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Original Article

Stone Attenuation and Skin-to-Stone Distance on Computed Tomography Predict the Performance of Shock Wave Lithotripsy in Renal Stone Disease

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Abstract

Shock wave lithotripsy (SWL) is a noninvasive, safe, and effective method of treating renal stones. The overall stone-free rate (SFR) varies greatly depending on stone location and size. Failure to disintegrate the stone results in unnecessary exposure to shock waves and radiation, as well as the need for alternative treatment procedures, which raises medical costs. Prior to treatment, it is critical to identify predictors of treatment success or failure in patients who are potential candidates for SWL. The purpose of this study is to determine if stone attenuation and skin-to-stone distance in computed tomography have the ability to predict the success of shock wave lithotripsy in renal stone disease. This prospective observational study was carried out in the Department of Urology at Bangabandhu Sheikh Mujib Medical University (BSMMU) in collaboration with the Department of Radiology and Imaging from January to December 2023. Patients with renal stones who were scheduled for shock wave lithotripsy (SWL) were enrolled in this study after obtaining their consent. The history of these patients, including their drug and dietary histories, was recorded in detail. Each patient was given computed tomography to evaluate stone attenuation and skin-to-stone distance. After SWL, Stone clearance rate was compared with stone attenuation and skin-to-stone distance. The statistical package for social sciences (SPSS) version 20.0 was used to analyze the data. Males were more prevalent than females, but the stone-free rate was higher in females, though this difference was not statistically significant. Younger patients experienced a higher stone-free rate, and patients with low BMI had better outcomes than those with high BMI. Stones were most abundant in the lower pole, followed by the pelvis, central, and upper pole. The stone-free rate was highest in the pelvis, followed by the central, lower pole, and upper pole. Stone-free status was more common among patients with smaller stones and lower stone attenuation, though these differences were not statistically significant. Patients with a shorter skin-to-stone distance had a significantly higher rate of stone extraction. Skin-to-stone distance more effectively predicts the success of SWL in renal stone disease than stone attenuation.

Keywords: *CT scan, SWL and renal stone.*

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INTRODUCTION

Shock wave lithotripsy (SWL) remains a widely accepted, noninvasive, safe, and effective treatment option for renal stone, despite a wide range of current success rates (46%-91%; efficiency quotient 0.36-0.67).[1,2] The size and location of the stone play a significant role in patient selection. Stone attenuation, skin-to-stone distance (SSD) on non-contrast computed tomography (NCCT), and body mass index (BMI) are emerging as predictors of SWL fragmentation.[3,4] Such factors could help to streamline stone disease care and reduce unnecessary treatments. A major criticism of measuring stone attenuation is the volume averaging that occurs for smaller stones, resulting in fictitious low attenuation values that can confuse its association with the SWL outcome.[5,6]

Failure to disintegrate the stone results in unnecessary exposure to shock waves and radiation, additional patient suffering, and the need for alternative treatment procedures, which raises medical costs.[7] Prior to treatment, it is critical to identify predictors of treatment success or failure in patients who are potential candidates for SWL.

A radiographic examination of the stone is required to determine the best treatment. Non-contrast computed tomography (NCCT) is now recommended as the standard diagnostic tool in urinary stone disease because it provides reliable information on stone location, size, number, and total stone burden.[6,7] Furthermore, several studies have found an effect of mean attenuation value (MAV) on the success of SWL treatment in kidney stones, leading to corresponding guideline recommendations.[8] Despite its widespread use, the impact of additional information provided by NCCT, such as skin-to-stone distance (SSD) and MAV, on stone fragmentation in renal stone disease has received little attention.[9-11] Furthermore, three of the four studies reported on so far covered only one SWL session, regardless of whether disintegration occurred or not, and treatment success was evaluated in all four studies at the earliest 2 weeks after SWL. Ng et al. (2009) also only included proximal renal stones, and no real-time fluoroscopic screening was done during treatment.[10]

Failure of stone breakdown causes unnecessary exposure to radiation and shock waves, increased patient suffering, and the need for alternative treatment methods, all of which raise medical expenses. Determining treatment success or failure predictors in patients who may be candidates for SWL is crucial before starting treatment. This is why we decided to conduct a study to see if stone attenuation and skin-to-stone distance in computed tomography can predict shock wave lithotripsy performance in renal stone disease. The purpose of this study was to determine if SWL performance in renal stone disease can be predicted by CT stone attenuation and skin-to-stone distance.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Radiology and Imaging and Department of Urology, BSMMU, Dhaka over a period of one years from 01.01.2023 to 31.12.2023. Diagnosed adult patients of renal stone referred for SWL to the Department Urology, BSMMU, Dhaka during study period were enrolled as the study population. Severely ill patients were excluded from this study.

