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Original Article

Comparison of external drainage ureteral tube versus double-J catheter placement on subjective comfort and adverse events after percutaneous nephrolithotomy

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Abstract: Background: The procedure of percutaneous nephrolithotomy (PCNL) is widely recognized as the primary approach for the removal of large renal stones, yet the optimal postoperative drainage strategy in tubeless procedures remains debated. This study compares external ureteral catheter (EUC) and double-J stent (DJS) regarding patient comfort and complications. Method: This retrospective analysis included patients undergoing tubeless PCNL from July 2021 to June 2025, divided into DJS and EUC groups based on drainage method. Pain in the postoperative period was measured using the visual analogue scale (VAS) at both 24 and 48 hours. Stent-related symptoms (SRS) were assessed two weeks, and a voiding cystourethrogram was conducted prior to catheter removal for the evaluation of vesicoureteral reflux (VUR) grade. Analgesic requirements, hospital stays, and complications (fever, urinary extravasation, perirenal hematoma) were recorded. Results: The study encompassed 262 patients, of whom 135 were allocated to the DJS cohort and 127 to the EUC cohort. The frequency of SRS was markedly greater in the DJS group than the EUC group (60.74% vs. 19.69%, P<0.001). Furthermore, the DJS group had a markedly greater percentage of patients with high-grade VUR (42.22% vs. 24.41%, P=0.002). There were no notable differences found between the groups regarding postoperative VAS scores, analgesic requirements, hospital stays, or the incidence of fever, urinary extravasation, or perirenal hematoma (all P>0.05). Multivariate analysis confirmed EUC as a protective factor against SRS (OR=0.200, P<0.001). Conclusion: EUC drainage following tubeless PCNL significantly reduces SRS and severe VUR compared to DJS, while maintaining comparable safety.

Keywords: Percutaneous nephrolithotomy, double-J stent, external ureteral catheter, patient comfort, vesicoureteral reflux, postoperative complications

Introduction

Urolithiasis is a highly prevalent global health issue, and percutaneous nephrolithotomy (PCNL) is acknowledged as the primary treatment for large or complex upper urinary tract stones [1]. Traditionally, PCNL concludes with a nephrostomy tube placement; however, the adoption of tubeless PCNL - using either an internal double-J stent (DJS) or an external ureteral catheter (EUC) - has gained widespread acceptance to reduce postoperative morbidity and shorten hospital stays [2, 3]. Despite these advancements, the optimal drainage strategy remains debated. The DJS is frequently associated with stent-related symptoms (SRS), including storage lower urinary tract symptoms and flank pain, which significantly impair patients' quality of life [4, 5]. Conversely, EUC allows for early removal without the need for a secondary cystoscopy but requires external device management [6].

The biological mechanisms underlying these clinical differences are well-established. The presence of a DJS within the bladder induces mechanical irritation of the trigone and sustained activation of afferent sensory neurons, leading to detrusor overactivity [7, 8]. Furthermore, the stent compromises the anti-reflux mechanism at the ureterovesical junction, possibly resulting in vesicoureteral reflux (VUR) and elevated renal pelvic pressure during micturition [9, 10].

Crucially, the clinical benefits of EUC over DJS have already been substantiated by high-level evidence. Zhou et al. (2017) demonstrated in a

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randomized controlled trial (RCT) that EUC significantly reduced SRS (19.6% vs. 60.4%) compared to DJS [11]. This finding was subsequently consolidated by Chen et al.'s meta-analysis (2018) and most recently reaffirmed by Tania et al.'s comprehensive systematic review and meta-analysis (2025), which pooled nine studies and confirmed that EUC effectively alleviates SRS while maintaining comparable safety profiles [12, 13].

