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Original Article

Flexible ureterorenoscopy with holmium laser lithotripsy for ureteral calculi complicated by hydronephrosis

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Abstract: Objective: To clarify the effects of flexible ureterorenoscopy (FURS) combined with holmium laser lithotripsy on surgical outcomes, postoperative pain (POP), and renal function (RF) for the treatment of ureteral calculi (UC) complicated by hydronephrosis (HN). Methods: A total of 128 patients diagnosed with UC complicated with HN treated between February 2024 and December 2025 were enrolled in this retrospective study and divided according to surgical approach. Among them, 65 patients underwent FURS combined with holmium laser lithotripsy (FURS group), and 63 patients received conventional ureteroscopy (URS) combined with laser lithotripsy (URS group). The two groups were compared in terms of clinical efficacy, surgical metrics (intraoperative blood loss, operative time, one-time stone clearance success rate), hospitalization indicators (hospitalization duration and medical expenses), POP, renal function, routine urine test results, serum inflammatory markers, and postoperative complications. Results: The FURS group exhibited a significantly higher overall treatment efficacy rate (P=0.035). Additionally, the FURS group had less intraoperative blood loss, a shorter operative time, and a shorter hospital stay (all P<0.001). In terms of postoperative recovery, patients in the FURS group experienced milder pain on postoperative days 1 (P=0.032) and 3 (P<0.001), with better preserved postoperative renal function (P<0.05), improved routine urine test indicators (P<0.05), lower serum inflammatory levels (P<0.05), and fewer total complications (P<0.001). No significant differences were observed between the two groups in the one-time stone clearance success rate and hospitalization expenses (all P>0.05). Conclusion: FURS demonstrated significantly superior clinical efficacy to conventional URS for the treatment of UC complicated by HN, with better surgical outcome and more safety.

Keywords: Ureteral calculi, hydronephrosis, flexible ureterorenoscopy combined with holmium laser lithotripsy, ureteroscopy with laser lithotripsy, surgical metrics, postoperative pain, renal function

Introduction

Ureteral calculi (UC) are common urological disorders with a gradually rising global incidence [1]. The disease can cause urinary tract obstruction, urinary system infection, renal colic and renal dysfunction, imposing a substantial burden on healthcare systems [2]. Epidemiologic data show that UC occur predominantly in middle-aged adults with a median onset age of 45 years and a male-to-female incidence ratio of 1.65:1. Calcium oxalate and uric acid stones are more prevalent in male patients, whereas infectious calculi are more commonly seen in female patients [3]. Delayed or ineffective treatment of UC may lead to residual stones, secondary ipsilateral hydronephrosis (HN), irreversible renal function damage, and increased difficulty and risk of subsequent treatment [4, 5]. Clinically, HN is detected in up to 90% of UC patients, among which mild HN accounts for 71% of cases, indicating a high comorbidity rate of HN in UC patients [6]. At present, minimally invasive surgery is the mainstream treatment for UC complicated by HN, which is particularly applicable to patients with large stones, obvious clinical symptoms, or ineffective conservative treatment. Common surgical methods include percutaneous nephrolithotomy (PCNL), extracorporeal shock wave lithotripsy (ESWL), and ureteroscopic (URS) laser lithotripsy [7]. PCNL is effective for large and complex calculi but is associated with potential risks such as intraoperative bleeding, infection and renal

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parenchymal injury [8]. Although ESWL is minimally invasive, its application is limited by poor clearance efficacy for large or impacted calculi [9]. Conventional URS relying on rigid ureteroscopes yields favorable outcomes for intraluminal ureteral stones and small renal calculi but carries risks of ureteral injury, secondary infection and bleeding complications [10]. In contrast, flexible ureterorenoscopy (FURS) combined with holmium laser lithotripsy adopts a bendable flexible ureteroscope, which delivers higher stone clearance efficiency and lower complication rates. Nevertheless, this technique has certain limitations, including higher equipment costs and more complex operational procedures [11, 12].

Currently, the specific effects of FURS on surgical quality, postoperative pain (POP) and renal function in patients with UC complicated by HN have not been fully elucidated. This study conducted a comparative analysis between FURS and conventional URS to verify the clinical advantages of FURS, aiming to provide optimized and evidence-based treatment strategies for UC combined with HN. The novelty of this study lies in the comprehensive and systematic evaluation of FURS efficacy and safety in UC plus HN treatment from multiple dimensions, including clinical efficacy, perioperative surgical indicators, hospitalization status, POP, renal function, urinary and systemic inflammatory responses, and complication incidence. The findings provide valuable clinical references for the standardized clinical use of FURS for this disease.

