Stone density and skin-to-stone distance in noncontrast computed tomography as prognostic indicators for the success of extracorporeal shock wave lithotripsy in ureteral stone disease

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Background
Urinary stones are becoming more common, which is a major health issue. Ureteral stones that originate in the kidney and then descend the ureter are a frequent cause of renal colic. Extracorporeal shock wave lithotripsy (ESWL) and ureteroscopy are the two main procedures used to treat symptomatic ureteral calculi.
Aim
The aim of the present study was to assess the prognostic significance of skin-to-stone distance (SSD) and mean stone attenuation value in patients who may be candidates for ESWL for ureteral stones.
Patients and methods
This retrospective cohort observational study evaluated the prognostic value of SSD, mean attenuation value, and BMI in 66 patients with upper ureteral calculi who underwent ESWL. After a maximum of two sessions, if no stone particles were discovered, we categorized patients as stone free. Age, sex, SSD, maximum stone length, and stone Hounsfield units were examined in univariate and multivariate regression analyses.
Results
We found that factors including obesity (BMI >30.41), high stone density (Hounsfield units >935), and SSD more than 10 cm limited the effectiveness of therapy. On the contrary, higher shock levels (>2500 shocks each session) and shock intensities (>17 kV) were reliable indicators of treatment success.
Conclusion
We proposed a thorough analysis of the parameters prior to therapy to choose the best treatment option for each patient. It was found that a patient and stone feature before ESWL evaluation can predict the outcome of ureteric stone therapy. It was found that using these criteria can improve patient selection for ESWL and consequently ESWL effectiveness.

Keywords:
extracorporeal shock wave lithotripsy, stone density, stone distance, ureteral stone disease

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Introduction

Urinary stones are becoming more common, which is a major health issue. Urolithiasis is especially prevalent, with a 10% prevalence rate, among countries with high standards of living. Renal colic is a frequent symptom of ureteral stones generated in the kidney and then descending the ureter [1].

The two main methods of treatment for symptomatic ureteral calculi are extracorporeal shock wave lithotripsy (ESWL) and ureteroscopy. Other methods include medical expulsive therapy to encourage spontaneous stone passage, percutaneous antegrade ureteroscopy, and laparoscopic and open surgical ureterolithotomy [2].

ESWL is still one of the most popular and well-tolerated techniques for treating urinary lithiasis [3]. ESWL, however, has a lower rate of therapeutic success than either percutaneous nephrolithotomy or ureteroscopy, according to several studies. It is critical to identify predictors of ESWL outcome and choose the optimal course of action for patients with ureteral stone disease as residual stone fragments after ESWL may result in the patient experiencing major

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complications such as colic pain or the need for reintervention [4].

Additionally, this can lead to increased ESWL sessions, needless exposure to ionizing radiation, patients with obstructed kidneys becoming worse, and wasted medical resources. Therefore, it is preferable to identify the individuals who might benefit from ESWL and separate them from those who require a different type of treatment [5].

A recent study by Kim and colleagues showed that 24-h urinalysis alone does not reliably predict the composition of stones, despite some studies' focus on characterizing it using urine. According to the study, there is no correlation between urine pH and stone composition, presumably because of diurnal urinary pH variations and the selection bias they cause. Several studies have focused on the relationship between Hounsfield units (HU), particularly mean stone density, urinary stone composition, and treatment success, as noncontrast computed tomography (NCCT) has become the gold standard for identifying urinary stones [6].

In the last ten years, NCCT has become the standard investigation for identifying kidney stones because of its excellent sensitivity and specificity. With a probability of 0.5% difference ranges, NCCT may be used to determine the density of urinary stones. In several studies, it was also revealed that the HU and Hounsfield density of stones evaluated by NCCT were significantly related to stone fragility with ESWL [7].

According to the American Urological Association and the European Association of Urology (EAU) recommendations on urinary stone disease, the choice of therapy for ureteral stones should be dependent on the location and size of the stone. Skin-to-stone distance (SSD) and BMI can be used to help with decisions in unclear situations [8].

The EAU guidelines suggest using less invasive treatment methods like ESWL or retrograde ureteroscopy for ureteric stones and using percutaneous antegrade removal of ureteral stones as an alternative when shock wave lithotripsy is not indicated or has failed and when the upper urinary tract is not amenable to retrograde ureteroscopy [9].

Obesity and higher stone density as measured by NCCT were found to be significant predictors of failure to fragment stones by ESWL in the investigations of El-Nahas *et al.* [10] Clinical decision algorithms for patients with urinary stones should consider these factors on NCCT [11].