Given this robust body of evidence, the main objective of this single-institution retrospective study was not to reassess the effectiveness of EUC, but to provide contemporary confirmatory data from a routine clinical practice setting. While prior RCTs often employed selective inclusion criteria, our cohort reflects the heterogeneity of daily urologic practice. Additionally, unlike many previous individual studies that focused solely on subjective symptoms, we systematically evaluated objective physiologic findings- specifically, VUR grades via voiding cystourethrography - alongside comprehensive safety outcomes. Therefore, this study served to reinforce the external validity of existing meta-analytic conclusions by providing detailed, contemporaneous comparative data on both subjective comfort and objective reflux grading in a modern PCNL cohort.

Materials and methods

Study population

A retrospective analysis was conducted on 262 patients with upper urinary tract stones who underwent PCNL at Qingdao Chengyang People's Hospital from July 2021 to June 2025. Inclusion criteria were: ① age 18 years or older; ② stone diameter ≤4 cm; ③ received single-channel tubeless PCNL treatment; ④ complete clinical, surgical, and follow-up data. Exclusion criteria included: ① preoperative ureteral obstruction, pyuria, or uncontrolled urinary tract infection; ② intraoperative occurrence of renal collecting system perforation or severe bleeding requiring secondary surgery; ③ postoperative residual stone diameter ≥4 mm; ④ presence of severe heart, liver, kidney, or other organ dysfunction. According to the different postoperative drainage methods following PCNL, the 262 patients were divided into a Double-J Stent (DJS) group (n=135), and an External Ureteral Catheter (EUC) group (n=127).

Ethical statement

This research strictly complied with the ethical guidelines set forth in the Declaration of Helsinki. The study protocol was submitted to the Institutional Review Board (IRB) of Qingdao Chengyang People's Hospital for review and subsequently obtained official approval. Given that the study involved a retrospective chart review with no additional interventions, the IRB approved the waiver of written informed consent from participants. Patient privacy and medical data confidentiality were strictly maintained throughout the study, and all data were used solely for statistical analysis in this research.

Treatment process

All tubeless PCNL procedures were performed by the same experienced urologist [14, 15]. Patients were initially placed in the lithotomy position, and a 5 Fr ureteral catheter was retrogradely inserted into the renal pelvis of the affected side. After placement of a Foley catheter, patients were repositioned to the prone position. Under ultrasound and fluoroscopic guidance, an 18G puncture needle was used to puncture the target calyx, and after successful puncture with urine flow, a 0.035-inch hydrophilic guidewire was inserted. A fascial dilator was used to sequentially dilate from 8 Fr to 18 Fr, and a working sheath of corresponding size was placed. An 8.5/11.5 Fr nephroscope was inserted, and a pneumatic lithotripter was used to fragment the stones. Stone fragments were extracted using forceps or flushed out utilizing pulse irrigation. Upon completion of the surgery, a 5 Fr double-J stent (DJS group) was inserted antegrade through the working sheath, or a 5 Fr ureteral catheter (EUC group) was left in place and secured to the skin. The nephrostomy tract was closed with one stitch using 4-0 silk sutures.

In the DJS group, the double-J stent was routinely left *in situ* for 2-4 weeks and subsequently removed under local anesthesia by cystoscopy in an outpatient setting. In the EUC group, the color and volume of the drainage fluid were closely monitored postoperatively. If there were no complications such as fever (temperature >38°C) or urine extravasation, the EUC and Foley catheter were removed on the first day following surgery. If any of these complications

occurred, the drainage tubes were retained until 24-48 hours after the symptoms resolved before removal.

