

Predictors of Proximal Stone Migration During Ureteroscopic Pneumatic Lithotripsy For Proximal Ureteric Calculi: A Retrospective Study

A Ramesh¹, Dr. Bhaskarappurakash. A. R², Dr. V. Selvaraj³, Dr. Vijaya Suriya. R⁴

¹Senior Resident, Department of Urology, MMCHRI, Kanchipuram

²Associate Professor, Department of Urology, MMCHRI, Kanchipuram. (Corresponding author)

³Professor & HOD, Department of Urology, MMCHRI, Kanchipuram

⁴Assistant Professor, Department of Urology, MMCHRI, Kanchipuram

ABSTRACT

Background:

Proximal stone migration during semirigid ureteroscopic pneumatic lithotripsy is a common cause of procedural failure, resulting in reduced stone-free rates and increased need for secondary interventions. Identifying factors associated with stone migration may help improve surgical planning and outcomes.

Aim:

To evaluate the predictors of proximal stone migration during ureteroscopic pneumatic lithotripsy in patients with proximal ureteric calculi.

Methods:

This retrospective observational analytical study included 150 adult patients who underwent semirigid ureteroscopic pneumatic lithotripsy for a single proximal ureteric calculus. Demographic, clinical, radiological, operative, and postoperative data were collected from hospital records. Patients were categorized into migration and non-migration groups. Univariate analysis followed by multivariable logistic regression was performed to identify independent predictors of proximal stone migration. Statistical significance was considered at $p < 0.05$.

Results:

Proximal stone migration occurred in 31 patients (20.7%). Patients with migration had significantly larger stones (13.9 ± 2.8 mm vs. 10.8 ± 2.5 mm; $p < 0.001$), higher stone density (1125 ± 180 HU vs. 945 ± 165 HU; $p < 0.001$), a greater incidence of impacted stones (74.2% vs. 37.8%; $p < 0.001$), and more moderate-to-severe hydronephrosis (61.3% vs. 29.4%; $p = 0.002$). The migration group had significantly lower stone-free rates (38.7% vs. 95.8%; $p < 0.001$), higher rates of secondary procedures (71.0% vs. 4.2%; $p < 0.001$), and more complications (25.8% vs. 8.4%; $p = 0.009$). Multivariable logistic regression identified stone size ≥ 12 mm (OR 3.82; $p = 0.002$), impacted stone (OR 3.11; $p = 0.011$), stone density ≥ 1000 HU (OR 2.68; $p = 0.019$), and non-use of an anti-retropulsion device (OR 4.27; $p = 0.003$) as independent predictors of proximal stone migration.

Conclusion:

Proximal stone migration occurred in approximately one-fifth of patients undergoing semirigid ureteroscopic pneumatic lithotripsy. Larger stone size, higher stone density, stone impaction, and non-use of anti-retropulsion devices were independent predictors of migration. Early identification of high-risk patients and the selective use of anti-retropulsion devices may improve stone-free rates and reduce the need for secondary procedures.

Keywords: Proximal ureteric calculi; ureteroscopy; pneumatic lithotripsy; stone migration; retropulsion; predictors; anti-retropulsion device.

INTRODUCTION

Urolithiasis is a common urological disorder affecting millions of individuals worldwide and represents a significant cause of morbidity and healthcare expenditure. The global prevalence of urinary stone disease has increased steadily over the past few decades, largely due to changes in dietary habits, sedentary lifestyles, obesity, metabolic syndrome, and environmental factors. The lifetime risk of developing urinary calculi is estimated to be between 10% and 15%, with recurrence rates approaching 50% within ten years of the initial episode. Ureteric stones constitute a substantial proportion of urinary tract calculi, and proximal ureteric calculi are particularly important because they frequently cause obstruction, hydronephrosis, recurrent renal colic, urinary tract infections, and deterioration of renal function if not managed appropriately.¹

The management of ureteric stones has evolved considerably with advances in endourological technology. Ureteroscopic lithotripsy (URSL) has emerged as one of the most effective and widely accepted treatment modalities for ureteric calculi, offering high stone-free rates, minimal invasiveness, and rapid postoperative recovery. Current international guidelines recommend ureteroscopy as a primary treatment option for proximal ureteric stones, particularly when stone size exceeds 10 mm or when extracorporeal shock wave lithotripsy (ESWL) is unlikely to be successful. Technological advancements in ureteroscopes, guidewires, optical systems, and lithotripsy devices have further improved procedural efficacy and safety.²