ESWL has swiftly gained notoriety throughout the world because to its ease, noninvasiveness, high efficacy in treating kidney and ureteral stones, and widespread accessibility to lithotripters. Stones are affected by ESWL by a variety of mechanical and dynamic forces, including shear, spalling, and cavitation [12].

The success percentage of ESWL in Egypt for upper ureteric calculi was reported to be between 58 and 78% [5,13].

Aim

The aim of the present study was to assess the prognostic significance of SSD and mean stone attenuation value in patients who may be candidates for ESWL for ureteral stones.

Patients and methods

Study design: using patients who may be candidates for ESWL for ureteral stones, this retrospective cohort observational study evaluated the prognostic value of SSD, mean attenuation value, and BMI.

Enrollment: from January 2019 to July 2020, patients with upper ureteral stones who were indicated for ESWL were assessed at the Urology Department's outpatient clinic at Theodor Bilharz Research Institute (TBRI) and Ain Shams University, and their data were gathered and maintained. After that, their records were reviewed to see if the patients met the requirements for inclusion in the study. The records were all randomly selected.

Ethical committee approval and written, informed consent were obtained from all participants.

Inclusion criteria

Inclusion criteria for patients were patients who were getting treatment for radiopaque ureteral stones that were smaller than 1.5 cm in diameter, capable of giving informed permission, and ready to provide medical history information.

Exclusion criteria for patients were active urinary tract infection, bleeding disorder, chronic renal failure (estimated glomerular filtration rate <30 ml/min), bilateral stones, pregnant women, patients with a history of kidney or stone disease, patients without NCCT prior to treatment, maximum stone size more than 15 mm, patients with multiple stones on the same side, patients with DJ stents, patients who are unable to tolerate shocks, patients in the pediatric age group (age <16 years), patients over 60 years old, and patients with obstructing stones.

Sampling method: a convenience sampling was used.

Sample size: to achieve 80% power to detect a difference of 0.2000 between the area under the receiver operating characteristic (ROC) curve (AUC) under the null hypothesis of 0.5 and an AUC under the alternative hypothesis of 0.70 using a two-sided z test at a significance level of 0.050, a sample size of at least 66 cases was required to yield at least 40 successful procedures and 26 failures. Responses on a rating scale make up the data. Between false-positive rates of 0.00 and 1.00, the AUC is calculated.

Preoperative workup

All patients provided an informed consent. The following parameters were obtained before the procedure: age, sex, BMI, medical history (diabetes, hypertension, and medications affecting kidney function), blood pressure, the length of the ESWL session, the location and size of the stone, as well as preoperative blood tests like complete blood counts, prothrombin times, prothrombin concentrations, and international normalized ratios. Regular computed tomography (CT) procedures were carried out, and shock wave energy, frequency, and number were all used.

All the patients underwent postoperative plain radiograph [kidney, ureter, and bladder (KUB)] 2 weeks after intervention for follow-up and assessment of success of treatment and urine analysis and culture to monitor any acquired infection.

The procedure went as follows: patients were treated with analgesia in the form of diclophenac sodium or diclophenac potassium by dripping, with intravenous fluids with pethidine hydrochloride if the patient's pain was not controlled. Localization of the stone was done by fluoroscopy in posteroanterior direction by moving the table electrically cranio-caudally and sideways, until putting the stone in the center of crosshairs at the monitor of posteroanterior localization. Then, fluoroscopy's C-Arm was moved obliquely at 30° and moved the table up or down to bring the stone to the center of crosshairs in the monitor. Then, the cushion was elevated to do perfect coupling. The procedure time was 40–45 min, and 2500–3000 shock waves were given every session, at a frequency of 55–60 shocks per minute. Energy utilized was 15–19 kV with the Novalith NT-10 and settings 1–4 with the Dornier Compact Sigma (equivalent to 10–14 kV). Preoperative NCCT pictures were used to determine factors including SSD, maximum stone length, and mean stone density in HUs. The Dornier Compact Sigma at Ain Shams University Hospital and the Novalith NT-10 at Theodor Bilharz Research Institute Hospital were the lithotripters used, and an equal number of patients treated with each lithotripter were included in the study. BMI was calculated as weight (kg)/height (m)^2=kg/m^2.