On the first postoperative day, a complete blood count (CBC) was rechecked using an automated hematology analyzer (XN-1000, Sysmex, Japan), and the decrease in hemoglobin levels was recorded. Postoperatively, pain levels were assessed every 6 hours using the visual analogue scale (VAS), which ranges from 1 (no pain) to 10 (worst imaginable pain). If the VAS score was ≥4, a dose of 30 mg intravenous Toradol was administered. The intraclass correlation coefficient (ICC) for this scale was 0.99 [16]. A voiding cystourethrography (VCUG) was conducted prior to removing the Foley catheter to evaluate VUR. The severity of VUR was classified as follows: Grade I - reflux into non-dilated ureters; Grade II - reflux into the renal pelvis and calyces without dilation; Grade III - reflux with mild to moderate dilation and slight blunting of the fornices; Grade IV - reflux with moderate ureteral tortuosity and dilation of the renal pelvis and calyces; Grade V - reflux with severe dilation of the ureter, pelvis, and calyces, loss of papillary impressions, and ureteral tortuosity [17]. Follow-up at two weeks postoperatively evaluated SRS, which included urinary frequency, urgency, dysuria, flank pain, and bladder pain.

Statistical method

Data processing and analysis were conducted using SPSS 29.0 statistical software (IBM Corp., Armonk, NY, USA). The normality of continuous variables was evaluated through the Shapiro-Wilk test, separately for each group (DJS and EUC) and for each variable. Additionally, histograms and Q-Q plots were visually inspected. Variables with a Shapiro-Wilk *P*-value >0.05 were deemed to follow a normal distribution; those with a *P*-value of 0.05 or less were considered non-normally distributed. For variables exhibiting a normal distribution, data are reported as mean ± standard deviation (SD), with intergroup comparisons conducted using the independent samples t-test. For non-normally distributed variables, data were expressed as the median along with interquartile range (IQR), using the Mann-Whitney U test for intergroup comparison. Categorical variables were presented as counts (percentages), utilizing the χ^2 test (or Fisher's exact test when expected frequencies were <5) for intergroup comparison. Univariate and multivariate logistic regression analyses were conducted with the occurrence of SRS as the dependent variable (no occurrence = 0, occurrence = 1) to identify independent risk factors for the incidence of SRS after PCNL. The multivariate model demonstrated good calibration, as evidenced by a non-significant Hosmer-Lemeshow test (P=0.721), indicating that the model fit the observed data well.

Results

Baseline characteristics

In **Table 1**, we compared the baseline characteristics between the DJS group and the EUC group. There were no significant differences found in age (P=0.432), gender distribution (P=0.878), BMI (P=0.932), history of previous kidney surgery (P=0.849), stone size (P=0.773), site of stone (P=0.953), or presence of hydronephrosis (P=0.658) between the two groups. These results indicate that the two groups were well-matched in terms of their baseline characteristics, thus minimizing potential confounding factors for subsequent analyses.

Operative data

Comparing the operative data between the DJS group and the EUC group, as presented in **Table 2**, no significant differences were found across various findings. There was no notable difference in the surgery side distribution (P=0.890), puncture site selection (P=0.496), operative time (P=0.513), hemoglobin drop levels (P=0.359), or the need for blood transfusion (P=0.823) between the two groups. These findings suggest a high degree of similarity in surgical experiences and outcomes between the DJS and EUC groups, indicating that neither procedure significantly differed from the other in terms of these measured operative factors.

Patients' comfort

Regarding the comparison of VAS scores between the DJS group and the EUC group as outlined in **Figure 1**, our analysis revealed that there were no significant differences in VAS scores at either postoperative 24 hours (P= 0.087) or 48 hours (P=0.211). These results indicate that the immediate postoperative pain

Table 1. Comparison of baseline characteristics between the two groups

Data	DJS group (n=135)	EUC group (n=127)	t/χ^2	P
Age (years)	49.35 ± 13.44	50.63 ± 12.89	0.786	0.432
Gender [n (%)]			0.024	0.878
Male	71 (52.59%)	68 (53.54%)		
Female	64 (47.41%)	59 (46.46%)		
BMI (kg/m^2)	24.12 ± 3.58	24.08 ± 3.62	0.085	0.932
Previous kidney surgery [n (%)]	17 (12.59%)	17 (13.39%)	0.036	0.849
Stone size (cm^2)	4.58 ± 1.24	4.62 ± 1.31	0.289	0.773
Site of stone [n (%)]			1.113	0.953
Pelvis	65 (48.15%)	55 (43.31%)		
Upper calyx	8 (5.93%)	7 (5.51%)		
Middle calyx	4 (2.96%)	5 (3.94%)		
Lower calyx	28 (20.74%)	26 (20.47%)		
Upper ureter	12 (8.89%)	13 (10.24%)		
Multiple	18 (13.33%)	21 (16.54%)		
Hydronephrosis [n (%)]	60 (44.44%)	53 (41.73%)	0.196	0.658