Among the available intracorporeal lithotripsy modalities, pneumatic lithotripsy continues to be extensively used in many developing countries because of its affordability, ease of use, reliability, and effective stone fragmentation capability. Pneumatic lithotripters utilize compressed air to generate ballistic energy, which is transmitted through a metallic probe to fragment the stone. Despite its effectiveness, pneumatic lithotripsy is associated with a significant drawback known as proximal stone migration or retropulsion. This phenomenon occurs when the stone or its fragments are displaced retrogradely from the ureter into the renal pelvis or calyceal system during fragmentation.³

Proximal stone migration remains one of the most common intraoperative challenges encountered during ureteroscopic pneumatic lithotripsy. The reported incidence varies widely, ranging from approximately 5% to 30% depending on stone characteristics, anatomical factors, surgical technique, and the use of anti-retropulsion devices. The ballistic mechanism of pneumatic lithotripsy generates a “jackhammer effect,” which can propel the stone upward before complete fragmentation is achieved. Migration may also be facilitated by irrigation flow, ureteral dilatation, hydronephrosis, and the presence of a capacious renal collecting system.⁴

The clinical consequences of stone migration are significant. Retropulsion may result in incomplete stone clearance, prolonged operative duration, increased fluoroscopy exposure, and reduced stone-free rates. In many cases, migrated fragments require additional interventions such as repeat ureteroscopy, retrograde intrarenal surgery (RIRS), extracorporeal shock wave lithotripsy, or percutaneous nephrolithotomy. These secondary procedures increase healthcare costs, expose patients to additional anesthesia and procedural risks, and negatively impact patient satisfaction. Therefore, understanding the factors that predispose to stone migration is essential for optimizing treatment outcomes.⁵

Several studies have investigated potential predictors of proximal stone migration. Factors such as stone size, stone location, degree of hydronephrosis, stone impaction, ureteral diameter, irrigation pressure, operative duration, surgeon experience, and the use of anti-retropulsion devices have been reported to influence the likelihood of migration. However, the findings remain inconsistent, and many studies have been conducted in settings where laser lithotripsy has largely replaced pneumatic lithotripsy. Consequently, evidence regarding predictors of migration during pneumatic lithotripsy, particularly in resource-limited settings where this technology remains widely utilized, is relatively scarce.^{6,7}

Identification of reliable predictors of proximal stone migration would enable surgeons to recognize high-risk cases preoperatively, select appropriate treatment strategies, employ preventive measures such as anti-retropulsion devices, and provide better patient counseling regarding procedural outcomes. In addition, knowledge of these factors may help improve stone-free rates, reduce the need for secondary interventions, and enhance the overall efficiency of endourological stone management. Therefore, the present study aims to evaluate the clinical, radiological, and operative predictors of proximal stone migration in patients undergoing ureteroscopic pneumatic lithotripsy for proximal ureteric calculi.

MATERIALS AND METHODS

This retrospective observational analytical study was conducted in the Department of Urology, Meenakshi Medical College, Kanchipuram, over a period of 18 months to evaluate the predictors of proximal stone migration during ureteroscopic pneumatic lithotripsy in patients with proximal ureteric calculi. All eligible patients aged 18 years and above who underwent semirigid ureteroscopic pneumatic lithotripsy for a single proximal ureteric stone during the study period were included, with an estimated sample size of 150 patients. Patients with mid or distal ureteric stones, bilateral or multiple ureteric calculi, concomitant renal calculi, congenital urinary tract anomalies, previous ureteral reconstructive surgery, laser lithotripsy, or incomplete records were excluded. A proximal ureteric stone was defined as a stone located between the ureteropelvic junction and the upper border of the sacroiliac joint, while proximal stone migration was defined as intraoperative displacement of the stone or significant fragments into the renal collecting system during pneumatic lithotripsy.

Data were collected retrospectively from hospital records, operative notes, radiological imaging, anesthesia records, and discharge summaries using a structured proforma. Demographic, clinical, radiological, and operative variables, including age, sex, body mass index, stone size, stone density, hydronephrosis, stone impaction, operative duration, irrigation pressure, guidewire use, anti-retropulsion device use, and surgeon experience, were recorded. The primary outcome was proximal stone migration, while secondary outcomes included stone-free rate, requirement for secondary procedures, hospital stay, and perioperative complications graded according to the Clavien–Dindo classification.

