Am J Transl Res 2025;17(4):2984-2991
www.ajtr.org /ISSN:1943-8141/AJTR0162444

Original Article

Effectiveness and safety profiles of percutaneous nephrolithotomy and ureteroscopic lithotripsy for proximal ureteral calculi

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Received December 3, 2024; Accepted March 3, 2025; Epub April 15, 2025; Published April 30, 2025

Abstract: Objective: To compare the effectiveness and safety of percutaneous nephrolithotripsy (PCNL) and ureteroscopic lithotripsy (URSL) in treating proximal ureteral stones. Methods: The clinical data of 86 patients with proximal ureteral stones, admitted to the Department of Urology at the First People's Hospital of Chun'an County from May 2021 to May 2023, were retrospectively analyzed. Patients were divided into a PCNL group (n=41) and a URSL group (n=45) based on the treatment modality. Key outcomes compared between the two groups included surgical time, intraoperative blood loss, incidence of complications, hospital stay, stone clearance rate, lithotripsy success rate, renal function indicators, and levels of inflammatory factors. Results: The PCNL group had significantly higher intraoperative blood loss and longer postoperative hospital stay compared with the URSL group, whereas the operative time was remarkably shorter (P<0.05). The stone clearance and lithotripsy success rates were considerably higher in the PCNL group than in the URSL group, and the complication rates were significantly lower (P<0.05). After treatment, the levels of renal function indicators, including serum creatinine (Scr), blood urea nitrogen (BUN), and cystatin C (CysC), decreased significantly in both groups, with the PCNL group showing more pronounced decrease compared to the URSL group (P<0.05), approaching normal levels. Additionally, while the levels of procalcitonin (PCT), interleukin-13 (IL-13), and high-sensitivity C-reactive protein (hs-CRP) were elevated in both groups after treatment, the PCNL group showed significantly lower levels of these inflammatory markers compared to the URSL group (all P<0.05). Conclusion: Both PCNL and URSL are effective treatments for proximal ureteral stones. However, PCNL offers superior clinical effectiveness and safety.

Keywords: Percutaneous nephrolithotomy, ureteroscopic lithotripsy, proximal ureteral calculi, efficacy, safety

Introduction

Ureteral stones are a common condition in urology. With changes in lifestyle and the influence of environmental factors, the incidence of ureteral stones is increasing annually and younger populations are affected [1, 2]. Contributing factors include metabolic abnormalities, infections, improper diet, and medication side effects, all of which can lead to the deposition of stone-forming substances in the urine, resulting in the development of ureteral stones [3]. Depending on the location of the stones, ureteral stones can be categorized into upper, middle, and lower ureteral stones [4]. Among these, upper ureteral stones present challenges for treatment due to their special anatomical location and pathological characteristics. These stones can obstruct urine flow, leading to increased pressure in the renal pelvis, which may cause intermittent colic in the lower back or hematuria. Furthermore, prolonged obstruction can impair kidney filtration and metabolism, eventually causing irreversible damage to the parenchymal tissues of the kidneys [5, 6].

Minimally invasive surgery is the preferred approach for treating upper ureteral stones, with ureteroscopic lithotripsy (URSL) and percutaneous nephrolithotripsy (PCNL) emerging as the primary techniques due to their advantages of less trauma and faster recovery [7]. However, significant differences in lithotripsy success rates have been reported between these two methods [8, 9]. URSL involves the retrograde insertion of an ureteroscope into the natural

https://doi.org/10.62347/GYUQ6118

lumen to locate and fragment the stones. It doesn't need an additional access channel, offering greater flexibility than PCNL and reducing surgical trauma, which supports quicker patient recovery [10]. PCNL accesses the renal collecting system through percutaneous puncture, using endoscopic and lithotripsy equipment to directly manage the stones. It offers a high stone clearance rate, particularly suitable for larger and more complex upper ureteral stones [11].

Despite their widespread use, the efficacy and safety of PCNL and URSL can vary depending on patient characteristics and stone types. The comparative advantages of PCNL and URSL for upper ureteral stones remain inconclusive. Some studies suggest PCNL achieves higher stone clearance rates, while others highlight URSL's superior safety profile and fewer complications [12]. In addition, PCNL is generally recommended for stones larger than 1.5 cm in diameter [6], whereas URSL is preferred for ureteral stones smaller than 2 cm. However, there is limited guidance on choosing between the two surgical modalities for stones with diameters ranging from 1.5 to 2.0 cm.