DJS, double-J stent; EUC, external ureteral catheter; BMI, body mass index.

Table 2. Comparison of operative data between the two groups

Data	DJS group (n=135)	EUC group (n=127)	t/χ^2	P
Surgery side [n (%)]			0.019	0.890
Right	66 (48.89%)	61 (48.03%)		
Light	69 (51.11%)	66 (51.97%)		
Puncture site [n (%)]			1.403	0.496
Upper pole access	82 (60.74%)	68 (53.54%)		
Middle calix access	33 (24.44%)	36 (28.35%)		
Lower pole access	20 (14.81%)	23 (18.11%)		
Operative time (min)	65.34 ± 15.28	66.71 ± 18.46	0.655	0.513
Hemoglobin drop (g/L)	11.23 ± 3.45	10.87 ± 2.92	0.918	0.359
Blood transfusion [n (%)]	6 (4.44%)	4 (3.15%)	0.050	0.823

DJS, double-J stent; EUC, external ureteral catheter.

experience was comparable between patients managed with DJS and those managed with EUC.

Examining **Table 3**, which compares SRS and VUR grades between the DJS group and the EUC group, significant differences were observed. Notably, the incidence of SRS was markedly higher in the DJS group compared to the EUC group (P<0.001). Additionally, the distribution of VUR grades showed a significant difference between the two groups (P=0.002). The DJS group had a higher proportion of patients with high-grade VUR (grades IV to V) compared to the EUC group, while the EUC group had a greater proportion of patients with low-grade VUR (grades I to III) than the DJS group. These findings highlight that patients in the DJS group not only experienced SRS more frequently but also had a higher likelihood of presenting with severe VUR grades. This suggests potential disadvantages associated with the use of DJS in terms of patient comfort and severity of reflux, indicating a need for careful consideration when selecting treatment options for patients with similar conditions.

Table 4, which compares the analgesic requirement and hospital stays between the DJS group and the EUC group, showed no significant differences. The analgesic requirement did not differ significantly between the two groups (P=0.384), nor did the duration of hospital stays show a significant difference (P=

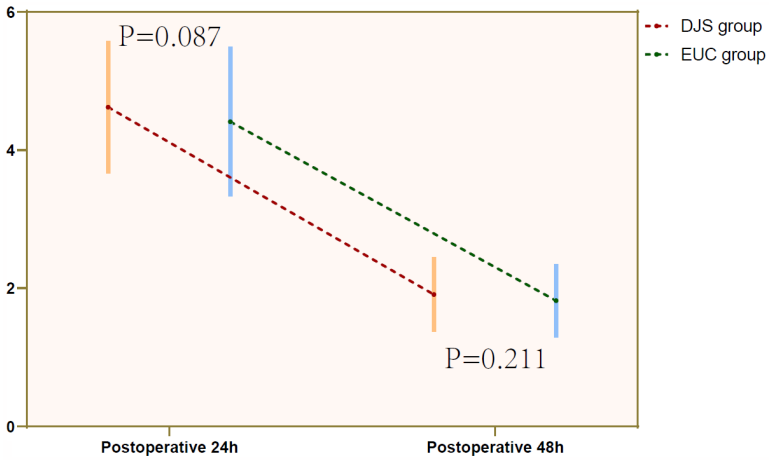

Figure 1. Comparison of VAS scores between the two groups (points). VAS, visual analogue scale; DJS, double-J stent; EUC, external ureteral catheter.