Statistical analysis was performed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation or median (interquartile range) and compared using the Independent Student's t-

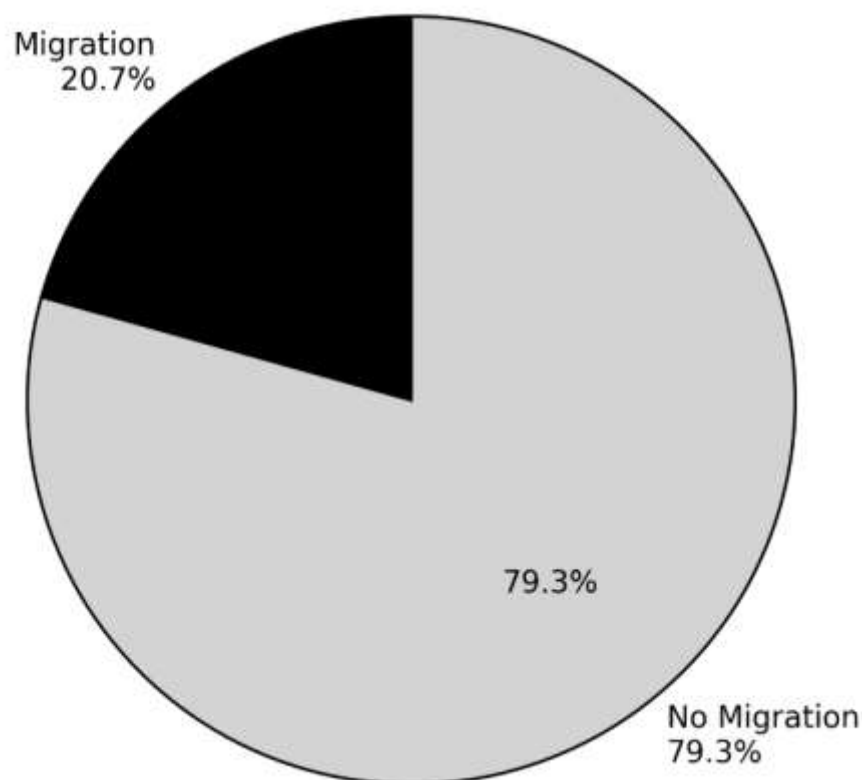
test or Mann–Whitney U test, while categorical variables were compared using the Chi-square test or Fisher's exact test. Variables with a p-value <0.20 on univariate analysis were included in multivariable logistic regression to identify independent predictors of proximal stone migration. Adjusted odds ratios with 95% confidence intervals were calculated, and a p-value <0.05 was considered statistically significant.

Institutional Ethics Committee approval was obtained before the study. Patient confidentiality was maintained by anonymizing all data, and the study was conducted in accordance with the Declaration of Helsinki and institutional ethical guidelines.