This study collected and analyzed the clinical data from patients with upper ureteral stones measuring 1.5-2.0 cm to comprehensively evaluate the efficacy and safety of PCNL and URSL in treating these stones. This study aims to provide a scientific basis for the selection of clinical treatment strategies.

Materials and methods

Case selection

This retrospective study included 86 patients with upper ureteral stones treated at the Department of Urology, First People's Hospital of Chun'an County, between May 2021 and May 2023. The PCNL group consisted of 41 cases (29 males and 12 females), while the URSL group comprised 45 cases (32 males and 13 females). This study was approved by the Medical Ethics Review Committee of the First People's Hospital of Chun'an County (No. 2024-01-03-08) and conducted in accordance with the Declaration of Helsinki.

Inclusion criteria [6]: (1) Meeting the diagnostic criteria for upper ureteral stones; (2) Disease duration of at least 2 months; (3) Stone diameter between 1.5 and 2 cm; (4) First-time lithotripsy treatment; (5) Normal renal function and coagulation function; (6) Complete inpatient medical history data.

Exclusion criteria: (1) Disease course of less than 2 months; (2) Stone diameters less than 1.5 cm or greater than 2 cm; (3) History of previous lithotripsy treatment; (4) Abnormal renal function or coagulation function; (5) Incomplete or missing inpatient medical history data; (6) Concurrent kidney stones, kidney disease, or urinary tract infections; (7) Presence of tumors, hematologic diseases, and other conditions; (8) Severe cardiopulmonary insufficiency; (9) Women who were breastfeeding or pregnant.

Intervention method

Both groups of patients underwent general anesthesia with endotracheal intubation and were placed in the lithotomy position after anesthesia. In the PCNL group, the surgical procedure involved the following steps: A ureteral catheter was inserted into the renal pelvis under cystoscopy via the urethra. Water was injected into the affected side to create artificial hydronephrosis, and an F16 catheter was left in place. After catheterization, the patient was repositioned to the prone position, and the puncture site was selected at the junction of the 11th intercostal space or the 12th rib below the armpit. Under B-ultrasound guidance, a puncture was performed. The tract was dilated using a fascial dilator, and a pediatric nephroscope was inserted. The stone position was confirmed, followed by fragmentation and removal of the stones. Postoperatively, an F6 double-J stent was routinely placed, and a renal fistula tube was left at the puncture site. In the URSL group, the surgical procedure included: A ureteroscope was introduced via the urethra and advanced into the ureter with a safety guide wire. After confirming the stone's position, larger stones were fragmented using a laser. The fragments were retrieved into the bladder using a stone retrieval basket or stone forceps. An F6 double-J stent and a catheter were left in place.

Data collection and outcome measurements

(1) General information: Age, sex, disease duration, body mass index value (BMI), stone hardness, and stone diameter.

Table 1. Comparison of the general data between the two groups of patients [($x \pm s$, n (%)]

Item	PCNL group (n=41)	URSL group (n=45)	t/χ^2	P
Age (year)	49.16±12.37	47.50±11.04	0.658	0.513
Gender (male/female)	29/12	32/13	0.001	0.969
Disease Duration (month)	5.33±2.15	6.01±2.32	-1.406	0.164
BMI (kg/m^2)	25.00±4.97	24.10±5.19	0.820	0.415
Stone hardness (HU)	982.13±213.18	971.04±197.41	0.250	0.803
Stone diameter (mm)	1.76±0.21	1.73±0.24	0.614	0.541

Note: BMI, body mass index; PCNL, percutaneous nephrolithotripsy; URSL, ureteroscopic lithotripsy.

(2) Surgical time: The operation time was recorded, starting from the first introduction of the scope until the final withdrawal of the scope following residual stone inspection. This period included the process of inserting the ureteroscope, the lithotripsy procedure, and the scope withdrawal.

(3) Intraoperative blood loss: The weight of the sterile gauze was measured before and after the surgery, and the blood loss was calculated as their weight difference.

(4) Complication rates [13]: Postoperative bleeding, infection, residual stones, renal colic, renal function damage, ureteral stenosis, and urinary leakage were recorded. The complication rate = (number of complication cases/total number of cases) * 100%.

