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Transrenal Antegrade Ureteral Occlusion Assisting Percutaneous Nephrolithotomy: A Preliminary Single-Center Study

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Abstract

Objective: To evaluate the efficacy and safety of antegrade ureteral occlusion during Mini Percutaneous Nephrolithotomy(mPCNL).

Methods: A retrospective analysis was conducted on patients who underwent mPCNL at our institution between December 2021 and December 2023. Based on the use of a ureteral occluder for intraoperative antegrade ureteral occlusion, patients were categorized into Occlusion-Assisted(OA) mPCNL group and standard mPCNL group. Two groups were compared in terms of operative time, intraoperative blood loss, intrarenal pelvic pressure, incidence of postoperative stone migration, length of hospital stay, first-stage stone-free rate, rate of secondary procedures, and incidence of postoperative complications.

Results: No significant differences were found between the two groups in terms of operative time, intraoperative blood loss, renal pelvic pressure, length of hospital stay, first-stage stone-free rate, or postoperative complication rate. However, the incidence of postoperative stone migration was significantly lower in OA group compared to standard group (2.4% vs. 16.7%, P = 0.029). Although the rate of secondary procedures was lower in OA group (11.9% vs. 21.4%), the difference was not statistically significant (P = 0.242). Notably, the need for retrograde intrarenal surgery (RIRS) or ureteroscopic lithotripsy (URL) was significantly lower in OA group(2.4% vs. 14.3%, P = 0.048).

Conclusion: The use of a ureteral occluder during mPCNL can effectively prevent stone migration and residual fragments during lithotripsy, and may reduce the need for secondary procedures. Its safety profile appears comparable to that of the standard procedure. Further studies are warranted to validate these findings.

1. Introduction

In the minimally invasive surgical management of renal calculi, percutaneous nephrolithotomy (PCNL) remains the standard treatment for large-volume stones (maximum diameter >2 cm) or staghorn calculi [1]. Compared to single-session Retrograde Intrarenal Surgery (RIRS), PCNL achieves a higher stone clearance rate. With ongoing advances in surgical techniques and instrumentation, mini-PCNL (mPCNL) has demonstrated comparable stone clearance outcomes to standard PCNL while reducing operative trauma and perioperative complications [2–4]. However, during mPCNL, distal migration of stone fragments into the ureter can still occur, potentially leading to ureteral obstruction and necessitating secondary interventions [3,5]. These complications not only increase patient discomfort but also add to the economic burden. Ureteral occluders are commonly used during

ureteroscopic lithotripsy to prevent proximal stone migration, thereby significantly improving stone-free rates [6]. Nevertheless, the use of ureteral occluders in PCNL has not been extensively studied, and current evidence remains limited.

2. Patients and Methods

2.1 Study Design and Inclusion Criteria

This was a retrospective study of patients with renal calculi who underwent Percutaneous Nephrolithotomy (PCNL) at our hospital between December 2021 and December 2023. Patients were categorized into two groups based on whether a ureteral occluder was used intraoperatively(as judged by the same surgeon): the occlusion-assisted mPCNL group and the standard mPCNL group.

Inclusion criteria

- Diagnosis of renal calculi confirmed by imaging, in accordance with the Chinese Guidelines for the Diagnosis and Treatment of Urological Diseases [6,7];
- Age between 18 and 70 years;
- Maximum stone diameter between 2.0 cm and 4.0 cm;
- Mild hydronephrosis or absence of hydronephrosis;
- Normal serum creatinine level (<133 μmol/L).

Exclusion criteria

- Renal insufficiency or patients on dialysis;
- Acute urinary tract infection within 2 weeks prior to surgery;
- Congenital urinary tract malformations;
- History of prior PCNL or ureteroplasty.

2.2 Surgical Procedures and Research Methods

All patients underwent preoperative evaluation including urinary ultrasound, kidney-ureter-bladder (KUB) X-ray, and 1-mm thin-slice Computed Tomography (CT) scans. All surgeries were performed by the same senior urologist to ensure consistency.