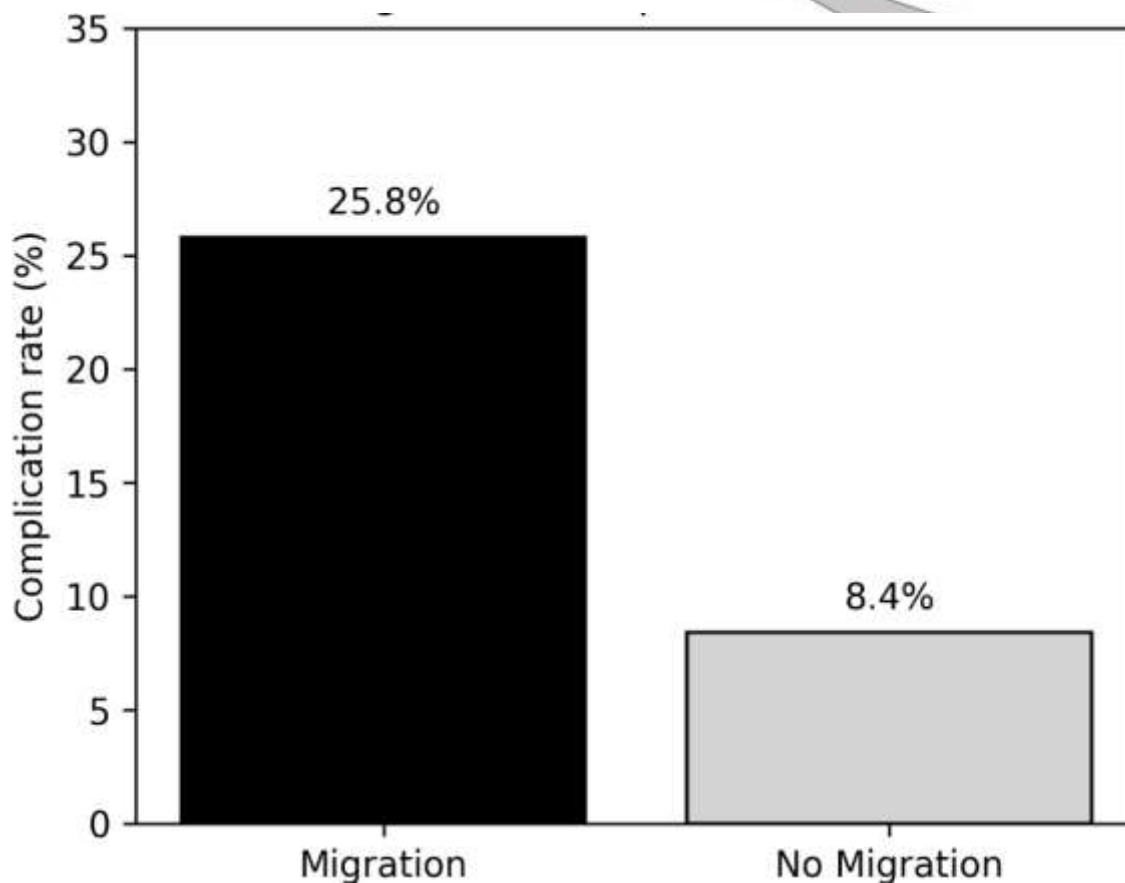
RESULTS

A total of 150 patients underwent semirigid ureteroscopic pneumatic lithotripsy for proximal ureteric calculi. Proximal stone migration occurred in 31 patients (20.7%). Patients with stone migration had significantly larger stones (13.9 ± 2.8 mm vs. 10.8 ± 2.5 mm; $p<0.001$), higher stone density (1125 ± 180 HU vs. 945 ± 165 HU; $p<0.001$), a higher incidence of impacted stones (74.2% vs. 37.8%; $p<0.001$), and more moderate-to-severe hydronephrosis (61.3% vs. 29.4%; $p=0.002$). Operative time was longer (54.8 ± 12.3 vs. 41.2 ± 9.8 minutes; $p<0.001$), and anti-retropulsion devices were used less frequently (19.4% vs. 52.9%; $p=0.001$) in the migration group.

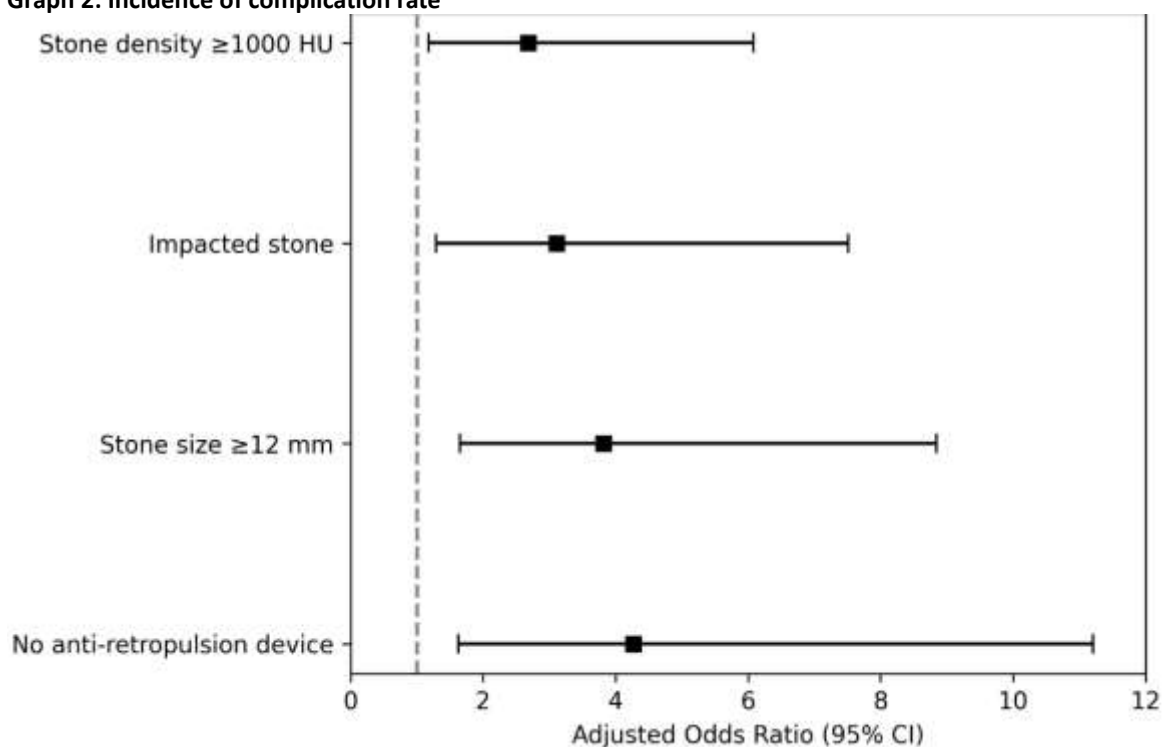
The stone-free rate was significantly lower (38.7% vs. 95.8%; $p<0.001$), while the need for secondary procedures (71.0% vs. 4.2%; $p<0.001$) and complication rate (25.8% vs. 8.4%; $p=0.009$) were significantly higher in patients with stone migration. Multivariable logistic regression identified stone size ≥ 12 mm (OR 3.82, $p=0.002$), impacted stone (OR 3.11, $p=0.011$), stone density ≥ 1000 HU (OR 2.68, $p=0.019$), and non-use of an anti-retropulsion device (OR 4.27, $p=0.003$) as independent predictors of proximal stone migration.