(5) Lithotripsy success rate [14]: The lithotripsy success rate = (number of successful lithotripsy cases/total number of cases) * 100%.

(6) Stone clearance rate [15]: One month postoperation, B-ultrasound was used to assess the surgical area for residual stones. The stone clearance rate = (number of patients with no residual stones/total number of cases) * 100%.

(7) Hospital stay: The total number of days from the operation to discharge was recorded.

(8) Renal function indicators: The serum levels of creatinine (Scr), blood urea nitrogen (BUN), and cystatin C (CysC) were measured before and 24 h after surgery.

(9) Inflammatory indicators: The serum levels of procalcitonin (PCT), high-sensitivity C-reactive protein (hs-CRP), and interleukin-13 (IL-13) were measured before and 24 h after surgery.

Statistical methods

Data analysis was performed using SPSS 27.0, and graphical representations were created with GraphPad prism 8.0. Quantitative data conforming to a normal distribution were expressed as mean ± standard deviation. Between-group comparisons were made using the independent samples t-test, while within-group comparisons were assessed using the paired samples t-test. Categorical data were expressed as frequencies and percentages [n (%)] and analyzed using the chi-square test or Fisher's exact test, depending on the data distribution. A P-value <0.05 was considered statistically significant.

Results

General information

There were no significant differences between the PCNL and URSL groups in terms of age, gender, disease duration, BMI, stone hardness, and stone diameter (all P>0.05) (**Table 1**).

Surgical time, intraoperative blood loss, and hospital stay

Patients in the PCNL group had more intraoperative blood loss and longer postoperative hospital stays compared to the URSL group (both P<0.05), whereas the operative time was significantly shorter than that in the URSL group (P<0.05) (**Table 2**).

Occurrence of complications

In the PCNL group, there was 1 case of postoperative hemorrhage, 4 cases of infection, 5 cases of renal colic, and 2 cases of residual stones, with a total complication rate of 29.27%. In the URSL group, there were 2 cases of hemorrhage, 6 cases of infection, 6 cases of renal colic, 7 cases of residual stones, 1 case of ureteral ste-

Table 2. Comparison of operation time, intraoperative blood loss and hospital stay between the two groups of patients [$x \pm s$]

Item	PCNL group (n=41)	URSL group (n=45)	*t*	*P*
Operation time (min)	49.00±10.05	64.00±13.25	-5.946	<0.001
Intraoperative blood loss (mL)	8.07±2.41	4.35±1.27	8.830	<0.001
Hospital stay (day)	5.59±1.40	2.66±1.10	10.841	<0.001

Note: PCNL, percutaneous nephrolithotripsy; URSL, ureteroscopic lithotripsy.

Table 3. Comparison of the incidence of complications between the two groups of patients [n (%)]

Item	PCNL group (n=41)	URSL group (n=45)	χ^2	*P*
Bleeding	1 (2.44)	2 (4.44)		
Infection	4 (9.76)	6 (13.33)		
Renal colic	5 (12.20)	6 (13.33)		
Stone residue	2 (4.88)	7 (15.56)		
Renal dysfunction	0 (0)	0 (0)		
Ureteral stricture	0 (0)	1 (2.22)		
Urinary extravasation	0	1 (2.22)		
Total occurrences	12 (29.27)	23 (51.11)	4.241	0.039

Note: PCNL, percutaneous nephrolithotripsy; URSL, ureteroscopic lithotripsy.

Table 4. Comparison of stone clearance rate and lithotripsy success rate between the two groups of patients [*n* (%)]

Item	PCNL group (n=41)	URSL group (n=45)	χ^2	*P*
Stone clearance rate	39 (95.12)	36 (80.00)	4.398	0.036
Lithotripsy success rate	41 (100.00)	39 (86.67)	-	0.027

Note: PCNL, percutaneous nephrolithotripsy; URSL, ureteroscopic lithotripsy.

nosis, and 1 case of urine leakage, with a total complication rate of 51.11%. The incidence of complications in the PCNL group was significantly lower than that in the URSL group ($P<0.05$) (**Table 3**).