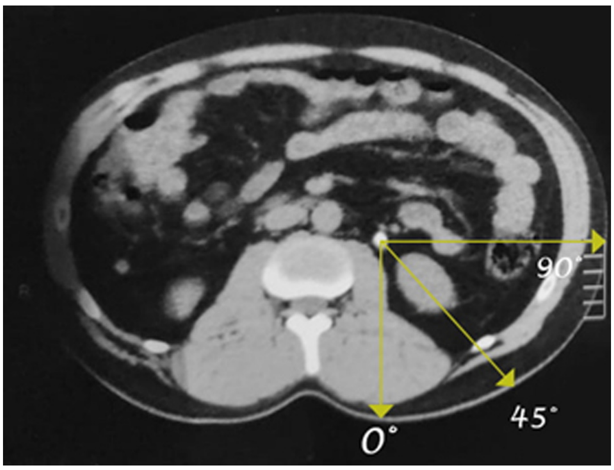
SSD was calculated as the average distance from the skin to the surface of targeted stone at 0°, 45°, and 90° angles on NCCT [14] (Fig. 1).

We chose a cutoff point of 10 cm SSD, as it was associated with lower stone-free (SF) rates in previous studies [15].

On the NCCT, the HU was used to quantify stone density. In NCCT, HU is a dimensionless unit that is always used. The observed attenuation coefficients undergo a linear translation, which yields HUs. This transformation is based on the arbitrary densities of pure water and air at standard pressure and temperature (0°C) (105 pascals). Air has a radiodensity of −1000 HU, whereas purified water has a radiodensity of 0 HU (Fig. 2).

Two weeks after receiving therapy, every patient was checked in the same facility's outpatient clinic. KUB was used to assess leftover pieces.

Figure 1



Measurement of SSD in three planes. SSD, skin-to-stone distance.

Figure 2

	uric acid	calcium oxalate	calcium phosphate	cystine	Struvite
mean	680	1815	1748	1123	997
minimum	544	1303	1382	1062	401
▲ maximum	816	2327	2114	1184	1593

Hounsfield unit density and stone composition [16].

The patient had to be SF or there had to be no pieces larger than 5 mm found after a maximum of two sessions with a 1-month gap in between the treatments [17].

Statistical analysis

Data were gathered, edited, coded, and put into IBM SPSS (Armonk, NY: IBM Corp. NewYork, USA), version 23.0 of the Statistical Package for the Social Sciences. When the quantitative data were parametric, they were displayed as means, SDs, and ranges, and when they were nonparametric, they were displayed as medians and interquartile ranges. Qualitative factors were also shown as percentages and numbers.

When the predicted count in a particular cell was less than 5, the groups were compared using the χ^2 test and/or Fisher exact test.

The independent *t* test was used to compare the two groups' quantitative data with a parametric distribution, whereas the Mann–Whitney test was used with a nonparametric distribution.

With the use of the ROC curve's sensitivity, specificity, positive predictive value, negative predictive value, and AUC, the appropriate cutoff point between two groups was determined.

The most significant ESWL failure predictors were evaluated using univariate and multivariate logistic regression analyses, along with their odds ratios (OR) and 95% confidence intervals (CI).

The allowable margin of error was set at 5%, whereas the CI was set at 95%. The *P* value was therefore deemed significant as follows: *P* value more than 0.05 indicates nonsignificant, *P* value 0.05 indicates significant, and *P* value 0.01 indicates highly significant.

Results

Our study included 66 patients aged between 17 and 59 years, comprising 31 were males and 25 were females. The heights of studied patients ranged from 1.41 to 1.95 m, and the weights ranged from 49 to 115 kg (BMI 17.76–45.75). Overall, 22.7% of the patients experienced comorbidities unrelated to primary disease (10.6% were diabetic and 16.7% were hypertensive) (Table 1).

Our demographic and anthropometric data reveal that although there was statistically significant growth in weight and BMI in failed cases compared with success cases, with *P* value 0.001, there was no statistically significant difference between success and failed cases regarding age, sex, or height, with *P* values of 0.653, 0.915, and 0.122, respectively. Regardless of age, sex, or height, obesity (increased weight and BMI) has a substantial effect on treatment failure. The data show that the percentage of patients with comorbidities as a total and the percentage of patients with diabetes mellitus and hypertension were found higher in the failed group than the success group, with *P* values of 0.000, 0.001, and 0.013, respectively. This suggests a strong relation between comorbidities and treatment outcome, which is in reality due to their strong association with increased weight and BMI, which will be confirmed by the multivariate logistic regression analysis (Table 2).

Table 1 Descriptive for demographic data and anthropometric measures of the studied patients as well as presence of comorbidities

	N=66 [*n* (%)]
Age (years)	
Mean±SD	37.32±11.49
Range	17–59
Sex	
Female	31 (47.0)
Male	35 (53.0)
Height (m)	
Mean±SD	1.65±0.11
Range	1.41–1.95
Weight (kg)	
Mean±SD	80.14±18.61
Range	49–115
BMI	
Mean±SD	29.62±7.56
Range	17.76–45.75
Comorbidities	
Yes	15 (22.7)
No	51 (77.3)
DM	7 (10.6)
HTN	11 (16.7)

DM, diabetes mellitus; HTN, hypertension.