Under general anesthesia with endotracheal intubation, the procedure began with the patient in the lithotomy position, as a 6 Fr ureteral catheter was inserted retrograde through ureteroscope, guided by a guidewire, into the renal pelvis. Low-pressure irrigation was performed via the catheter to dilate the collecting system. The patient was then repositioned into the lateral decubitus position. Under ultrasound guidance, an 18G puncture needle was used to access the middle or lower renal calyx. Successful entry into the collecting system was confirmed by urine outflow from the needle tip. A guidewire was then advanced through the needle, and percutaneous tract dilation was performed sequentially up to 18 Fr using fascial dilators. An access sheath of the corresponding diameter was introduced into the kidney.

A nephroscope (WOLF) was inserted through the access sheath, and the sheath position was adjusted under direct vision for optimal visualization of the stone. Lithotripsy was performed under direct vision using either a 550 μm holmium:YAG laser fiber or pneumatic ballistic lithotripsy. Stone fragments were removed with a stone basket in conjunction with continuous irrigation and aspiration through the access sheath. At the conclusion of the procedure, a 6 Fr double-J stent and a 16–18 Fr nephrostomy tube were placed.

Occluder Placement

Upon entering the renal pelvis and identifying the Ureteropelvic Junction (UPJ), either before or during lithotripsy, a blocking catheter (IVX-OC16) was introduced through the percutaneous tract and deployed at the UPJ (Figure 1) to prevent downward migration of stone fragments into the ureter. The whole process takes less than 3 minutes. If repositioning of the access sheath was required during the procedure (e.g., to access another calyx), the occluder could be temporarily withdrawn to avoid interference with lithotripsy.

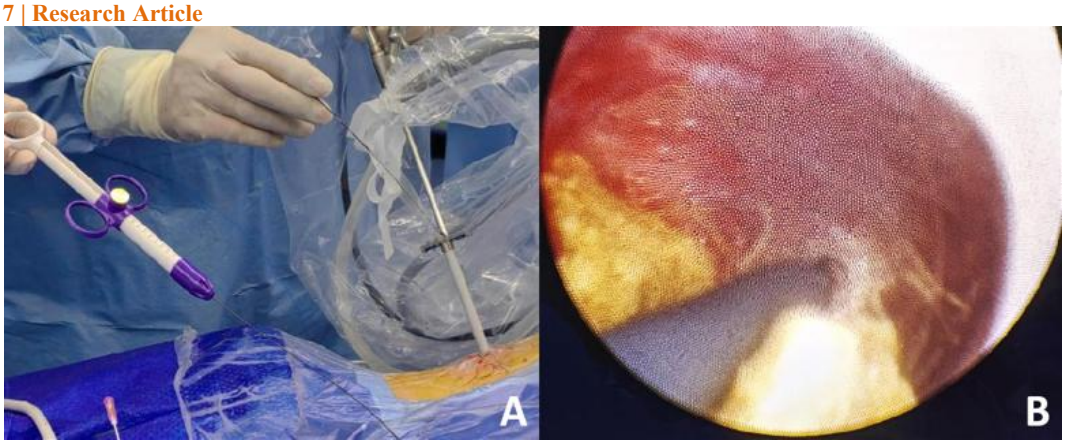

Figure 1: (A, B) A, antegrade insertion of ureteral occluder through transrenal peel-away sheath. B, stone fragments migration blocked by deployment of ureteral occlusion in UPJ.

Measurement of Intrarenal Pelvic Pressure (RPP)

A PowerPICC catheter (BD) was inserted into the collecting system via the percutaneous tract for pressure monitoring. Prior to initiating irrigation, baseline pressure was calibrated to 0 cmH_2O. Continuous irrigation was delivered using a perfusion pump at a fixed rate of 300 mL/min. Renal pelvic pressure was continuously recorded for 1 minute at three time points: 3 minutes and 15 minutes after the initiation of lithotripsy, and during the final phase of fragment removal. The average of the three measurements was used as the final recorded RPP for each patient.

2.3 Observation Indicators

Baseline patient characteristics and perioperative clinical parameters were systematically recorded and analyzed using a dedicated database. Prior to surgery, two experienced urologists jointly reviewed the imaging data to determine stone size, location, number, and CT attenuation values.

Stone size was defined as the sum of the maximum diameters of individual stones, or the largest dimension in the case of a single stone. **Stone location** was categorized into four groups: isolated renal pelvis, isolated renal calyx, multiple mixed locations, and staghorn calculi. **Stone number** was classified as either solitary (1) or multiple (>1).