Stone clearance rate and lithotripsy success rate

The stone clearance rate in the PCNL group was 95.12%, with a lithotripsy success rate of 100%. In contrast, the URSL group had a stone clearance rate of 80.00% and a lithotripsy success rate of 86.67%. The stone removal and lithotripsy success rates in the PCNL group were remarkably higher than those in the URSL group (both $P<0.05$) (**Table 4**).

Renal function indicators

Renal function indicators, including Scr, BUN, and CysC, decreased after treatment in both groups. Notably, the PCNL group demonstrated considerably lower levels than those in the URSL group (all $P<0.05$) (**Figure 1**).

Inflammatory markers

Following treatment, the levels of PCT, IL-13, and Hs-CRP were elevated in both groups compared with pretreatment. However, the levels of PCT, IL-13, and Hs-CRP after treatment in the PCNL group were remarkably lower than those in the URSL group ($P<0.05$) (**Figure 2**).

Discussion

PCNL and URSL, as minimally invasive surgical approaches, offer advantages such as small incisions, minimal blood loss, few postoperative complications, and rapid patient recovery [16-18]. However, the applicability of these two surgical methods varies slightly. PCNL is primarily suitable for patients with upper ureteral stones, physiological deformities of the ureter, hydronephrosis, and complex kidney stones [19]. This is because PCNL accesses the renal collecting system directly through the kidney surface, allowing for precise stone fragmentation and removal [20]. URSL, on the other hand, is primarily suitable for patients with middle and lower ureteral stones, as it involves the insertion of the ureteroscope through the urethra without passing through the kidney [16, 21, 22].

In terms of surgical outcomes, PCNL offers a higher success rate for stone fragmentation and shorter operation times [23]. This advantage arises from PCNL's ability to directly reach the stone site through a percutaneous nephro-