0.449). These results suggest that both the amount of analgesics needed and the length of hospitalization were similar for patients in the DJS and EUC groups. This similarity indicates that neither procedure notably affects postoperative analgesic consumption or extends hospital stays, supporting the comparability of these interventions in terms of patient management and resource use following surgery.

Complications

Figure 2 compares the incidence of complications between the DJS group and the EUC group. Nosignificant differences were observed among types of complications. There was no difference in the incidence of fever (P= 0.444), urinary extravasation (P=0.935), or perirenal hematoma (P=0.864) between the two groups. These findings indicate that the likelihood of developing these complications does not markedly differ between patients treated with DJS and those treated with EUC. Consequently, this similarity suggests that both procedures carry comparable risk regarding these specific postoperative complications.

Logistic regression analysis

In the univariate logistic regression analysis of risk factors for the incidence of SRS following PCNL, as shown in **Table 5**, several significant predictors were identified. The use of EUC compared to DJS was a protective factor against SRS (P<0.001, OR=0.250), indicating that patients in the EUC group had markedly lower odds of experiencing these symptoms. Conversely, previous kidney surgery emerged as a significant risk factor (P=0.035, OR=2.100), suggesting that those with a history of kidney surgery were more than twice as likely to develop SRS. Additionally, stone size (P=0.046, OR=1.250) and the presence of hydronephrosis (P=0.040, OR=1.800) were also identified as risk factors, with increases in either being associated with higher odds of developing symptoms. Lastly, operative time was anther significant predictor (P=0.035, OR=1.019), indicating that longer surgical procedures slightly increased the likelihood of SRS. These findings highlight the importance of considering both procedural choice and patient-specific factors in managing postoperative symptoms effectively.

In the multivariate logistic regression analysis of risk factors for the incidence of SRS following PCNL, as presented in **Table 6**, several significant predictors were identified. The use of EUC compared to DJS remained a strong protective factor (P<0.001, OR=0.200), indicating that patients in the EUC group had markedly lower odds of experiencing SRS. Conversely, previous kidney surgery was confirmed as a notable risk factor (P=0.038, OR=2.300), suggesting that individuals with a history of kidney surgery were more than twice as likely to develop these symptoms. Stone size (P=0.149, OR=1.139), hydronephrosis (P=0.256, OR= 1.234), and operative time (P=0.253, OR= 1.008) did not reach statistical significance by this multivariate model. However, the trends suggested that larger stone sizes and the presence of hydronephrosis might slightly increase the likelihood of developing SRS, although these increases were not significant. Similarly, longer operative times showed a minimal trend towards increased symptom incidence, but this too was not significant. These results underscore the importance of considering both procedural choice (EUC vs. DJS) and patient history (previous kidney surgery) in predicting and managing postoperative SRS effectively.

Table 3. Comparison of SRS and VUR between the two groups [n (%)]

Data	DJS group (n=135)	EUC group (n=127)	χ^2	P
SRS	82 (60.74%)	25 (19.69%)	45.653	<0.001
VUR grade			9.308	0.002
Low (grades I-III)	78 (57.78%)	96 (75.59%)		
High (grades IV-V)	57 (42.22%)	31 (24.41%)		

SRS, stent-related symptoms; VUR, vesicoureteral reflux; DJS, double-J stent; EUC, external ureteral catheter.

Table 4. Comparison of analgesic requirement and hospital stays between the two groups

Data	DJS group (n=135)	EUC group (n=127)	t	P
Analgesic requirement (mg)	62.45 ± 21.39	59.82 ± 26.97	0.873	0.384
Hospital stays (d)	5.78 ± 1.85	5.61 ± 1.78	0.759	0.449

DJS, double-J stent; EUC, external ureteral catheter.