Materials and methods

Case selection

A total of 128 patients diagnosed with UC complicated by HN who received surgical treatment from February 2024 to December 2025 were enrolled in this retrospective study, including 65 cases in the FURS group and 63 cases in the URS group. Baseline data were well-balanced between the two groups with good clinical comparability (P>0.05). This study was approved by the Ethics Committee of Jiangnan University Medical Center.

Inclusion criteria: Patients diagnosed with UC combined with HN by imaging and pathologic examinations [13]; aged 18-80 years; diagnosed with unilateral upper ureteral calculi; meeting the surgical indications for ureteroscopic holmium laser lithotripsy; treatment-naive with no prior stone-related surgery within six months before enrollment; with normal cognitive and communication ability; and with complete clinical medical records.

Exclusion criteria: Patients receiving concurrent lithagogue drug therapy; patients with active or uncontrolled urinary tract infection; pregnant or lactating women; patients with ureteral stricture, adhesion, severe obstruction or malformation secondary to calculi; patients with severe cardiovascular and cerebrovascular diseases; patients with coagulation dysfunction; patients with uncontrolled chronic diseases such as hypertension and diabetes; patients with severe cardiac, pulmonary or renal insufficiency; and patients with mental disorders.

Intervening methods

FURS group: All patients underwent FURS combined with holmium laser lithotripsy. Patients were placed in the lithotomy position. A F8.0/9.8 or F6.0/7.6 ureteroscope was initially inserted to locate the calculi and then withdrawn. A ureteral dilator and sheath were placed and advanced to the stone site for the insertion of a flexible ureteroscope. After accurate stone localization, a holmium laser fiber was implanted, and lithotripsy was performed gradually with parameter settings of 1.0-1.5 J/10 Hz. Small stone fragments were flushed out using perfusion water through the ureteral sheath or extracted using a stone retrieval basket. The laser fiber tip was positioned at the center of the stone for thorough lithotripsy. After confirming complete stone clearance, the endoscope was withdrawn, and an indwelling urinary catheter and a 4.7-French double-J stent were placed routinely.

URS group: All patients received rigid ureteroscopic holmium laser lithotripsy. With patients in the lithotomy position, a rigid ureteroscope was inserted into the bladder, followed by the placement of a zebra guidewire. After scope withdrawal, a ureteral dilator and sheath were advanced along the guidewire to the stone site. A holmium laser fiber was implanted, and stones were fragmented by the nibbling method with consistent laser parameters of 1.0-1.5 J/10 Hz. All crushed stone fragments were extracted, and no residual stones were confirmed intraoperatively. Finally, an indwelling urinary catheter and a 4.7-French double-J stent were placed.

All lithotripsy procedures in both groups were performed by the same team of senior urological surgeons to ensure operational consistency.

Data collection

Clinical efficacy: Postoperative clinical efficacy was classified into three grades: markedly effective (complete resolution of clinical symptoms and no residual calculi on postoperative computed tomography [CT]), effective (alleviation of clinical symptoms with residual calculi ≤4 mm in maximum diameter on CT), and ineffective (unrelieved clinical symptoms with residual calculi >4 mm in maximum diameter requiring further intervention). The total effective rate was calculated as the proportion of patients with markedly effective and effective outcomes among the total cases.

Surgical metrics: Intraoperative blood loss, operative time, and one-time stone clearance success rate were recorded. The one-time stone clearance success rate was defined as no residual stones or residual calculi ≤4 mm in maximum diameter on abdominal plain film re-examination at one month postoperatively.

Hospitalization indices: Postoperative hospitalization duration and total medical expenses of all patients were statistically analyzed.

POP assessment: The Visual Analogue Scale (VAS, score range: 0-10) [14] was adopted to evaluate patients' pain degree at baseline (preoperatively) and on postoperative days 1 and 3, with higher scores indicating more severe pain.

Renal function: Fasting elbow venous blood (3 mL) was collected from all patients before surgery and on postoperative day 1. Serum samples were obtained after centrifugation, and serum blood urea nitrogen (BUN) and serum creatinine (Scr) levels were detected using an automatic electrochemiluminescence analyzer.