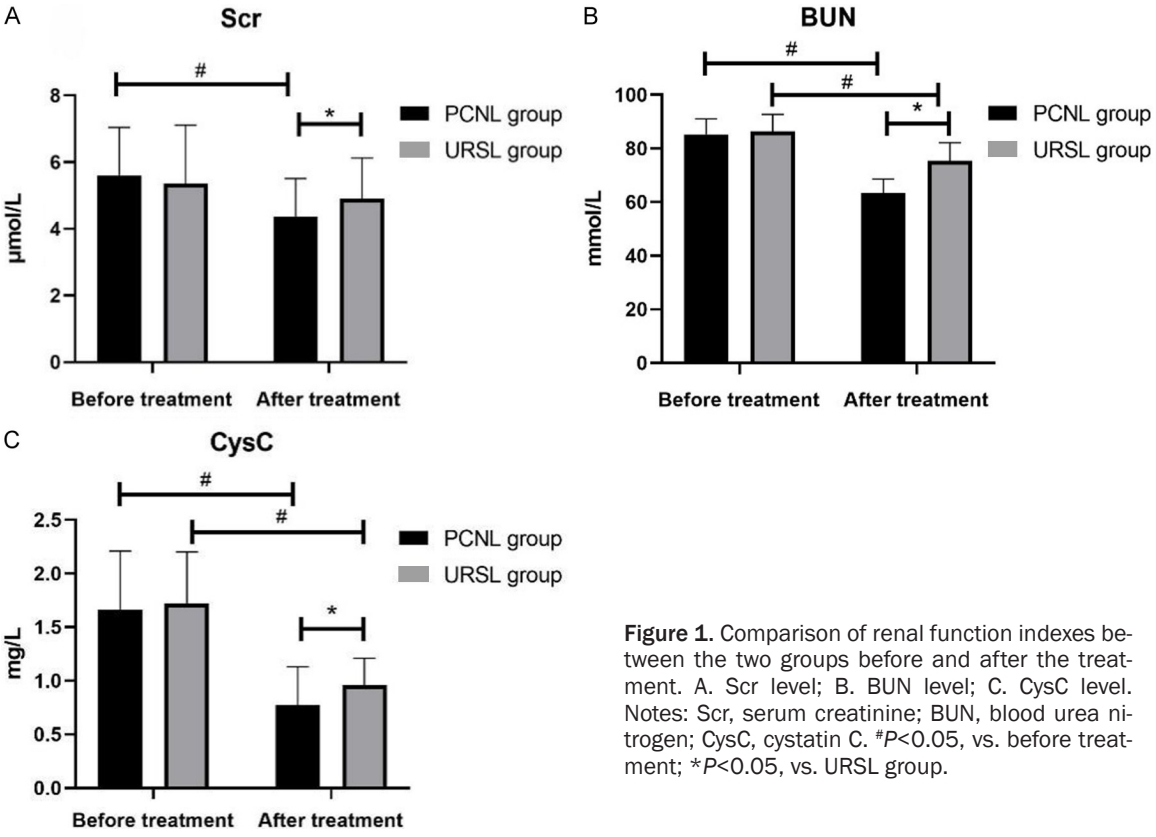

Figure 1. Comparison of renal function indexes between the two groups before and after the treatment. A. Scr level; B. BUN level; C. CysC level. Notes: Scr, serum creatinine; BUN, blood urea nitrogen; CysC, cystatin C. #*P*<0.05, vs. before treatment; **P*<0.05, vs. URSL group.

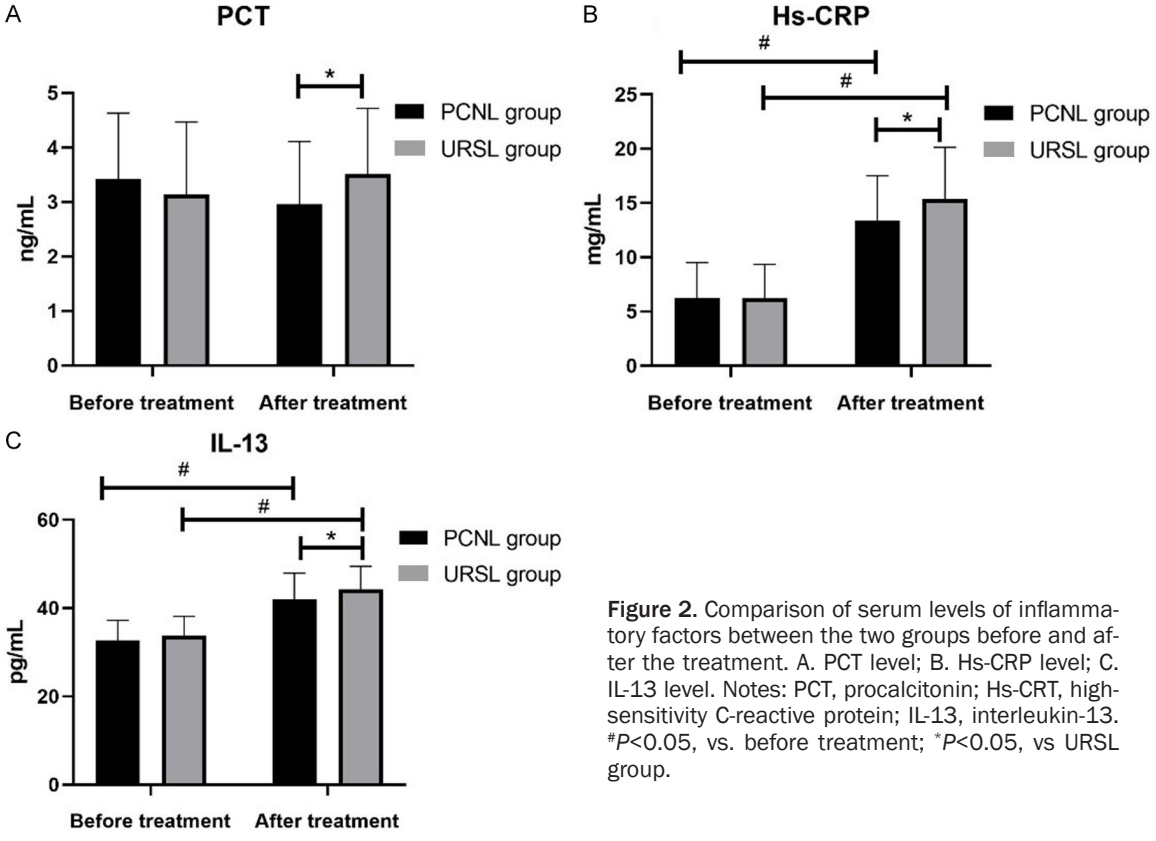

Figure 2. Comparison of serum levels of inflammatory factors between the two groups before and after the treatment. A. PCT level; B. Hs-CRP level; C. IL-13 level. Notes: PCT, procalcitonin; Hs-CRT, high-sensitivity C-reactive protein; IL-13, interleukin-13. #*P*<0.05, vs. before treatment; **P*<0.05, vs URSL group.