In this study, patients had radiopaque stones with density of 405–1250 HU and stone size of 0.7–1.5 cm. The SSD ranged from 7.8 to 12.9 cm, with an averaging of 10.7 cm. A total of 20 patients had SSD less than 10 cm (30.3%) and 46 patients had SSD more than 10 cm (69.7%). Moreover, 36 patients had stones on the right side, whereas 30 patients had stones on the left side (Table 3).

Maximum stone length and stone laterality were not statistically different between successful and unsuccessful instances (*P*=0.075 and 0.270, respectively); however, stone density and SSD were statistically different between the two groups (*P*=0.001). In our investigation, a cutoff point of 10 cm was statistically significant, with a *P* value of 0.001, and was related with decreased SF rates.

Table 2 Comparison between success and failed cases regarding demographic and anthropometric measures as well as comorbidities

	Success [*n* (%)] *N*=40	Failed [*n* (%)] *N*=26	Test value	*P* value	Significance
Age (years)					
Mean±SD	36.80±12.81	38.12±9.26	–0.452•	0.653	NS
Range	17–59	26–59			
Sex					
Female	19 (47.5)	12 (46.2)	0.011*	0.915	NS
Male	21 (52.5)	14 (53.8)			
Height (m)					
Mean±SD	1.67±0.11	1.63±0.10	1.566•	0.122	NS
Range	1.46–1.95	1.41–1.82			
Weight (kg)					
Mean±SD	71.75±13.91	93.06±17.67	–5.462•	0.000	HS
Range	49–115	55–115			
BMI					
Mean±SD	25.88±5.08	35.38±7.16	–6.302•	0.000	HS
Range	18.22–40.46	17.76–45.75			
Comorbidities					
Yes	3 (7.5)	12 (46.2)	13.406*	0.000	HS
No	37 (92.5)	14 (53.8)			
DM					
Yes	0	7 (26.9)	12.047*	0.001	HS
No	40 (100.0)	19 (73.1)			
HTN					
Yes	3 (7.5)	8 (30.8)	6.143*	0.013	S
No	37 (92.5)	18 (69.2)			

DM, diabetes mellitus; HTN, hypertension. *χ^2 test. •Independent *t* test. *P* value more than 0.05: nonsignificant; *P* value less than 0.05: significant; *P* value less than 0.01: highly significant.

Additionally, the type of lithotripter used had no effect on the outcomes (Table 4).

Each patient underwent up to two sessions with each session consisting of 2500–3000 shock at 15–19 kV with the Novalith NT-10, or setting 1–4 with the Dornier Compact Sigma with a rate of 55–60 shock/min according to the patient's pain tolerance. The duration of treatment sessions ranged from 25 to 62.5 min, where 41 patients required only one session, whereas 25 patients required a second session (Table 5).

Table 3 Stone parameters among the studied patients

	N=66 [*n* (%)]
Stone size (cm)	
Mean±SD	1.17±0.23
Range	0.7–1.5
Stone density (HU)	
Mean±SD	806.97±221.58
Range	405–1250
Skin-to-stone distance	
Mean±SD	10.70±1.51
Range	7.8–12.9
$<$10	20 (30.3)
$>$10	46 (69.7)
Laterality	
Right	36 (54.5)
Left	30 (45.5)
Lithotripter	
Novalith NT-10	33 (50.0)
Dornier compact sigma	33 (50.0)

HU, Hounsfield units.

With *P* values of 0.031 and 0.015, respectively, there was a statistically significant increase in the number of sessions and shock waves in unsuccessful instances compared with successful ones. Additionally, we discovered that there was no statistically significant difference between the two groups regarding the length of each session (*P*=0.811), but there was a statistically significant relationship between maximum shock intensity and session success (*P*=0.006 for the Novalith NT-10 and 0.026 for the Dornier Compact Sigma). We were able to attain a better success rate with fewer sessions needed to reach a SF condition thanks to patients with higher pain tolerance and greater shock tolerance (Table 6).

A total of 31 (47%) studied patients experienced minor complications, namely, renal colic (20 patients, 30.3%) followed by gross hematuria (four patients, 6.1%) and symptomatic bacteriuria (seven patients, 10.6%), whereas none experienced any major complications. All of them were classified as grade I according to the Clavien-Dindo classification [18]. Between successful and unsuccessful cases, the proportion of patients who experienced complications was found to be nonsignificant (*P*=0.691); additionally, renal colic, hematuria, and symptomatic bacteriuria were not found to differ between the two groups statistically (Table 7).

