

Effect of Stone Size, Location, and Density on the Success Rate of Extracorporeal Shock Wave Lithotripsy

Kumar Gaurav Mishra¹, Kaushal Kumar²

¹Assistant Professor, Department of Urology, Anugrah Narayan Magadh Medical College Hospital, Gaya, Bihar, India

²Assistant Professor, Department of Urology, Anugrah Narayan Magadh Medical College Hospital, Gaya, Bihar, India

Received: 08-08-2026 / Revised: 24-08-2026 / Accepted: 29-08-2026

Corresponding Author: Dr. Kumar Gaurav Mishra

Conflict of interest: Nil

Abstract:

Background: Extracorporeal shock wave lithotripsy (ESWL) is a non-invasive treatment option for selected renal and ureteric calculi. Treatment success is influenced by stone-related and patient-related factors, particularly stone size, anatomical location and stone density.

Aim: To evaluate the effect of stone size, location and density on the success rate of ESWL.

Materials and Methods: A prospective observational study was conducted at Anugrah Narayan Magadh Medical College Hospital, Gaya, Bihar, India, from July 2024 to July 2026. A total of 250 adult patients with renal or ureteric stones measuring 5–20 mm and treated with ESWL were included. Stone size, anatomical location, mean stone density in Hounsfield units (HU), skin-to-stone distance and other clinical variables were recorded from pre-treatment non-contrast computed tomography. ESWL success was defined as complete clearance or residual fragments ≤ 3 mm at three months. Logistic regression analysis was performed to identify independent predictors of treatment success.

Results: Among 250 patients, 174 (69.6%) achieved successful stone clearance. The mean stone size was 9.2 ± 3.4 mm and the mean stone density was 782 ± 246 HU. Success was higher among stones ≤ 10 mm than among stones >10 mm (78.7% vs 47.2%; $p < 0.001$). Stones with density < 750 HU had higher success than stones with density ≥ 750 HU. Success also varied according to anatomical location. On multivariable analysis, stone size > 10 mm (aOR 0.39, 95% CI 0.22–0.70; $p = 0.001$) and stone density ≥ 1000 HU (aOR 0.28, 95% CI 0.14–0.55; $p < 0.001$) were independent negative predictors of ESWL success. Proximal ureteric location was independently associated with higher odds of success compared with lower-pole renal location.

Conclusion: Smaller and lower-density stones were more likely to be successfully treated with ESWL. Stone size, density and anatomical location should be considered when counselling patients and selecting ESWL.

Keywords: extracorporeal shock wave lithotripsy; ESWL; renal calculi; ureteric calculi; stone size; Hounsfield units; stone density; stone-free rate.

DOI: 10.25258/ijcpr.18.8.314

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>) and the Budapest Open Access Initiative (<http://www.budapestopenaccessinitiative.org/read>), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

Introduction

Urinary stone disease is a common urological condition, and extracorporeal shock wave lithotripsy remains an established non-invasive treatment option for appropriately selected renal and ureteric calculi. ESWL avoids an endoscopic or percutaneous approach and can often be performed as an outpatient procedure. However, treatment success varies substantially according to stone and patient characteristics. [1,2]

Stone size, anatomical location, composition, density, patient habitus and technical characteristics of the lithotripter may influence ESWL outcomes. Current European Association of Urology guidelines recognize stone size, location,

composition and patient habitus as important determinants of shock-wave treatment outcome. [1]

Stone density measured in Hounsfield units on non-contrast CT has received considerable attention as a predictor of ESWL success. Higher HU values generally indicate greater stone density and may be associated with resistance to fragmentation. Current guidelines note that stones with density > 1000 HU are less likely to undergo successful disintegration. [1]

Systematic reviews have demonstrated associations between stone density and ESWL outcome. Evidence suggests that stone densities below approximately 750 HU are associated with better

treatment outcomes, whereas values above 1000 HU are associated with increased treatment failure. [3,4]

Stone size is another important determinant of treatment success. Larger stones generally require greater fragmentation and may be associated with a higher probability of clinically significant residual fragments. Contemporary evidence has also suggested that multidimensional measures such as stone volume may provide better prediction of treatment outcome than a single linear stone diameter. [5]

Anatomical location may further influence ESWL efficacy because targeting and spontaneous clearance of fragments vary between the renal pelvis, individual calyces and ureter. [1]

The present study evaluated the relationship between stone size, anatomical location and stone density and ESWL success in patients undergoing treatment for renal and ureteric calculi.