scope, facilitating efficient and precise fragmentation and removal [18]. URSL, however, requires passage through the urethra and uses shock wave lithotripsy, whose effectiveness may be influenced by the physiological structure of the urethra, resulting in a relatively lower success rate of lithotripsy [24]. In conclusion, previous studies indicate that URSL and PCNL have distinct advantages and disadvantages when treating upper ureteral stones, and the clinical treatment strategy should be selected based on the patient's actual situation and the surgeon's proficiency [25].

This study focused on patients with upper ureteral stones measuring 1.5-2.0 cm in diameter, systematically analyzing the impact of PCNL and URSL lithotripsy on renal function, inflammatory levels, postoperative complication incidence, and stone fragmentation success rate. The results showed that the PCNL group had a longer hospital stay but a shorter operative time compared to the URSL group, aligning with Chen's findings [10]. The reasons may include the followings: PCNL procedure involves establishing a percutaneous renal channel through the waist, allowing direct access to the lithotripsy site. This shortens the operation time but requires larger surgical incision, leading to a longer hospitalization recovery time. In contrast, URSL involves inserting a ureteroscope through the urethra to perform the procedures within the ureter. Due to the relatively narrow and curved ureteral lumen, the surgical difficulty and complexity are higher, resulting in a longer operative time. However, since the surgical trauma is less, the hospital recovery time is correspondingly shorter. The PCNL group showed significantly higher stone fragmentation and stone clearance rates, demonstrating its clinical efficacy, which is consistent with previous research findings [26, 27]. This result may be related to the fact that in URSL, smaller fragments created by shock wave lithotripsy may be difficult to discharge, particularly due to the physiological narrowing of the ureter, leading to residual stones; while PCNL can directly remove the stone fragments. Furthermore, the incidence of complications in the PCNL group was lower than that in the URSL group, again consistent with the results of the previous study [12]. This is associated with a relatively high stone clearance rate of PCNL, which reduces the risk of complications related to stone retention.

The levels of renal function indicators and inflammatory factors in the PCNL group were significantly lower than those in the URSL group, indicating that PCNL caused less renal parenchymal damage, induced a milder inflammatory response, and demonstrated higher safety. These findings are consistent with previous studies [28]. PCNL involves minimal disruption to the kidneys, enabling a quicker restoration of normal renal functions such as filtration, reabsorption, and excretion. As a result, metabolic wastes like creatinine, urea nitrogen, and cystatin C are cleared more efficiently, maintaining these indicators at lower levels within a shorter recovery period post-surgery. Surgical trauma typically triggers an inflammatory response. However, PCNL causes less tissue damage compared to URSL, leading to lower postoperative levels of inflammatory factors. A milder inflammatory response also correlates with reduced postoperative stress, contributing to a lower risk of complications. This observation aligns with the lower complication rate in the PCNL group compared to the URSL group.

There are still some shortcomings in this study. Although potential biases were reduced, complete avoidance of selection bias was not possible. As a single-center retrospective study with small sample size, the generalizability of the findings may be limited. In addition, the economic impact of surgical procedures is a critical concern for both patients and urologists, but this study did not assess the costs associated with PCNL and URSL, which may affect the financial burden on patients. Therefore, to enhance the reliability and applicability of these findings, further multicenter, large-sample, and comprehensively designed randomized controlled trials are needed to validate the results of this study.

In conclusion, this study demonstrates that PCNL and URSL are both safe and effective treatments for upper ureteral measuring 1.5 cm-2.0 cm, with distinct advantages. PCNL offers high clinical efficacy and a low complication rate, making it suitable for cases requiring high stone clearance rates and complex stone conditions; while USRL has relatively less intraoperative bleeding and shorter postoperative hospitalization, making it a viable option for patients prioritizing minimal surgical trauma and quick recovery. Ultimately, the choice be-

tween PCNL and URSL should be based on individual patient characteristics, surgeon expertise, and clinical circumstances, ensuring an optimized treatment strategy tailored to the patient's needs.

Disclosure of conflict of interest

None.

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