Among the 40 patients in our research, 60.6% had effective surgeries whereas 39.4% were unable to reach a SF state. For the operation to be successful, the patient should be SF with no stones larger than

Table 4 Comparison between success and failed cases regarding stone parameters

	Success [*n* (%)] *N*=40	Failed [*n* (%)] *N*=26	Test value	*P* value	Significance
Maximum stone length (cm)					
Mean±SD	1.12±0.24	1.23±0.21	–1.812•	0.075	NS
Range	0.72–1.5	0.79–1.49			
Stone density (HU)					
Mean±SD	717.38±152.71	944.81±242.21	–4.685•	0.000	HS
Range	440–1200	405–1250			
Skin-to-stone distance					
Mean±SD	10.05±1.37	11.70±1.12	–5.135•	0.000	HS
Range	7.8–12.7	8.1–12.9			
$<$10	18 (45.0)	2 (7.7)	10.385*	0.001	HS
$>$10	22 (55.0)	24 (92.3)			
Laterality					
Right	24 (60.0)	12 (46.2)	1.218*	0.270	NS
Left	16 (40.0)	14 (53.8)			
Lithotripter					
Novalith NT-10	20 (50.0)	13 (50.0)	0.000*	1.000	NS
Dornier compact sigma	20 (50.0)	13 (50.0)			

HU, Hounsfield units. *χ^2 test. •Independent *t* test. *P* value more than 0.05: nonsignificant; *P* value less than 0.05: significant; *P* value less than 0.01: highly significant.

5 mm after a maximum of two sessions with a 1-month gap in between them.

According to the ROC curve, the best cutoff points for factors affecting outcome in our study were found to be BMI more than 30.41 kg/m^2, SSD more than 11.1 cm (as opposed to the expected cutoff value of 10 cm), and stone density more than 935 HU (Fig. 3).

The univariate logistic regression analysis shows that all the previous parameters were found to be associated with failure of ESWL. The multivariate logistic regression analysis using the Backward: Wald method shows that the most factors associated with failure of ESWL in ureteral stones were BMI more than 30.41 kg/m^2, with OR (95% CI) of 25.518 (2.605–249.976); stone density (HU) more than 935, with OR (95% CI) of 124.855 (7.035–2215.902); and number of shock waves more than 5000, with OR (95% CI) of 6.768 (0.947–48.390). Although SSD is a statistically important significant factor in the univariate analysis with cutoff point of 10 and 11.1 cm (the best cutoff point in our study), it was not as significant as BMI and stone density in the multivariate analysis in our study population. This confirms that BMI and stone density were the most important factors affecting treatment outcome followed by number of shocks. As stated before, comorbidities (namely diabetes mellitus and hypertension), though associated with obesity (increased BMI), were not statistically significant in the multivariate analysis (Table 8).

Table 5 Session data among the studied patients

	N=66 [*n* (%)]
Number of sessions	
1	41 (62.1)
2	25 (37.9)
Number of shock waves	
Median (IQR)	3000 (2500–5000)
Range	2500–6000
Duration per session (min)	
Mean±SD	43.73±5.60
Range	25–62.5
Max shock intensity (kV) (Novalith NT-10)	
Mean±SD	17.27±1.15
Range	15–19
Max shock intensity (Dornier compact sigma)	
1	2 (6.1)
2	3 (9.1)
3	16 (48.5)
4	12 (36.4)

IQR, interquartile range.

Discussion

Urinary stones occur in 12% of men and 5% of women at some point in their lives, and two-thirds of patients will experience a recurrence within 20 years. According to reports, urinary stones are becoming more common in both industrialized and underdeveloped countries. Increasingly, urinary tract lithiasis is diagnosed radiologically by CT of the KUB (urinary tract) without contrast (CT-KUB/CT-UT) [19,20].