Routine urine tests: Automatic urine analyzers were used to detect urinary red blood cell (RBC) and white blood cell counts (WBC) at baseline and on postoperative day 1.

Serum inflammatory markers: Enzyme-linked immunosorbent assays (ELISA) were performed to detect serum levels of interleukin-6 (IL-6), C-reactive protein (CRP), and procalcitonin (PCT) before surgery and on postoperative day 1.

Complication statistics: The incidence of treatment-emergent adverse events including postoperative fever, gross hematuria, ureteral injury, sepsis and renal colic was monitored and recorded to calculate the total complication rate.

Clinical efficacy and postoperative complications were defined as primary outcome measures; surgical indicators, hospitalization indices, postoperative pain (POP), renal function, routine urine test results, and serum inflammatory markers were secondary outcome measures.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation (SD). Independent sample t-tests were used for inter-group comparison, and paired t-tests were used for intra-group comparison of pre- and postoperative data. Categorical variables were presented as cases and percentages (n/%), and the chi-square test was applied for inter-group comparison. All statistical analyses were performed using SPSS 21.0 software. A P value <0.05 was considered significant.

Results

Patient baseline information

There were no significant differences between the FURS group and URS group in terms of age, gender distribution, disease course, stone diameter and stone location (all P>0.05), indicating balanced baseline data between the two groups (**Table 1**).

Clinical efficacy

In the FURS group, 31 cases were markedly effective, 29 cases were effective, and 5 cases were ineffective, with a total effective rate of 92.31%. In the URS group, 24 cases were markedly effective, 26 cases were effective, and 13 cases were ineffective, with a total effective rate of 79.37%. The total clinical effective rate

Table 1. Baseline patient data

Indicator	FURS group (n=65)	URS group (n=63)	χ^2/t	P
Age (years)	41.20±6.24	42.76±5.31	1.521	0.131
Sex			0.110	0.740
Male	38 (58.46)	35 (55.56)		
Female	27 (41.54)	28 (44.44)		
Disease course (years)	6.60±3.04	6.35±3.00	0.468	0.641
Stone diameter	1.81±0.51	1.87±0.51	0.665	0.507
Stone location			0.141	0.708
Left	30 (46.15)	27 (42.86)		
Right	35 (53.85)	36 (57.14)		

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy.

Table 2. Clinical efficacy

Indicator	FURS group (n=65)	URS group (n=63)	χ^2	P
Markedly effective	31 (47.69)	24 (38.10)		
Effective	29 (44.62)	26 (41.27)		
Ineffective	5 (7.69)	13 (20.63)		
Overall effectiveness	60 (92.31)	50 (79.37)	4.434	0.035

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy.

of the FURS group was significantly higher than that of the URS group (P=0.035, **Table 2**).

Surgical metrics

Patients in the FURS group had significantly less intraoperative blood loss and shorter operative time than those in the URS group (all P<0.001). The one-time stone clearance success rate was 96.92% in the FURS group and 95.24% in the URS group, with no significant inter-group difference (P>0.05, **Table 3**).

Hospitalization indices

The FURS group had a significantly shorter postoperative hospital stay than the URS group (P<0.001), while no significant difference was found in hospitalization expenses between the two groups (P>0.05, **Table 4**).

Postoperative pain (POP)

Preoperative VAS scores were comparable between the two groups (P>0.05). The VAS scores of both groups decreased postoperatively, and the FURS group presented significantly lower VAS scores on postoperative days 1 and 3 (P<0.05, **Table 5**).

Renal function

Baseline BUN and Scr levels were similar between the two groups (P>0.05). Both renal function indicators increased to varying degrees after surgery in both groups (P<0.05), and the postoperative BUN and Scr levels in the FURS group were significantly lower than those in the URS group (P<0.05, **Figure 1**).

Routine urine test results

Preoperative urinary RBC and WBC counts were balanced between the two groups (both P>0.05). Both indicators decreased significantly after surgical intervention in both groups (P<0.001), with a more remarkable reduction in the FURS group (P<0.05, **Figure 2**).

Serum inflammatory markers

Baseline serum IL-6, CRP, and PCT levels showed no significant differences between the two groups (P>0.05). All inflammatory markers were elevated postoperatively in both groups (P<0.05), and the postoperative levels of the three markers in the FURS group were significantly lower than those in the URS group (P<0.05, **Figure 3**).