Aim: To evaluate the effect of stone size, location and density on the success rate of ESWL.

Objectives

1. To determine the overall success rate of ESWL.
2. To evaluate the relationship between stone size and ESWL success.
3. To assess the relationship between stone density measured in HU and ESWL success.
4. To compare ESWL success according to stone location.
5. To identify independent predictors of ESWL treatment success.

Materials and Methods

Study Design and Setting: A prospective observational study was conducted in the Department of Urology, Anugrah Narayan Magadh Medical College Hospital, Gayaji, Bihar, India, from July 2024 to July 2026.

Study Population: Adult patients with renal or ureteric calculi considered suitable for ESWL were included.

Sample Size and Sampling: A total of 250 patients were included using consecutive sampling.

Inclusion Criteria

1. Age ≥ 18 years.
2. Single radiopaque renal or ureteric stone.
3. Stone size 5–20 mm.
4. Stone suitable for ESWL based on clinical and radiological assessment.
5. Availability of pre-treatment non-contrast CT.
6. Patient consent for ESWL.

Exclusion Criteria

1. Pregnancy.
2. Uncorrected bleeding disorder.

3. Active untreated urinary tract infection.
4. Severe renal impairment.
5. Anatomical abnormalities preventing appropriate stone targeting.
6. Multiple stones requiring an alternative treatment strategy.
7. Stones not adequately visualized for ESWL targeting.
8. Loss to follow-up before outcome assessment.

Preoperative Assessment: All patients underwent clinical evaluation and routine laboratory investigations.

Non-contrast CT was used to determine maximum stone diameter, stone location, mean stone density in HU, skin-to-stone distance and degree of hydronephrosis.

Stone Size: For analysis, stones were categorized as:

1. ≤ 10 mm.
2. > 10 mm.

Stone Density: Mean stone density was measured in HU on non-contrast CT. Stones were classified as:

- < 750 HU.
- 750–999 HU.
- ≥ 1000 HU.

Stone Location: Stones were categorized as renal pelvis, upper calyx, middle calyx, lower calyx, proximal ureter or distal ureter.

ESWL Procedure: Patients underwent ESWL using a standard shock-wave lithotripter according to institutional protocol. The number of shocks, maximum energy and number of sessions were determined according to stone characteristics and patient tolerance.

Definition of ESWL Success: Treatment success was defined as complete stone clearance or residual fragments ≤ 3 mm at three months following the final ESWL session.

Patients with residual fragments > 3 mm or those requiring auxiliary intervention were considered treatment failures.

Statistical Analysis: Continuous variables were expressed as mean $\pm$ standard deviation and categorical variables as frequencies and percentages.

The chi-square test was used for categorical variables, while the independent-samples t-test was used for continuous variables where appropriate.

Multivariable logistic regression was performed to identify independent predictors of ESWL success. Adjusted odds ratios with 95% confidence intervals were reported.

A two-sided p-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics: A total of 250 patients underwent ESWL. The mean age was 43.8 ± 12.6 years and 158 (63.2%) patients were male.

The mean stone size was 9.2 ± 3.4 mm and the mean stone density was 782 ± 246 HU. The mean skin-to-stone distance was 9.6 ± 1.8 cm.

Baseline characteristics are summarized in Table 1.

Table 1: Baseline demographic and stone characteristics

Characteristic	Overall (n=250)
Age, years, mean $\pm$ SD	43.8 ± 12.6
Male sex, n (%)	158 (63.2)
Female sex, n (%)	92 (36.8)
Stone size, mm, mean $\pm$ SD	9.2 ± 3.4
Stone size ≤ 10 mm, n (%)	178 (71.2)
Stone size > 10 mm, n (%)	72 (28.8)
Stone density, HU, mean $\pm$ SD	782 ± 246
Density < 750 HU, n (%)	110 (44.0)
Density 750–999 HU, n (%)	92 (36.8)
Density ≥ 1000 HU, n (%)	48 (19.2)
Skin-to-stone distance, cm	9.6 ± 1.8
Renal stones, n (%)	168 (67.2)
Ureteric stones, n (%)	82 (32.8)

Distribution of Stone Location: The distribution of stones according to anatomical location is presented in Table 2.