Early in the 1980s, ESWL, a less invasive procedure, was used to replace open or endoscopic renal

Table 6 Comparison between success and failed cases regarding session data

	Success [*n* (%)] *N*=40	Failed [*n* (%)] *N*=26	Test value	*P* value	Significance
Number of sessions					
1	29 (72.5)	12 (46.2)	4.648*	0.031	S
2	11 (27.5)	14 (53.8)			
Number of shock waves					
Median (IQR)	2500 (2500–4250)	5000 (2500–6000)	–2.425≠	0.015	S
Range	2500–6000	2500–6000			
Duration per session (min)					
Mean±SD	43.87±5.55	43.53±5.78	0.240•	0.811	NS
Range	25–62.5	25–50			
Max shock intensity (kV) (Novalith NT-10)					
Mean±SD	17.7±1.0	16.6±1.1	2.938•	0.006	HS
Range	16–19	15–19			
Max shock intensity (Dornier compact sigma)					
1	0	2 (15.4)			
2	0	3 (23.1)			
3	12 (60.0)	4 (30.8)	9.265*	0.026	S
4	8 (40.0)	4 (30.8)			

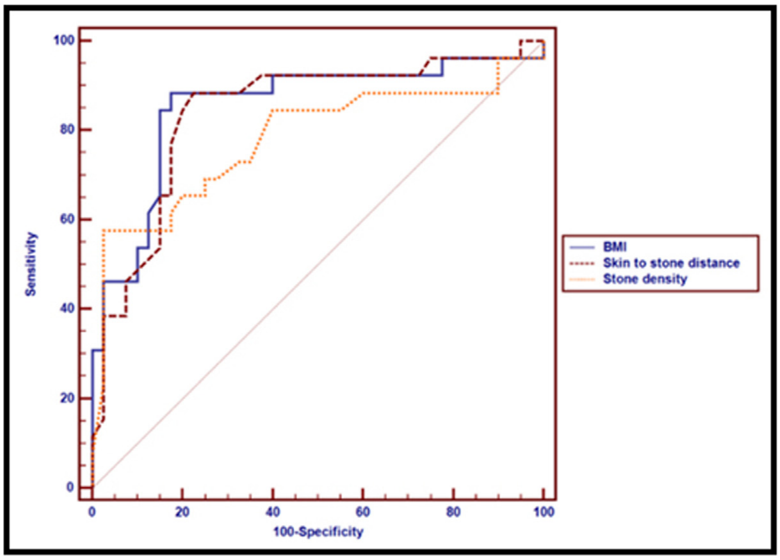
IQR, interquartile range. *χ^2 test. •Independent *t* test. ≠Mann–Whitney test. *P* value more than 0.05: nonsignificant; *P* value less than 0.05: significant; *P* value less than 0.01: highly significant.

Table 7 Comparison between success and failed cases regarding complications

	Total [*n* (%)] *N*=66	Success [*n* (%)] *N*=40	Failed [*n* (%)] *N*=26	Test value	*P* value	Significance
Complication						
Yes	31 (47.0)	18 (45.0)	13 (50.0)	0.158*	0.691	NS
No	35 (53.0)	22 (55.0)	13 (50.0)			
Renal colic						
Yes	20 (30.3)	11 (27.5)	9 (34.6)	0.378*	0.539	NS
No		29 (72.5)	17 (65.4)			
Hematuria						
Yes	4 (6.1)	4 (10.0)	0	2.768*	0.096	NS
No		36 (90.0)	26 (100.0)			
Symptomatic bacteriuria						
Yes	7 (10.6)	3 (7.5)	4 (15.4)	1.033*	0.309	NS
No		37 (92.5)	22 (84.6)			

*χ^2 test. *P* value more than 0.05: nonsignificant; *P* value less than 0.05: significant; *P* value less than 0.01: highly significant.

Figure 3



	Cut off point	AUC	Sensitivity	Specificity	PPV	NPV
BMI	>30.41	0.854	88.46	82.50	76.7	91.7
Skin to stone distance	>11.1	0.841	88.46	77.50	71.9	91.2
Skin to stone distance	>10	0.636	92.31	45.00	52.2	90.0
Stone density	>935	0.781	57.69	97.50	93.7	78.0

Receiver operating characteristic (ROC) curve for stone density (HU), skin-to-stone distance, and BMI. HU, Hounsfield units.

procedures for urinary stones. For some criteria of renal and ureteral calculi, it is now thought to be a successful first-line treatment. Owing to its noninvasiveness, low need for anesthesia, and high degree of acceptability by both patients and doctors, ESWL is particularly alluring [21].

The patient and stone-related variables have a significant effect on the effectiveness of ESWL. Numerous variables have been investigated and shown to influence ESWL outcomes. These factors can be divided into two categories: those that are related to the patient, such as age, sex, and BMI, and those that are related to the stone, such as stone size, location, density, and SSD, as well as the type and characteristics of the lithotripter that was used [22].