Perioperative data—including laboratory results, intraoperative blood loss, operative time, postoperative complications, length of hospital stay, need for secondary surgical intervention, and renal pelvic pressure—were extracted from surgical records and inpatient case notes. Intraoperative renal pelvic pressure was recorded separately as outlined in Section 1.2.

Septic shock was defined as persistent hypotension and elevated serum lactate levels requiring vasopressor support to maintain hemodynamic stability despite adequate fluid resuscitation**. Postoperative stone migration** was defined as the movement of any stone fragment ≥6 mm in diameter into the ureter confirmed by imaging examinations such as KUB or plain CT scan following surgery. **Stone clearance rate** was evaluated one month postoperatively after removal of the ureteral stent, using either KUB or ultrasound. A patient was considered to have achieved **first-stage stone clearance** if imaging(KUB or ultrasound) showed no residual stones or only asymptomatic residual fragments <4 mm in diameter, without evidence of infection, obstruction, or need for further surgical intervention [3]. In cases where the results of KUB and ultrasound were inconsistent, thin-slice CT was used as an adjunct to guide clinical decision-making.

2.4 Statistical Analysis

Statistical analysis was performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as medians with interquartile ranges (IQR, 25th–75th percentile). Comparisons between groups for continuous variables were conducted using the t-test if normally distributed or appropriate non-parametric tests otherwise. Categorical variables were expressed as frequencies and percentages, and comparisons between groups were made using the **Chi-square (χ^2) test.** A P value < 0.05 was considered statistically significant.

3.1. Baseline Characteristics of Enrolled Patients

A total of 84 patients were included in the study, with 42 patients in the occlusion-assisted mPCNL group and 42 in the standard mPCNL group. The cohort comprised 44 males and 40 females.

There were no statistically significant differences between the two groups in terms of age, body mass index (BMI), maximum stone diameter, number of stones, stone location, stone CT attenuation value, laterality (affected side), presence of preoperative hydronephrosis, preoperative urinary tract infection, baseline hemoglobin levels, serum creatinine levels, or comorbidities ($P > 0.05$). Details of the baseline characteristics are summarized in (Table 1).

Table 1: Baseline Characteristics of Patients and Renal Stones

	AO assisted mPCNL	Standard mPCNL	P value
N	**42**	**42**	
Age（years）	50(45,55)	51(43,59)	0.631
Gender, n(%)			0.081
Male	26(61.9)	18(42.9)	
Female	16(38.1)	24(57.1)	
BMI(kg/m2)	23.2(21.8,25.2)	24.0(22.4,25.8)	0.559
Stone max lenth(mm)	28.5（24.0，34.0）	28.0（24.0，36.0）	0.941
Number of stones			0.776
1	8（19.0）	7（16.7）	
≥2	34（81.0）	35（83.3）	
CT value of stone (HU)	1100.5（956.0，1262.5）	1172.0（988.0，1375.5）	0.148
Stone location			0.909
Simple pelvic	8（19.0）	8（19.0）	
Simple calyceal	10(23.8)	8（19.0）	
Pelvis with calyceal	8（19.0）	7（16.7）	
Staghorn	16(38.1)	19(45.2)	
Laterality, n (%)			0.662
left	21(50.0)	23(54.8)	
right	21(50.0)	19(45.2)	
Hydronephrosis, n (%)	28(66.7)	34(81.0%)	0.136
Initial positive urine culture, n (%)	13(31.0)	14(33.3)	0.815
Pre-Hb (g/l)	137.0(122.0,151.0)	129.0(119.0,145.0	0.244
Pre-Cr (mmol/l)	92.0(76.0,118.0)	104.0(80.0,126.0)	0.443
Comorbidity, n (%)	14(33.3)	15(35.7)	0.818

3.2. Effectiveness

The incidence of postoperative stone migration was significantly lower in the occlusion-assisted mPCNL group compared to the standard mPCNL group (2.4% vs. 16.7%, $P = 0.029$). There was no significant difference in operative time between the two groups (126.5 vs. 132.0 minutes, $P = 0.849$). The primary stone clearance rate was higher in the occlusion-assisted group (81.0% vs. 71.4%), although this difference was not statistically significant ($P = 0.306$). Likewise, the overall rate of secondary surgical interventions was lower in the occlusion-assisted group (11.9% vs. 21.4%), but without statistical significance ($P = 0.242$). Notably, the incidence of secondary ureteroscopic surgery due to stone-related ureteral obstruction was significantly reduced in the occlusion-assisted group (2.4% vs. 14.3%, $P = 0.048$).