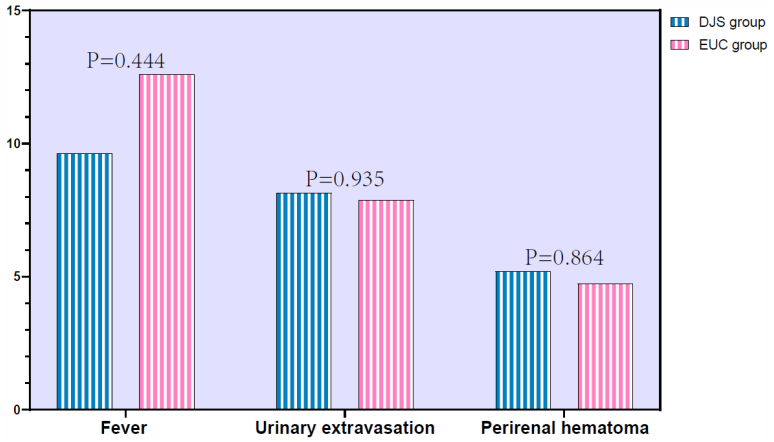

Figure 2. Comparison of complications incidence between the two groups [n (%)]. DJS, double-J stent; EUC, external ureteral catheter.

Subgroup analysis

To further explore the clinical applicability of EUC, a subgroup analysis was performed based on the history of previous kidney surgery. Among patients without a history of kidney surgery (n=228), the incidence of SRS remained significantly lower in the EUC group compared to the DJS group (17.27% vs. 58.47%, P<0.001). Notably, in patients with a history of kidney surgery (n=34), although the overall incidence of symptoms was higher, the EUC group still demonstrated a trend toward reduced symptom burden compared to the DJS group (35.29% vs. 76.47%, P=0.038). These results suggest that EUC provides consistent benefits across different surgical backgrounds, particularly offering a safer option for patients with prior renal interventions.

Discussion

This study compared EUC drainage and DJS placement after tubeless PCNL, revealing meaningful differences in patient comfort and physiologic outcome, while demonstrating comparable safety. Patients with external catheters had fewer SRS and a more favorable VUR pattern, indicating better postoperative recovery. Despite similar baseline characteristics, the choice of drainage method has clinical relevance for optimizing patient outcome.

Postoperative pain assessment revealed no significant differences in VAS scores between the two groups at either 24 hours or 48 hours, indicating comparable early postoperative pain experiences regardless of drainage method. The most notable difference between the two groups was the incidence of SRS, which occurred almost three times more frequently in patients using double-J stents. This finding strongly corroborates the extensive literature documenting irritative urinary symptoms linked to indwelling ureteral stents [18]. Previous studies in the development of the Ureteral Stent Symptom Questionnaire found that most patients with indwelling stents experience bothersome voiding symptoms, including urinary frequency, urgency, and dysuria [19]. The underlying mechanisms involve continuous mechanical irritation of the trigone of the bladder

Table 5. Univariate logistic regression analysis of risk factors for the SRS incidence following PCNL

Data	Coefficient	Std Error	Wald	P	OR	95% CI
EUC (vs DJS)	-1.386	0.324	18.301	<0.001	0.250	0.132-0.472
Previous kidney surgery	0.842	0.351	4.469	0.035	2.100	1.055-4.180
Stone size	0.223	0.112	3.964	0.046	1.250	1.004-1.556
Hydronephrosis	0.588	0.287	4.198	0.040	1.800	1.025-3.160
Operative time	0.019	0.009	4.456	0.035	1.019	1.001-1.037

SRS, stent-related symptoms; PCNL, percutaneous nephrolithotomy; OR, odds ratio; CI, confidence interval; DJS, double-J stent; EUC, external ureteral catheter.

