ansari MS, Kesarvani P, Kapoor A, Mukhopadhyay S Role of computed tomography with no contrast medium enhancement in predicting the outcome of extracorporeal shock wave lithotripsy for urinary calculi. BJU Int 2005; 95:1285–1288.

16 Gonulalan U, Akand M, Coban G, Cicek T, Kosan M, Goktas S, *et al.* Skin-to-stone distance has no impact on outcomes of percutaneous nephrolithotomy. Urol Int 2014; 94: 444–448.

17 Foda K, Abdeldaeim H, Youssif M, Assem A. Calculating the number of shock waves, expulsion time, and optimum stone parameters based on noncontrast computerized tomography characteristics. Urology 2013; 82:1026–1031.