Procedure

Prior to the study, ethical approval was taken from the Institutional Review Board, and the study was conducted in accordance with the Declaration of Helsinki. The present study was conducted on 73 adult patients of both sexes with renal stones in the Department of Radiology, BSMMU. All patients were informed regarding the study and written consent was taken from each patients. Adult patients with renal stones who were referred for SWL were enrolled in this study. After enrollment in this study, general information such as name, age, gender etc. were recorded. A thorough clinical examination was done. CT scan was done for each patient to find out stone volume, location and skin-to-stone distance. If tolerated by the patient, up to 4,000 shocks (60–90/ min) with an energy level of up to 8 according to the manufacturer's scale was delivered during each SWL session. The energy level 8 corresponded to 16.4 kV with the precise focus and 12.8 kV with the extended focus. In patients with pain resistant to analgesic treatment, the energy and number of shocks were reduced according to the patient's tolerance. Stones were targeted and fragmentation was monitored by biplanar fluoroscopy at regular intervals during treatment. Patients were further evaluated by kidney, ureter, and bladder (KUB) film, renal ultrasound, and sieving of urine to assess fragmentation, the presence of renal dilatation and expulsion of renal stones the day after the respective session. In cases of missing or inadequate disintegration in KUB, SWL was repeated once or twice at intervals of 1 day. The clinical outcome was defined as successful (visible stone fragmentation on KUB) or failed (absent fragmentation on KUB) immediately after the last SWL session.

A predesigned questionnaire was used to record all the information which was then fed into the computer using Statistical Package for the Social Sciences (SPSS) software. Statistical analyses performed using SPSS 20.0 software (SPSS, Chicago, IL, USA). Data presented on categorical scale were expressed as frequency and corresponding percentages and were compared between groups using Chi-square test, while data presented on continuous scale were expressed as mean and standard deviation and were compared between groups by using Student's t-Test and p value < 0.05 will be taken as statistically significant. Sensitivity, specificity, positive predictive value, negative predictive value of stone volume and skin-to-stone distance will be calculated to predict success rate of stone clearance.

RESULTS

This prospective observational study was conducted among 73 adult patients of both sexes with renal stones and the aim of this study was to determine if SWL performance in renal stone disease can be predicted by CT stone attenuation and skin-to-stone distance.

Table I displays the demographic profile of the study subjects; according to sex here 43 (58.90%) were males and 30 (41.10%) females. The mean age of stone free group was 49.16 ± 8.50 years and 52.76 ± 9.57 in residual fragment group. Stone-free outcomes were more prevalent in younger individuals

Here, males exhibited a higher frequency than females, however, the stone-free rate was higher in females compared to males, but this difference was not statistically significant.

Table- I : Demographic profile of the study subjects according to the success of shock wave lithotripsy in renal stone disease (N=73)

	Frequency (%)	Stone free	Residual fragment	p-value
Gender				
Male	43 (58.90%)	31 (72.1)	12 (27.9)	0.264
Female	30 (41.10%)	25 (83.3)	5 (16.7)	
Age (years)		49.16 ± 8.50	52.76 ± 9.57	0.141

Figure 1 illustrates success rate of SWL Stone-free rate was 77% (56) and residual fragment rate was 23% (17).

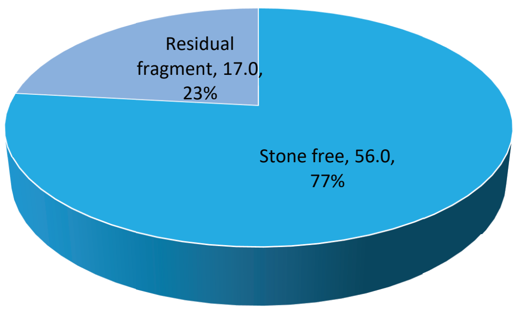

Figure- 1: Success rate of SWL

Table II shows the stone location of the study subjects; residual fragment rates were 3 (14.3%), 4 (57.1%), 2 (15.4%) and 8 (25.8%) in the location of pelvis, upper pole, central and lower pole respectively. The stone-free rate was maximum 18 (85.7%) in the pelvis, followed by the central 11 (84.6%), lower pole 24 (75.0%), and upper pole 3 (42.9%).