Table 6. Multivariate logistic regression analysis of risk factors for the SRS incidence following PCNL

Data	Coefficient	Std Error	Wald Stat	P	OR	OR CI Lower	OR CI Upper
EUC (vs DJS)	-1.609	0.357	20.311	<0.001	0.200	0.099	0.403
Previous kidney surgery	0.833	0.401	4.317	0.038	2.300	1.048	5.048
Stone size	0.132	0.091	2.086	0.149	1.139	0.955	1.358
Hydronephrosis	0.212	0.185	1.288	0.256	1.234	0.859	1.774
Operative time	0.018	0.007	1.306	0.253	1.008	0.994	1.022

SRS, stent-related symptoms; PCNL, percutaneous nephrolithotomy; OR, odds ratio; CI, confidence interval; DJS, double-J stent; EUC, external ureteral catheter.

by the distal curl of the stent, leading to detrusor overactivity and sensory urgency [20]. Additionally, the stent passing through the ureteral orifice may disrupt the normal valve mechanism, exposing sensitive areas to urine during micturition [21]. Our findings extend these observations to the PCNL population, indicating that external drainage effectively avoids these issues by completely eliminating the need for intravesical placement of a foreign body. The external catheter exits the ureteral orifice without curling inside the bladder, maintaining the integrity of the trigonal mucosa and minimizing afferent nerve stimulation.

The differential distribution of VUR grades provides further mechanistic insight into the observed symptom differences. Compared to patients using external catheters, those with DJS exhibited a higher proportion of high-grade reflux, indicating that internal stents may compromise the anti-reflux mechanism at the ureterovesical junction, possibly leading to retrograde urine flow and increased intrarenal pressure [22]. This finding is consistent with work demonstrating by videourodynamic studies that indwelling stents consistently impair the anti-reflux mechanism at the ureterovesical junction. The presence of a stent at this critical junction keeps the ureteral orifice constantly open, allowing intravesical pressures during micturition to be directly transmitted to the upper urinary tract [23]. High-pressure reflux during voiding not only causes flank pain but may also delay percutaneous urinary tract healing and impair renal function recovery [24]. In contrast, EUC provides drainage without fully compromising the function of the ureterovesical junction. The catheter exits the ureteral orifice but does not keep it in a fixed open position, which may partially preserve the anti-reflux mechanism [25]. This physiological advantage may explain the lower reflux grades observed in the external catheter group and could contribute to reduced incidence of flank pain and associated symptoms. This finding has clinical significance, as high-grade VUR predisposes patients to recurrent infections, back pain, and delayed stone clearance.

Despite differences in symptom characteristics, analgesic requirements and the lengths of hospital stays were similar between the two groups. Standardized analgesic protocols, such as administering ketorolac at predefined Visual Analog Scale thresholds, effectively controlled breakthrough pain, masking potential differences in analgesic consumption [26]. SRS, though bothersome, rarely reached the threshold for parenteral analgesia, especially when discomfort was mainly during micturition [27]. Discharge decisions are influenced by surgeon preference, institutional protocols, and social factors. These findings align with another study

showing similar hospital stays despite differences in subjective comfort. Clinically, while external catheters improve comfort, this may not reduce hospital stays due to the need for management guidance and patient education before discharge.

The incidence of major complications was comparable, confirming the safety of both methods. Previous studies show no difference in infection or bleeding complications between internal stents and external catheters [28]. Both methods provided adequate urine diversion and maintained a low-pressure system during early healing [29]. Our data do not support concerns that external catheters increase the risk of ascending infections, as proper care can mitigate this risk. Similar hemoglobin reduction and transfusion requirements indicate neither method adversely affects hemostasis or exacerbates bleeding.

Logistic regression analysis revealed that using an EUC consistently reduced the risk of SRS, supporting its preferential use when clinically feasible. Additionally, in the multivariate analysis, variables such as stone size and hydronephrosis lost statistical significance, whereas previous kidney surgery remained significant. This phenomenon is likely attributable to multicollinearity or mediating effects. Stone size and hydronephrosis are often closely correlated with each other and with surgical complexity; their effects on symptoms may be mediated through the choice of drainage method or surgical history. Once these shared variances were accounted for in the multivariate model, their independent predictive value diminished, leaving previous kidney surgery as the sole independent clinical predictor besides the drainage method itself.