Graph 1: Incidence of proximal stone migration



Graph 2: Incidence of complication rate



Graph 3: Forest plot showing independent predictors proximal stone migration.

DISCUSSION

The present study evaluated the predictors of proximal stone migration during semirigid ureteroscopic pneumatic lithotripsy in patients with proximal ureteric calculi. Proximal stone migration occurred in 20.7% of patients, which is comparable with previously reported migration rates ranging from 15% to 35% during

pneumatic lithotripsy. Stone retropulsion remains a major limitation of pneumatic lithotripsy, particularly in the management of proximal ureteric stones because of the direct transmission of ballistic energy to the calculus. Stone size was identified as an independent predictor of proximal stone migration in the present study. Patients with migration had significantly larger stones than those without migration (13.9 ± 2.8 mm vs. 10.8 ± 2.5 mm, $p < 0.001$), and stones measuring ≥ 12 mm increased the likelihood of migration by nearly four-fold (OR 3.82, $p = 0.002$).

The findings of the present study are consistent with those of Yalcin et al.⁶ (2006), who evaluated 433 patients undergoing ureteroscopic pneumatic lithotripsy and reported that anatomical and technical factors, including a longer proximal ureteral segment and lower surgeon experience, were significant predictors of stone migration and procedural failure. In the present study, operative factors also played an important role, with non-use of an anti-retropulsion device emerging as an independent predictor of proximal stone migration (OR 4.27, $p = 0.003$). Additionally, larger stone size and stone impaction were identified as significant predictors, emphasizing the combined influence of stone characteristics and surgical technique on treatment outcomes. Stone density was significant predictor in the present study. Stones with a density ≥ 1000 HU were associated with a significantly higher risk of migration (OR 2.68, $p = 0.019$). Higher-density calculi require greater fragmentation energy and repeated pneumatic impacts, thereby increasing the likelihood of retropulsion.

Our results also corroborate the findings of Farahat et al.⁷ (2011), who demonstrated that the use of Stone Cone and N-Trap devices significantly reduced proximal stone migration and improved stone-free rates during pneumatic lithotripsy. Similarly, the present study found that anti-retropulsion devices were used significantly less frequently in the migration group (19.4% vs. 52.9%, $p = 0.001$), and patients without these devices had a four-fold higher risk of migration. Furthermore, stone-free rates were significantly lower (38.7% vs. 95.8%, $p < 0.001$) and the requirement for secondary procedures was significantly higher (71.0% vs. 4.2%, $p < 0.001$) among patients with proximal stone migration.

Stone impaction showed a strong association with proximal migration (OR 3.11, $p = 0.011$). Although impacted stones are often considered relatively fixed within the ureter, fragmentation of these calculi can release the stone abruptly, resulting in proximal displacement of fragments. The use of anti-retropulsion devices significantly reduced proximal stone migration in the present study. Patients in whom these devices were not used had more than four times the risk of migration (OR 4.27, $p = 0.003$).