Table- II: Stone location of the study subjects (N=73)

	Stone free	Residual fragment	p-value
Pelvis	18 (85.7)	3 (14.3)	0.141
Upper pole	3 (42.9)	4 (57.1)	
Central	11 (84.6)	2 (15.4)	
Lower pole	24 (75.0)	8 (25.8)	

Table III demonstrates the stone characteristics and shocks delivered to the study subjects. Stone-free rate was higher in patients with smaller, lower attenuation stones, although these differences were not statistically significant. However, stone clearance was significantly greater in patients with shorter skin-to-stone distances.

Table- III: Stone characteristics and shocks delivered to the study subjects (N=73)

	Stone free (n=56)	Residual fragment (n=17)	p-value
Size volume (mm^3)	1718±1319	2387±1617	0.087
Skin to stone distance (mm)	73.96±7.85	87.24 ± 8.17	0.001
Stone attenuation (HU)	782.14±272.76	882.35±220.04	0.171
Shocks delivered (n)	2962.50±372.98	3076.47±253.79	0.243

Table IV states the multivariate analysis of variables predicting the stone-free rate by logistic regression analysis. Binary logistic regression was performed to assess the impact of several factors on stone-free rate in the shock wave lithotripsy in renal stone disease. The model contained four independent variables (Age, stone volume, stone-to-skin distance, and stone attenuation). The strongest predictor of stone-free was stone-to-skin distance, reporting an odds ratio of 1.4. This indicated that respondents who had stone-to-skin distance less were over 1.4 times more likely to have free stone.

Table- IV: Multivariate analysis of variables predicting the stone-free rate by logistic regression analysis (N=73)

	p-value	OR	95.0% CI of OR	
			Min	Max
Age	0.860	0.988	0.867	1.126
Stone volume	0.146	1.001	1.000	1.001
Skin-to-stone distance	0.000	1.400	1.172	1.673
Stone attenuation	0.066	1.005	1.000	1.010

Figure 2 expresses the receiver operating characteristic (ROC) curve for stone attenuation and skin-to-stone distance. The receiver operating characteristic (ROC) curve for stone attenuation and skin-to-stone distance using CT predicts shock wave lithotripsy performance in renal stone disease. The area under the curve for stone attenuation was 0.603 (95% CI 0.464 – 0.742), while for skin-to-stone distance, it was 0.901 (95% CI 0.801–1.000).

The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of stone attenuation in predicting the effectiveness of shock wave lithotripsy in renal stone disease at a cut-off point of 637.5 were 33.9%, 88.2%, 90.5%, and 28.8% respectively. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of skin-to-stone attenuation in predicting the effectiveness of shock wave lithotripsy for renal stone disease were 78.6%, 94.1%, 97.8%, and 57.1%, respectively, using a cut-off point of 80.5.

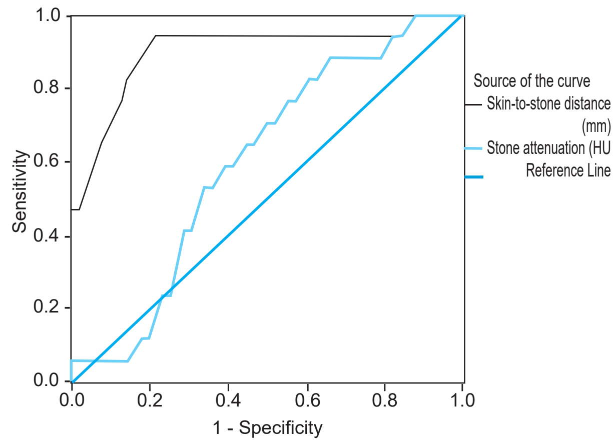

Figure- 2: The receiver operating characteristic (ROC) curve for stone attenuation and skin-to-stone distance

Table V explains the diagnosis efficacy of stone attenuation and skin-to-stone distance using CT in predicting the performance of shock wave lithotripsy in renal stone disease. Cut off, Sensitivity, Specificity, PPV, NPV, Accuracy of Stone attenuation presented 637.5, 33.9, 88.2, 90.5, 28.8, 44.6 and Skin-to-stone distance presented 80.5, 78.6, 94.1, 97.8, 57.1, 82.2 respectively.

Table- V: Diagnosis efficacy of stone attenuation and skin-to-stone distance using CT in predicting the performance of shock wave lithotripsy in renal stone disease.