Although the success rate for our study was predefined at 60.6%, previous studies have documented a broad range of ESWL success rates ranging from 46 to 91%. If there were pieces larger than 5 mm after two sessions, we judged the therapy to have failed [23,24]. Different studies used different definitions of successful and unsuccessful results. In one study, a failure outcome

Table 8 Univariate and multivariate logistic regression analyses for factors associated with failure of extracorporeal shock wave lithotripsy in upper ureteral stones

	Univariate				Multivariate			
			95% CI for OR				95% CI for OR	
	P value	OR	Lower	Upper	*P* value	OR	Lower	Upper
Weight (kg) >84	0.000	29.400	7.603	113.693	–	–	–	–
BMI >30.41	0.000	36.143	8.448	154.623	0.005	25.518	2.605	249.976
Stone density (HU) >935	0.000	53.182	6.308	448.398	0.001	124.855	7.035	2215.902
Skin-to-stone distance >11.1	0.000	26.407	6.424	108.553	–	–	–	–
Skin-to-stone distance >10	0.004	9.818	2.040	47.251	–	–	–	–
Number of sessions >1	0.034	3.076	1.090	8.679	–	–	–	–
Number of shock waves >5000	0.002	7.714	2.126	27.997	0.057	6.768	0.947	48.390
Comorbidities	0.001	10.571	2.589	43.158	–	–	–	–

CI, confidence interval; HU, Hounsfield units; OR, odds ratio.

of ESWL was defined as the presence of substantial residual fragments greater than 4 mm after three sessions of ESWL [25]. In a different trial, failure of the therapy was defined as either no stone fragmentation at all or the presence of residual pieces measuring 5 mm or larger after four sessions [17].

Failure of ESWL exposes the renal parenchyma to shock waves without necessity, which might result in consequences such renal hematomas [26].

We applied the energy ramping approach during the treatment sessions much like previous researchers. The patient is prepared to adjust to the notion of SWL using this procedure. The EAU guidelines then state that level 1b evidence shows that the ramping strategy causes less kidney damage. The screening effect, in which the powder produced and the small fragments by the cavitation bubbles and stress waves cluster around the remaining stones to attenuate and scatter the shock waves, was thought to be compensated for by this technique, which was hypothesized to strengthen the formation of cavitation bubbles. We discovered that it produced significantly better results in controlling the patients' pain by allowing them time to adjust to the shock waves [27,28].

Patients with upper ureteric stones less than or equal to 15 mm were included in our study, and the results revealed no correlation between treatment outcomes and stone size.

The HU of the stone was a significant predictor for the first ESWL session in our study as well. In situations with stones with a high HU, several ESWL procedures were ineffective, and endoscopic removal was frequently necessary. Therefore, if a stone is more than 935 HU, we should be prepared for ESWL failure. Prior research examined stone density on NCCT as a predictor of treatment success [29]. In various clinical investigations, individuals with stone densities more than 750 HU required more than three ESWL treatments compared with those with stone densities of 750 HU [30]. Additionally, ESWL is more likely to fail in patients with a stone density more than 750–1000 HU, according to a number of experts, and these individuals ought to look at alternative therapy options [31]. Patients with stones with a density of more than 1000 HU had a SF rate of 56.2%, whereas those with a density of less than 1000 HU had a rate of 87.7% [24].

Stones with greater than 900 HU were more likely to fail following ESWL in Wiesenthal's research and another one by Wang [25,32]. According to Nakasato *et al.* [33], success rates after ESWL were noticeably higher for stones under 815 HU than for stones beyond 815 HU (P=0.02). The most sensitive point in determining stone density, according to different research by Ouzaid *et al.* [34], was a stone density of 970 HU. They got 96% SF rates for stones less than 970 HU and 38% SF rates for stones more than 970 HU (P=0.001).

Al-Zubi and colleagues discovered that, like our work, the success rate of ESWL increases when stone density evaluated in HU lowers. However, we identified a robust association between high BMI and failure of ESWL, but they found no statistical significance between BMI and ESWL result [35].

Our study and numerous others have found that SSD is a significant indicator of ureteral stone therapy success [32,36]. Owing to the dispersion of fat, energy transmission reduces as distance from the stone grows. BMI and SSD were important indicators of ESWL success in our study. Treatment of morbidly obese individuals presents several technical difficulties, such as challenging patient posture, muted shock waves, and challenging stone localization. Therefore, the SSD has been found to be a reliable predictor of SF status after ESWL.