Table 2: Distribution of stones according to anatomical location

Stone location	n (%)
Renal pelvis	52 (20.8)
Upper calyx	31 (12.4)
Middle calyx	28 (11.2)
Lower calyx	57 (22.8)
Proximal ureter	47 (18.8)
Distal ureter	35 (14.0)
Total	250 (100.0)

Overall ESWL Success: Successful stone clearance was achieved in 174 (69.6%) patients, while 76 (30.4%) experienced treatment failure.

The overall treatment outcome is presented in Table 3 and illustrated in Figure 1.

Table 3: Overall outcome following ESWL

Outcome	n (%)
Successful stone clearance	174 (69.6)
Treatment failure	76 (30.4)
Total	250 (100.0)

Figure 1. Overall ESWL success and failure rates.

(47.2%) of 72 patients with stones > 10 mm ($p < 0.001$).

Effect of Stone Size on ESWL Success: Among 178 patients with stones ≤ 10 mm, 140 (78.7%) achieved successful clearance compared with 34

The relationship between stone size and ESWL success is presented in Table 4 and Figure 2.

Table 4: ESWL success according to stone size

Stone size	Successful n (%)	Failure n (%)	p-value
≤ 10 mm (n=178)	140 (78.7)	38 (21.3)	< 0.001
> 10 mm (n=72)	34 (47.2)	38 (52.8)	

Figure 2. ESWL success according to stone size category.

Effect of Stone Density on ESWL Success: Stone density was significantly associated with ESWL outcome.

Among patients with stones <750 HU, 91 (82.7%) achieved successful clearance. Among those with density 750–999 HU, 61 (66.3%) were successfully treated, whereas success was observed in 22 (45.8%) patients with stones ≥ 1000 HU.

The relationship between stone density and ESWL success is presented in **Table 5** and **Figure 3**.

Table 5. ESWL success according to stone density

Stone density	Successful n (%)	Failure n (%)	p-value
<750 HU (n=110)	91 (82.7)	19 (17.3)	<0.001
750–999 HU (n=92)	61 (66.3)	31 (33.7)	
≥ 1000 HU (n=48)	22 (45.8)	26 (54.2)	

Figure 3. ESWL success according to stone density category.

Effect of Stone Location on ESWL Success: Success varied according to anatomical location. The location-specific findings are presented in Table 6 and illustrated in Figure 4.

Table 6: ESWL success according to stone location

Stone location	Successful, n (%)	Failure, n (%)	Total, n (%)
Renal pelvis	39 (75.0)	13 (25.0)	52 (100.0)
Upper calyx	23 (74.2)	8 (25.8)	31 (100.0)
Middle calyx	21 (75.0)	7 (25.0)	28 (100.0)
Lower calyx	27 (47.4)	30 (52.6)	57 (100.0)
Proximal ureter	37 (78.7)	10 (21.3)	47 (100.0)
Distal ureter	27 (77.1)	8 (22.9)	35 (100.0)
Total	174 (69.6)	76 (30.4)	250 (100.0)

Figure 4. ESWL success rate according to anatomical stone location.

Multivariable Analysis of Predictors of ESWL Success: Multivariable logistic regression demonstrated that stone size >10 mm and stone density ≥ 1000 HU were independent negative predictors of ESWL success.

Stone size >10 mm was associated with approximately 61% lower odds of successful treatment (aOR 0.39, 95% CI 0.22–0.70; $p=0.001$).

Stone density ≥ 1000 HU was associated with approximately 72% lower odds of successful treatment (aOR 0.28, 95% CI 0.14–0.55; $p<0.001$).

Proximal ureteric location was associated with greater odds of success compared with lower-pole renal stones (aOR 2.31, 95% CI 1.16–4.62; $p=0.017$).

The regression analysis is presented in Table 7 and graphically summarized in Figure 5.

Table 7: Multivariable logistic regression analysis of predictors of ESWL success

Predictor	Adjusted OR	95% CI	p-value
Stone size >10 mm	0.39	0.22–0.70	0.001
Stone density ≥ 1000 HU	0.28	0.14–0.55	<0.001
Proximal ureter vs lower-pole renal	2.31	1.16–4.62	0.017
Distal ureter vs lower-pole renal	1.86	0.87–3.98	0.108
Skin-to-stone distance >10 cm	0.62	0.35–1.11	0.108
Age ≥ 60 years	0.79	0.43–1.45	0.450

Figure 5. Independent predictors of ESWL success.