	Cut off	Sensitivity	Specificity	PPV	NPV	Accuracy
Stone attenuation	637.5	33.9	88.2	90.5	28.8	44.6
Skin-to-stone distance	80.5	78.6	94.1	97.8	57.1	82.2

DISCUSSION

In this study, males were predominant than females but stone free rate was higher in female than male but not statistically significant. Similar finding was observed in the study of Müllhaupt et al. where male was prevalent than female but successful disintegration was found prevalent in male.[12] In Bangladesh, Pakistan, India, Thailand, Saudi Arabia, and Japan, the male-female ratio of stone burden is 2:1[13]. Similarly, Khan et al. reported the same ratio in their study of 60 symptomatic children.[14] Trinchieri affirmed that renal stones are more common in men.[15] In Western countries, kidney stone prevalence varies significantly by location, with rates ranging from 8% to 19% in men and 3% to 5% in women. A comprehensive 2010 study in Taiwan found the age-adjusted prevalence of urolithiasis to be 9.01% in males, 5.79% in females, and 7.38% overall.[16] Stone free was occurred more in younger patients. Successful disintegration was observed among the younger patients.[12]

The stone was most commonly detected in the lower pole, followed by the pelvis, central region, and upper pole. The stone-free rate was most common in the pelvis, followed by the central, lower pole, and higher pole.

Patients with smaller, lower attenuation stones had higher rates of stone-free outcomes, though these differences were not statistically significant in this study. El-Nahas et al. found that patients with small stones were more likely to achieve successful shock wave lithotripsy (SWL) than those with larger stones, but stone attenuation did not significantly differ between successful and failed SWL.[7] In successful SWL, stone attenuation was notably lower compared to failures.[4,17,18] Additionally, patients with shorter skin-to-stone distances experienced much higher stone clearance in this study. Those with successful disintegration had significantly shorter skin-to-stone distances than those without success.[12] Furthermore, successful SWL patients had a markedly reduced skin-to-stone distance compared to those who failed.[7]

Gupta et al. concluded that the worst outcome was in patients with calculus density >750 HU and stone diameter of >1.1 cm, as 77% of those patients needed more than three sessions of SWL and the clearance rate was 60%.[19] Wang et al.[20] concluded that stone density >900 HU and volume >700 mm3 were significant predictors of SWL failure. Comparable results were observed in their study, in which larger stone volume and higher stone density were significant predictors of the need for more than three sessions, and stone density >1000 HU was a significant predictor for failure of disintegration. The differences in the cut-off values that predicted extracorporeal SWL failure may be due to different inclusion criteria, use of different CT protocols, or measurement of different endpoints (eg, failure of disintegration, the need for multiple sessions, or rate of residual stones) in these studies. In contrast to Pareek et al., we found that SSD was a significant predictor.[18]

Binary logistic regression analysis was conducted to evaluate the effect of various parameters on the stone-free rate in shock wave lithotripsy for renal stone disease. The four independent variables in the model were stone attenuation, age, stone volume, and stone-to-skin distance. Stone-to-skin distance emerged as the strongest predictor of being stone-free, with an odds ratio of 1.4, indicating that responders with a lower stone-to-skin distance were nearly 1.4 times more likely to be free of stones.

Shock wave lithotripsy efficacy for renal stone disease can be predicted by the receiver operating characteristic (ROC) curve based on stone attenuation and skin-to-stone distance from CT scans. The area under the curve for skin-to-stone distance was 0.901 (95% CI 0.801–1.000), compared to 0.603 (95% CI 0.464–0.742) for stone attenuation. At a cut-off of 637.5, stone attenuation yielded a sensitivity of 33.9%, specificity of 88.2%, positive predictive value (PPV) of 90.5%, and negative predictive value (NPV) of 28.8% in predicting the effectiveness of shock wave lithotripsy. With an 80.5 mm cut-off point, our study found that the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of skin-to-stone in predicting the effectiveness of shock wave lithotripsy for renal stone disease were 78.6%, 94.1%, 97.8%, and 57.1%, respectively. These findings indicate that skin-to-distance is a more reliable predictor of shock wave lithotripsy's success in removing renal stones.

In a study comprising 94 patients with upper ureteral stones, Ng et al. found a considerably lower threshold of 593 HU as a predictor of therapeutic success.[10] Pareek et al. advocated a cut-off of 900 HU based on their analysis of 30 ureteral stones.[17] Despite the fact that research indicates that the stone to skin distance (SSD) for renal stones strongly influences the result of the SWL. SSD has been examined separately in two trials,[9,10] both of which have confirmed its importance as a predictor of SWL success in ureteral stones. Ng et al. only considered upper ureteral stones when they proposed an SSD cut-off of 9.2 cm for predicting SWL failure.[10] However, SSD at a 90° angle was found by Müllhaupt et al. to be a more reliable indicator of SWL failure than mean SSD, with a cut-off of 11.9 cm.[12]

CONCLUSION

Efficacy of skin-to-stone distance is better than stone attenuation in predicting the success of SWL in renal stone disease.

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