The lack of differences in surgical findings between groups enhances the study's validity. Similar operative times, puncture site distributions, and hemoglobin reductions indicate that the drainage method does not affect surgical complexity or outcomes [30]. This supports attributing postoperative differences to the drainage method rather than surgical factors. Surgeons can choose between a DJS and an EUC based on postoperative factors without worrying about impacting the surgery itself.

While we acknowledge that the superiority of EUC in reducing SRS has been established by previous RCTs and meta-analyses, this study adds to the field through several distinct contributions. First, unlike many prior studies that relied solely on subjective symptom scores, we incorporated objective physiologic measurements, specifically the grading of vesicoureteral reflux by VCUG. Our data provided detailed comparative evidence on how different drainage methods impact the anti-reflux mechanism, a secondary endpoint often overlooked in earlier RCTs. Second, as a real-world cohort, our data bridge the gap between highly controlled trial settings and routine clinical practice. We performed a subgroup analysis based on previous kidney surgery history, identifying a high-risk population that benefits most from EUC placement. Finally, our analysis confirms that the safety profile (including hemorrhage and infection) is non-inferior, providing clinicians with comprehensive evidence to make individualized drainage decisions. Therefore, rather than redefining efficacy, this study reinforced the external validity of EUC and highlighted its specific advantages in preserving ureterovesical function.

Several limitations of this research must be recognized. First, the study was a retrospective, single-institution cohort study without randomization or blinding. The choice of drainage method (EUC vs. DJS) was based on surgeon preference and intraoperative findings, which may have introduced selection bias and confounding by indication. Although we compared baseline characteristics and found no significant differences in measured variables, unmeasured confounders (e.g., surgeon experience, intraoperative complexity, patient expectations) could still have influenced the outcomes. Second, we did not perform propensity score matching (PSM) in this study. We chose to use multivariable logistic regression to adjust for potential confounders, which is an accepted method for retrospective analyses. We also performed a subgroup analysis to explore consistency of the treatment effect. Nonetheless, we acknowledge that PSM would have provided additional robustness, and we plan to apply it in future prospective or larger multicenter studies. The subgroup analysis involving patients who had prior kidney surgery (n=34) should be interpreted with caution due to the limited sample size, and these results need to be confirmed in a larger population. Third, the lack of blinding may have introduced

detection bias (e.g., VUR grading on voiding cystourethrography could be influenced by knowledge of the drainage method, although VUR grading is relatively objective). Fourth, this was a single-center study; our surgical techniques, perioperative care protocols, and patient population may not be representative of other institutions. Fifth, the duration of follow-up was comparatively brief (2 weeks for SRS and up to hospital discharge for VUR assessment). Long-term outcomes such as late ureteral stricture, chronic pain, or renal function changes were not evaluated. Sixth, SRS were assessed by patient self-report, which may be subject to recall bias, although we used a standardized questionnaire at a fixed time point (2 weeks postoperatively). Finally, although we adjusted for major clinical covariates, we did not include specific data on postoperative antibiotic regimens or detailed surgeon experience in the regression model. While all surgical procedures were conducted by a single experienced surgeon minimizing operator bias, the impact of antibiotic usage on symptom resolution warrants consideration in future studies.

Summary

Tubeless PCNL with EUC drainage was superior to DJS placement in reducing SRS and alleviating severe VUR, while maintaining equivalent safety. The external catheter method effectively avoided the inherent trigone irritation of indwelling stents, providing a more comfortable early recovery. These findings support external ureteral catheter drainage as the preferred strategy for appropriately selected patients undergoing tubeless PCNL, particularly those with a history of previous renal surgery.

Disclosure of conflict of interest

None.

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