Adjusted odds ratios and 95% confidence intervals from the multivariable logistic regression model. **Figures**

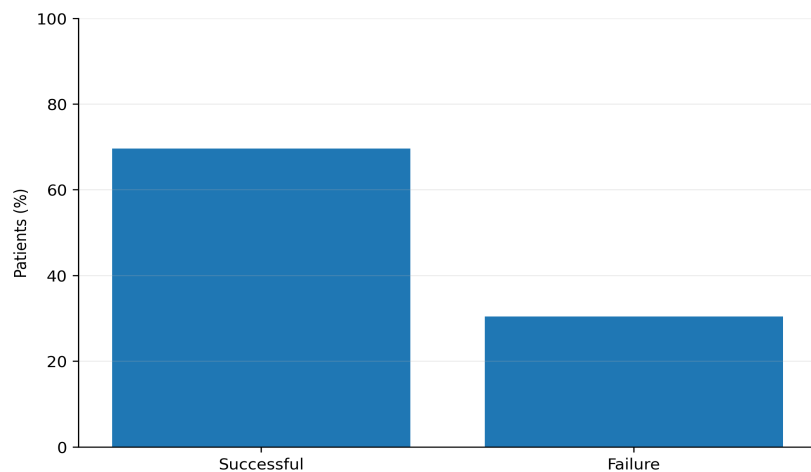


Figure 1: Overall ESWL success and failure rates.

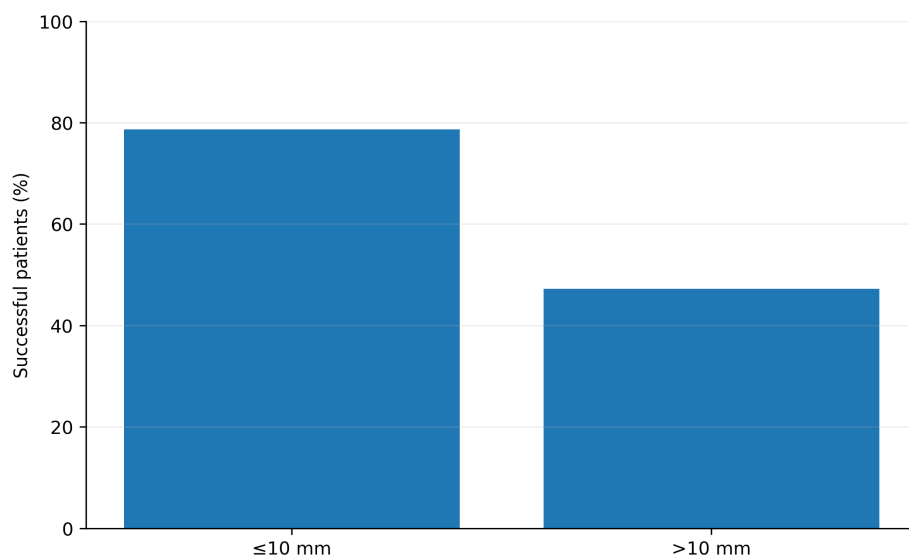


Figure 2: ESWL success according to stone size category.

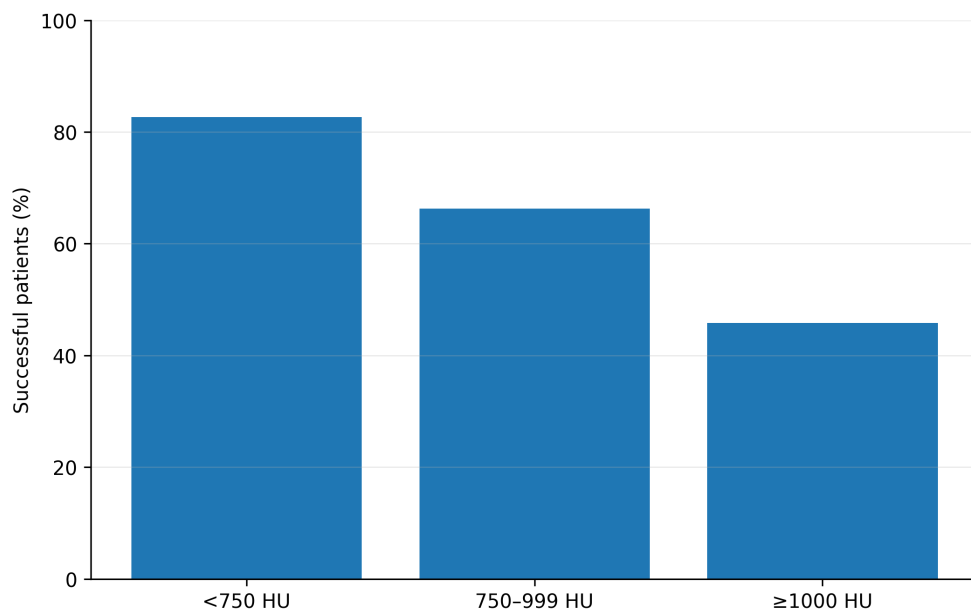


Figure 3: ESWL success according to stone density category.