In both groups, two patients underwent postoperative CT scans confirming residual stones embedded in the lower calyx mucosa or located within isolated calyces; therefore, no further intervention was required. Detailed results are presented in (Table 2).

Table 2. Intraoperative and postoperative Outcomes

Variables	AO assisted mPCNL	Standard mPCNL	P value
Operative time (mins)	126.5(106.0,155.0)	132(114.0,153.0)	0.849
Hemoglobin drop (g/l)	11(6.78,16.73)	11(7.55,15.95)	0.907
Average intrarenal pressure (mmH2O)	19.50(15.28,25.93)	18.05(14.63,22.10)	0.125
Downward displacement of stone fragments, n (%)	1(2.4)	7(16.7)	0.029
hospitalization (d)	7(6.00,8.00)	7(6.00,8.00)	0.686
One-session SFR, n (%)	34(81.0)	30(71.4)	0.306
Auxiliary procedure n (%)	5(11.9)	9(21.4)	0.242
Second-look PCNL	3(7.1)	3(7.1)	1
SWL	2(4.8)	3(7.1)	0.645
RIRS/URL	1(2.4)	6(14.3)	0.048
Complications n (%)	20(47.6)	18(42.9)	0.661
Grade 1	12(28.6)	13(31.0)	0.811
Grade 2	7(16.7)	3(7.1)	0.313
Grade 3	0(0.0)	2(4.8)	0.494
Grade 4	1(2.4)	1(2.4)	1
Transfusion,	3(7.1)	3(7.1)	1
Analgesics(NSAIDs)	16(38.1)	13(31.0)	0.491
Fever(≥38°C)	5(11.9)	4(9.5)	0.724
Sepsis shock require ICU treatment	1(2.4)	1(2.4)	1

3.3 Safety

The mean Renal Pelvic Pressure (RPP) was slightly higher in the occlusion-assisted mPCNL group compared to the standard mPCNL group, but this difference was not statistically significant (19.50 vs. 18.05 cmH_2O, P = 0.125). There were no significant differences between the two groups in postoperative hemoglobin decline (11 vs. 11 g/L, P = 0.907), overall complication rate (47.6% vs. 42.9%, P = 0.661), or length of hospital stay (7 vs. 7 days, P = 0.686). Detailed data are summarized in (Table 2).

4. Discussion

mPCN has demonstrated excellent efficacy in the management of renal and upper ureteral calculi, offering high stone clearance rates and a relatively low incidence of postoperative complications. Although ureteral obstruction following mPCNL is uncommon [5,7], delayed recognition can result in serious consequences due to prolonged obstruction.

Harry H. Lee et al. identified several risk factors for ureteral obstruction after PCNL, including concurrent ipsilateral ureteroscopic procedures, absence of visible stones in the renal pelvis during surgery, and puncture through non-lower calyx access channels [8]. Migration of stone fragments into the distal ureter can lead to multiple challenges. First, the placement and retention of double-J stents become difficult, often necessitating patient repositioning into the lithotomy position for ureteroscopic lithotripsy and retrograde stent insertion. Second, if distal migration goes unnoticed intraoperatively, patients are at increased risk of requiring early secondary surgery due to acute obstruction postoperatively. Moreover, this complication may prolong the duration of nephrostomy and ureteral stent retention [3,5].

It has been reported that performing PCNL in the oblique supine position facilitates spontaneous passage of stone fragments because the access tract lies more horizontally, thereby reducing the risk of distal stone migration. However, this position presents its own challenges, including a limited surgical field, a narrower operative area, increased difficulty in establishing multiple percutaneous tracts, longer puncture channel length, and a heightened risk of colon injury [9].

Ureteral occluders are commonly utilized during transurethral ureteroscopic lithotripsy to prevent stone migration [6]. Typically, after confirming the stone's location via ureteroscopy, the occluder is retrogradely inserted into the ureter to cross the stone. Previous studies have reported certain benefits of using ureteral occluders during PCNL. Matthew Wosnitzer et al. demonstrated that

transurethral retrograde placement of a Coaxial Accordion device at the ureteropelvic junction significantly reduced stone migration during PCNL, improved stone clearance rates, and shortened both operative and hospitalization times [10]. Conversely, Kafka et al. found that retrograde placement of an occlusion balloon did not significantly improve operative time or stone clearance rate, although it was more suitable for larger stones and associated with fewer surgical complications [11]. Asvadi et al. reported that antegrade insertion of a ureteral occluder via percutaneous renal access was effective for managing refractory ureteral fistulas and hematuria [12]. However, this antegrade approach has not been previously reported in the context of PCNL.