Complications

Common postoperative complications in this study included fever, gross hematuria, ureteral injury, sepsis and renal colic. Statistical analysis showed that the total complication rate was 15.38% in the FURS group compared to 46.03% in the URS group (P<0.001, **Table 6**).

Discussion

The present study confirmed that FURS has superior comprehensive clinical advantages over conventional URS in the treatment of UC complicated by HN, and the specific mechanisms and clinical implications are discussed as follows.

Table 3. Surgical metrics

Indicator	FURS group (n=65)	URS group (n=63)	Fisher's/t	P
Intraoperative blood loss (mL)	13.72±5.84	20.41±9.20	4.927	<0.001
Operative time (min)	42.75±5.18	54.29±9.27	8.729	<0.001
One-time stone clearance success rate	63 (96.92)	60 (95.24)		0.678

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy.

Table 4. Hospitalization indices

Indicator	FURS group (n=65)	URS group (n=63)	t/Z	P
Hospital stay (d)	5.00 (4.00, 6.00)	8.00 (6.00, 10.00)	-6.690	<0.001
Hospitalization cost (CNY)	13292.12±287.30	13357.73±263.27	1.346	0.181

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy.

Table 5. POP assessed by the visual analogue scale score

Indicator	FURS group (n=65)	URS group (n=63)	Z	P
Pre-operation (points)	7.00 (5.00, 8.00)	6.00 (5.00, 8.00)	-0.154	0.877
1 day post-operation (points)	5.00 (4.00, 6.00)	6.00 (5.00, 7.00)	-2.145	0.032
3 days post-operation (points)	2.00 (2.00, 3.00)	4.00 (3.00, 5.00)	-5.089	<0.001

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy; POP, postoperative pain.

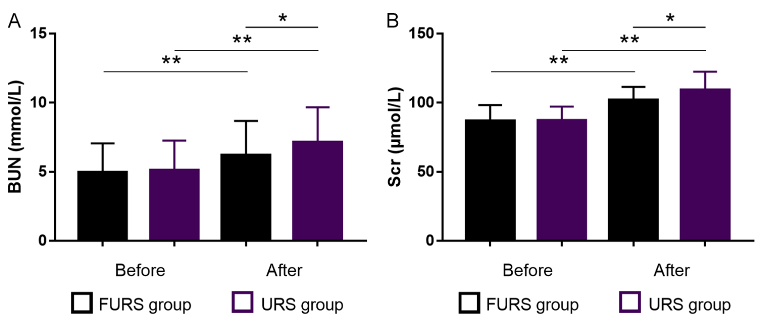

Figure 1. Renal function analysis. A. Pre- and post-operative blood urea nitrogen (BUN) across groups. B. Serum creatinine (Scr) pre- and post-operation. Note: *P<0.05, **P<0.01. FURS, flexible ureterorenoscopy; URS, ureteroscopy.

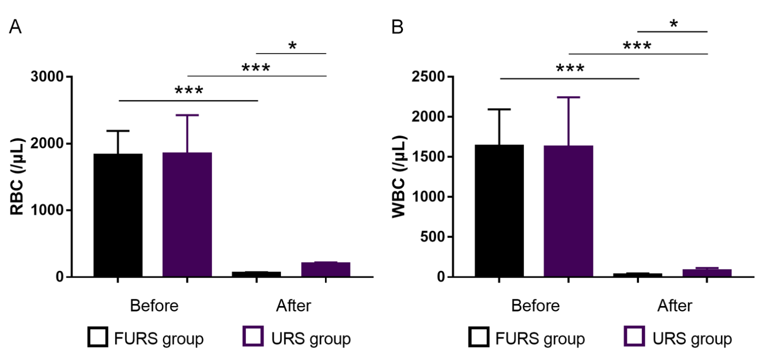

Figure 2. Urine routines. A. Pre- and post-operative red blood cell count (RBC) in two groups. B. White blood cell count (WBC) changes pre- and post-operation. Note: *P<0.05, ***P<0.001. FURS, flexible ureterorenoscopy; URS, ureteroscopy.