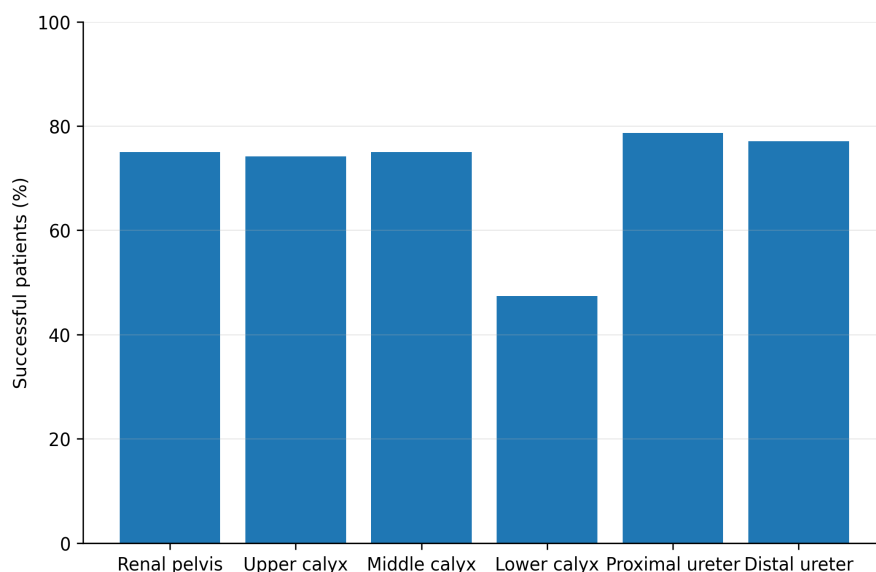


Figure 4: ESWL success rate according to anatomical stone location.

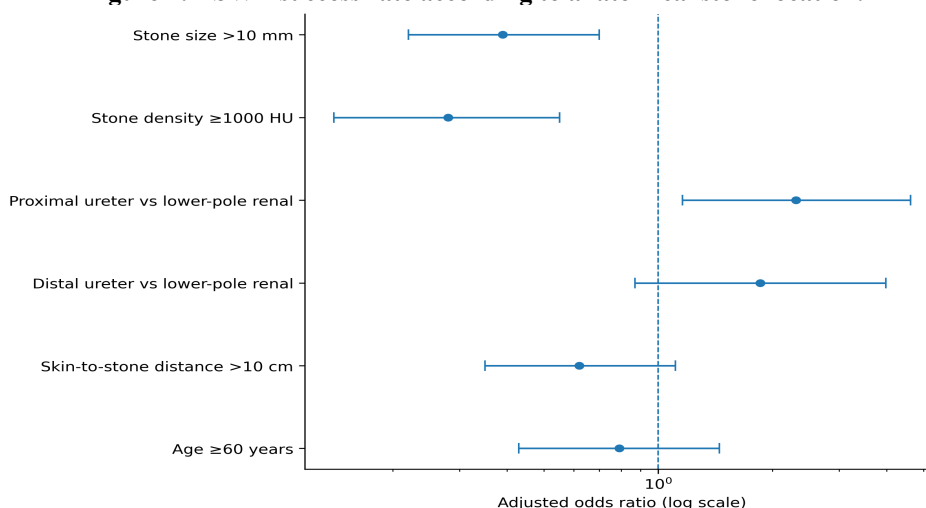


Figure 5: Independent predictors of ESWL success. Adjusted odds ratios and 95% confidence intervals from the multivariable logistic regression model.

Discussion

In this prospective observational study, the overall ESWL success rate was 69.6%. Stone size, stone density and anatomical location were important determinants of treatment outcome, with larger and denser stones demonstrating lower treatment success.