In the present study, we conducted a preliminary single-center retrospective analysis to evaluate the efficacy and safety of antegrade ureteral occlusion-assisted PCNL. Various types of ureteral occluders—such as Stone Cone, Accordion, and N-Ttap—are currently used in clinical practice, each capable of effectively occluding the ureter through different mechanisms [13]. The plugging interception catheter (IVX-OC16) used in this study functions by folding its blades into a cluster after crossing the stone, thereby preventing stone displacement. Its occlusion effect can be adjusted via a handle, allowing for easy control and retrieval. These features led us to select this device for our study.

Through this retrospective cohort study, we found that although antegrade placement of the ureteral occluder via the percutaneous tract may slightly prolong operative time, there was no statistically significant difference in operative duration between the occlusion-assisted and standard mPCNL groups. While the overall stone clearance rates did not differ significantly, the benefit of occlusion assistance was evident in the significantly lower incidence of stone migration and reduced need for secondary ureteroscopic interventions, thereby decreasing postoperative treatment burden.

RPP is a critical factor contributing to postoperative complications. Zhongsheng Yang et al. reported that monitoring and controlling RPP during mPCNL can reduce infectious complications and improve stone clearance rates [14]. Jaime Landman et al. found that indwelling ureteral access sheaths significantly reduce RPP during PCNL compared to ureteral stents or balloon occluders [15]. In our study, both groups had pre-indwelled ureteral catheters, and antegrade ureteral occlusion did not result in a significant increase in RPP. This may be attributed to the adjustable design of the occluder blades, which allows partial drainage of irrigation fluid distal to the occlusion site, preventing complete blockage.

Recently, novel stone occlusion devices with drainage capabilities used in ureteroscopic surgery may be adapted for antegrade occlusion in mPCNL to further mitigate intraoperative RPP elevation [16]. According to multiple large-scale studies, the overall complication rate following PCNL ranges from 15% to 20% [1–5], consistent with the complication rate observed in our study. There were no significant differences between groups in hemoglobin decline, postoperative complications (including fever and septic shock), or length of hospital stay, suggesting that antegrade occlusion does not compromise the safety of mPCNL.

However, antegrade occlusion presents certain technical challenges that require careful intraoperative management. Most notably, placement of the occluder through the percutaneous tract may interfere with lithotripsy performed via the same channel. Adjustments to the depth and orientation of the access sheath during calyceal exploration necessitate simultaneous repositioning of the occluder; otherwise, occluder displacement may lead to stone migration into the ureter. Based on our experience, the following recommendations are proposed:

- Confirm the occluder's functional integrity at the start of surgery to ensure smooth opening and closing, preventing entrapment within the ureter.
- Precisely identify the ureteropelvic junction (UPJ) prior to antegrade occluder deployment. Retrograde irrigation through the ureteral catheter should be performed to flush any embedded stones into the operative field before occlusion.
- When manipulating the access sheath during the procedure, adjust the occluder position accordingly to avoid procedural interference or complications.
- Antegrade occlusion is particularly advantageous and less disruptive in cases involving middle or upper pole calyx access and non-pelvic stones, where stone migration prevention is more effective.

This study has several limitations. First, as an innovative retrospective analysis of an unconventional surgical technique, the sample size was relatively small, limiting the statistical power. Second, although all surgeries were performed by the same surgeon to minimize variability, selection bias cannot be entirely excluded. Lastly, due to limited sample size, subgroup analyses based on stone location were not performed, and long-term follow-up data to assess the durability and safety of this technique are lacking.

5. Summary

This study compared the efficacy and safety of antegrade occluder assisted mPCNL versus standard mPCNL. Our findings suggest that percutaneous antegrade ureteral occlusion during PCNL effectively prevents stone fragment migration into the ureter, thereby reducing the incidence of intraoperative and postoperative ureteral obstruction as well as the need for secondary surgical interventions. However, these results warrant further validation through high-quality randomized controlled trials.

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