Although it was not the most important factor in the multivariate analysis, the SSD for our cohort was 10.7 ±1.51 cm, with the longest distance being associated with stones in the proximal ureter as would be expected. The patients in our study typically had high BMIs (29.62±7.56 kg/m^2), and the SSD was usually high. Additionally, we discovered that the success threshold must be SSD 11.1 cm. Using multivariate methodology, a comprehensive retrospective assessment of 1282 ESWL procedures found that an SSD more than 10 cm was related to decreased SF rates [15]. In most situations, ESWL failure is predicted by a cutoff SSD more than 10–12 cm [10]. However, several investigations in Asian communities have shown contradicting findings. Middle Eastern inhabitants have larger bodies than Asian ones; it was argued that it could not be applied to Asian patients. Various studies reported that SSD was not a meaningful factor [37].

We did not include patients in our study who had ureteral stents. The transit of fragments is hampered by ureteral stenting in ESWL patients, lowering the success rates for SF procedures [38,39]. To become SF, stented patients have been reported to need more adjuvant treatments [40], and the risk of infection or stein strasse after treatment sessions remains unaffected [41].

It is critical to use ESWL to optimize the treatment protocol in addition to patient and stone-related parameters. In our office, we adhere to the EAU recommendations, which include thorough fluoroscopic stone monitoring during treatment as well as the appropriate use of coupling gel to enhance energy transmission [9]. In accordance with our custom of administering 60 shocks per minute, Bajaj *et al.* [42] found that the ideal shock-wave frequency to produce maximum SF rates is 60–90 shocks per minute.

In contrast to the investigations by Yoon *et al.* [31], we discovered that greater intensity ESWL (>17 kV) can result in a higher stone-free rate. We found no renal hematomas during our investigation using the stepwise voltage ramping strategy, contrary to what was reported in a randomized trial employing the protocol versus a fixed power group. Owing to renal vascular vasoconstriction caused by the initial low shock wave energy, the kidney is less vulnerable to harm when the intensity is increased [43]. Despite this, we encountered some minor complications; all of them were classified as grade I according to The Clavien-Dindo classification and managed conservatively with oral and intravenous fluids and analgesics [18].

There is controversy over the effects of patient sex and age on ESWL results. Few studies have taken age into account in any meaningful way, even though many have examined factors influencing the result of ESWL. Age was related with a considerably reduced SF rate in a large-scale study of 3023 individuals with renal and ureteric calculi treated with ESWL by Abe *et al.* [44]. Patients older than 40 years had a considerably lower SF rate after receiving ESWL treatment for kidney stones, according to a second multivariate study of 2954 patients who had undergone the procedure [45]. This finding's origin is still a mystery. The acoustic impedance and reduced effectiveness of ESWL may be caused by age-related sclerotic kidney alterations. Reduced exercise might be another contributing reason. Further studies are needed to analyze age as a predictor for ESWL outcome.

According to Snicorius and colleagues, predictive variables alone cannot reliably identify all patients who will benefit from ESWL and rule out those who will experience a negative outcome. We concur with their conclusions and suggest a new method that considers a number of variables, such as stone position, size, SSD, BMI, and stone density. Delivered power and the stone volume ratio may be valuable tools to determine how much power is needed to break up the stone. Further research is required. Specialized and confirmed nomograms may aid to enhance patient selection for ESWL treatments [14].

Owing to its retroactive characteristics, this study has possible flaws. Another drawback is that KUB cannot be used to assess treatment outcomes. The best approach for identifying leftover stones appears to be CT as it has a very high accuracy rate for detecting urinary calculi. When the patient was SF or when pieces less than 5 mm were found after a maximum of two sessions with a 1-month gap in between the operations, we considered the surgery to have been successful [17].

A KUB radiograph used to confirm ESWL results raises the success rate. Contrarily, because of intestinal gas, feces, and soft tissue overlap, it is possible that the prevalence of remaining stones may be higher given the limits of plain films. The current study shares the same issue as the majority of ESWL studies. Furthermore, we solely took ESWL into account for the treatment of upper tract stones. As a result, it is unable to comment on the effectiveness of our therapy for mid-ureteric and lower-ureteric stones, which is a crucial contrast from other studies in the literature.

In the era of availability of modern endoscopic treatments, this study could be a basis for evaluation of ESWL in upper ureteric calculi and factors for patient selection. Further studies with more patients and more variable SSD and stone density will confirm these results.

Conclusion

We proposed a thorough analysis of the parameters prior to therapy to choose the best treatment option for each patient. It was concluded that the evaluation of patient and stone characteristics before ESWL can predict the outcome of ureteric stone therapy. It was found that using these criteria can improve patient selection for ESWL and consequently ESWL effectiveness. Our study was limited by the small sample size. It would be desirable to conduct further in-depth studies to support these findings.

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Conflicts of interest

There are no conflicts of interest.

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