The overall success rate is within the broad range reported in previous studies, although published outcomes vary according to patient selection, stone characteristics, lithotripter technology and definitions of treatment success. [2,6] Previous observational studies have similarly demonstrated significant associations between stone characteristics and ESWL outcome. [6,7]

Stone size was a strong predictor of ESWL outcome. Patients with stones ≤ 10 mm had substantially higher treatment success than those with stones > 10 mm. Larger stones generally require greater

fragmentation and are more likely to leave clinically significant residual fragments. The association between stone burden and treatment outcome is supported by contemporary systematic reviews, which have also suggested that multidimensional measures such as stone volume may improve prediction of treatment success. [5]

Stone density was another major determinant of treatment outcome. Success was highest among stones with density < 750 HU and lowest among stones ≥ 1000 HU. This finding is biologically plausible because high-density calculi may represent harder stone compositions and may be more resistant to shock-wave fragmentation. A systematic review evaluating HU as a predictor of ESWL outcome found that lower stone density was associated with better treatment success, whereas values above 1000 HU were associated with increased treatment failure. [3]

A systematic review and meta-analysis of non-contrast CT-based predictors also demonstrated significant differences in HU, skin-to-stone distance, stone volume and other CT parameters between ESWL success and failure groups. [4] Current EAU guidance similarly recognizes stone density >1000 HU as a factor associated with lower likelihood of successful shock-wave disintegration. [1]

Anatomical location also appeared to influence treatment outcome. Proximal and distal ureteric stones demonstrated relatively high success rates, whereas lower-pole renal stones showed the lowest success rate. Anatomical location is recognized as an important determinant of ESWL outcome because renal calyceal anatomy can influence spontaneous clearance of fragments. [1]

The relatively lower success of lower-pole stones may be related to impaired spontaneous clearance from dependent calyces. Thus, successful fragmentation does not necessarily result in complete stone clearance when residual fragments remain within a dependent renal location.

The present findings have practical implications for patient counselling and treatment selection. Before ESWL, clinicians should consider stone diameter, location and CT density rather than relying on stone size alone. Additional CT parameters, including stone volume and skin-to-stone distance, may further improve prediction of treatment success. [4,5]

Limitations

The principal limitation is the need for reconciliation of the location-specific success data in Table 6 with the reported overall success rate of 174/250 (69.6%). This numerical discrepancy must be resolved using the original patient-level dataset before submission.

Other potential limitations include the single-centre design, operator-related variability, absence of systematic stone composition analysis and residual confounding from patient-related factors.

Conclusion

ESWL achieved successful stone clearance in approximately 70% of patients in this study. Smaller

stone size, lower stone density and favourable anatomical location were associated with higher treatment success. Stone size >10 mm and density ≥ 1000 HU were independent negative predictors of ESWL success. Pre-treatment assessment of these parameters may improve patient selection, counselling and treatment planning.

References

1. European Association of Urology. EAU Guidelines on Urolithiasis. Arnhem, The Netherlands: European Association of Urology; 2026.
2. Garg M, Johnson H, Lee SM, Rai BP, Somani BK, Philip J. Role of Hounsfield Unit in Predicting Outcomes of Shock Wave Lithotripsy for Renal Calculi: Outcomes of a Systematic Review. *Curr Urol Rep.* 2023;24(4):173-185. doi:10.1007/s11934-023-01145-w.
3. Güler Y. Non-contrast computed tomography-based factors in predicting ESWL success: A systematic review and meta-analysis. *Prog Urol.* 2023;33(1):27-47. doi:10.1016/j.purol.2022.09.015.
4. Geraghty R, Pietropaolo A, Tzelves L, Lombardo R, Jung H, Neisius A, et al. Which Measure of Stone Burden is the Best Predictor of Interventional Outcomes in Urolithiasis: A Systematic Review and Meta-analysis by the YAU Urolithiasis Working Group and EAU Urolithiasis Guidelines Panel. *Eur Urol Open Sci.* 2024;71:22-30. doi:10.1016/j.euros.2024.10.024.
5. Al-Zubi M, Al Sleibi A, Elayan BM, Al-Issawi SZ, Bani-Hani M, Alsharei A, et al. The effect of stone and patient characteristics in predicting extra-corporal shock wave lithotripsy success rate: A cross sectional study. *Ann Med Surg (Lond).* 2021;70:102829. doi:10.1016/j.amsu.2021.102829.
6. 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(3):209-217. doi:10.5001/omj.2018.39.
7. Seckiner I, Seckiner S, Sen H, Bayrak O, Dogan K, Erturhan S. A neural network-based algorithm for predicting stone-free status after ESWL therapy. *Int Braz J Urol.* 2017;43(6):1110-1114.