The present findings are further supported by the meta-analysis conducted by Ding et al.⁸ (2012), which included 456 patients and demonstrated that the N-Trap device significantly reduced stone migration (OR 0.23; 95% CI 0.10–0.53) and improved stone-free rates while decreasing the need for auxiliary procedures. Likewise, the current study showed that the absence of an anti-retropulsion device was an independent predictor of migration, reinforcing the effectiveness of these devices in improving surgical outcomes.

Elashry and Tawfik (2012)⁹, in their comprehensive review, emphasized that stone retropulsion is a major cause of ureteroscopic treatment failure, particularly with pneumatic lithotripsy due to its greater retropulsive force compared with laser lithotripsy. They recommended the routine use of preventive measures such as Stone Cone, N-Trap, ureteral balloons, and retrieval devices to minimize migration. The findings of the present study support these recommendations, demonstrating that proximal stone migration was associated with significantly lower stone-free rates, increased operative time, higher complication rates, and a greater need for secondary interventions, highlighting the clinical importance of preventing retropulsion during ureteroscopic pneumatic lithotripsy.

The findings of the present study have important clinical implications. Preoperative identification of patients with larger stones, high stone density, and impacted proximal ureteric calculi may help surgeons anticipate the risk of migration and select appropriate preventive strategies, including the routine use of anti-retropulsion devices or flexible ureteroscopy when indicated. Such measures may improve stone-free rates, reduce secondary procedures, shorten hospital stay, and enhance overall patient outcomes.

The present study has certain limitations. Being retrospective in design, it is subject to selection and information bias. The study was conducted at a single center, which may limit the generalizability of the findings. In addition, surgeon preference regarding irrigation pressure and the use of anti-retropulsion devices may have influenced the outcomes. Nevertheless, the inclusion of a relatively large cohort and the use of multivariable logistic regression strengthened the validity of the results by identifying independent predictors of proximal stone migration.

CONCLUSION

Proximal stone migration remains a significant challenge during semirigid ureteroscopic pneumatic lithotripsy for proximal ureteric calculi. Larger stone size, higher stone density, stone impaction, and non-use of anti-

retropulsion devices were identified as independent predictors of stone migration. Stone migration was associated with lower stone-free rates, increased need for secondary procedures, longer operative time, and higher complication rates. Preoperative identification of high-risk patients and the selective use of anti-retropulsion devices may improve procedural success and overall patient outcomes.

REFERENCES

1. Dretler SP. Ureterscopy for proximal ureteral calculi: prevention of stone migration. *J Endourol.* 2000;14(7):565-567.
2. Maislos SD, Volpe M, Albert PS, Raboy A. Efficacy of the Stone Cone for treatment of proximal ureteral stones. *J Endourol.* 2004;18(9):862-864.
3. Holley PG, Sharma SK, Perry KT, Turk TM. Assessment of a novel ureteral occlusion device and comparison with Stone Cone in prevention of stone fragment migration during lithotripsy. *J Endourol.* 2005;19(2):200-203.
4. Zehri AA, Ather MH, Siddiqui KM, Sulaiman MN. A randomized clinical trial of lidocaine jelly for prevention of inadvertent retrograde stone migration during pneumatic lithotripsy of ureteral stone. *J Urol.* 2008;180(3):966-968. doi:10.1016/j.juro.2008.05.008.
5. Wang CJ, Huang SW, Chang CH. Randomized trial of NTrap for proximal ureteral stones. *Urology.* 2011;77(3):553-557.
6. Yalcin V, Erol A, Batislam E, Basar MM, Tuglu D. Operative failure during ureteroscopic pneumatic lithotripsy: factors affecting successful outcome. *Urol Int.* 2006;77(2):148-151. doi:10.1159/000093909.
7. Farahat YA, Elbahnasy AE, Elashry OM. A randomized prospective controlled study for assessment of different ureteral occlusion devices in prevention of stone migration during pneumatic lithotripsy. *Urology.* 2011;77(1):30-35. doi:10.1016/j.urology.2010.05.063.
8. Ding H, Wang Z, Du W, Zhang H. NTrap in prevention of stone migration during ureteroscopic lithotripsy for proximal ureteral stones: a meta-analysis. *J Endourol.* 2012;26(2):130-134. doi:10.1089/end.2011.0392
9. Elashry OM, Tawfik AM. Preventing stone retropulsion during intracorporeal lithotripsy. *Nat Rev Urol.* 2012;9(12):691-698. doi:10.1038/nrurol.2012.204.