First, FURS achieves a significantly higher clinical efficacy rate. The main reason is the difference in lithotripsy modes between the two techniques. FURS adopts central stone lithotripsy with laser fibers positioned at the stone center to fully disrupt the overall stone structure, whereas conventional URS applies the marginal nibbling lithotripsy method, which may leave tiny residual stone fragments [15]. In addition, FURS can thoroughly clear micro-stone fragments through combined water perfusion flushing through the ureteral sheath and stone basket extraction [16]. Moreover, the flexible and steerable ureteroscope used in FURS allows multi-angle observation of the renal pelvis and calyces, effectively avoiding missed detection and retention of residual stones [17], thereby ensuring a higher stone clearance rate and better clinical efficacy in UC plus HN patients. In terms

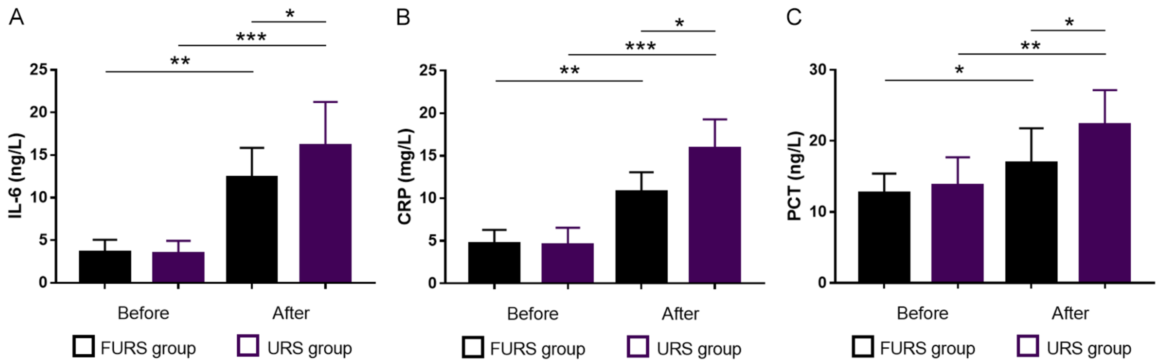

Figure 3. Serum inflammatory markers. A. Pre- and post-operative interleukin-6 (IL-6) across groups. B. Changes in C-reactive protein (CRP) before and after surgery. C. Procalcitonin (PCT) alterations pre- and post-operation. Note: *P<0.05, **P<0.01, ***P<0.001. FURS, flexible ureterorenoscopy; URS, ureteroscopy.

Table 6. Complications

Indicator	FURS group (n=65)	URS group (n=63)	χ^2	P
Pyrexia	4 (6.15)	10 (15.87)		
Hematuresis	2 (3.08)	8 (12.70)		
Ureteral injury	1 (1.54)	3 (4.76)		
Sepsis	1 (1.54)	3 (4.76)		
Renal colic	2 (3.08)	5 (7.94)		
Total	10 (15.38)	29 (46.03)	14.184	<0.001

Note: FURS, flexible ureterorenoscopy; URS, ureteroscopy.

of perioperative surgical indicators, FURS reduces intraoperative blood loss and shortens operative time while maintaining a comparable one-time stone clearance success rate with URS (96.92% vs. 95.24%). The minimally invasive characteristics of FURS contribute to these favorable outcomes. During FURS surgery, stones can be pushed into the renal pelvis for lithotripsy, creating a larger operational space and reducing thermal damage to surrounding normal tissues, which minimizes intraoperative bleeding [18]. The active bending function of the flexible ureteroscope also avoids repeated scope position adjustment and operational interruption caused by the limited maneuverability of rigid ureteroscopes, greatly saving operative time [19]. Meanwhile, intraoperative water perfusion can directly flush out fine stone fragments, reducing the repeated operation of stone basket extraction and further shortening surgical duration [20]. The consistent laser parameter settings (1.0-1.5 J/10 Hz) in both groups accounted for the equivalent one-time stone clearance efficiency, which is consistent with the findings of Serrão Gimenez et al. [21], who reported no significant difference in stone-free rates between FURS and URS for ureteral calculi treatment.

Furthermore, FURS significantly shortens postoperative hospital stay without increasing medical expenses. The flexible ureteroscope can reach all segments of the ureter with shallow tissue penetration, which maximally protects normal urinary tract mucosal tissues, accelerates postoperative patient recovery, and thus reduces hospitalization duration [22, 23]. Peng et al. [24] also confirmed that FURS performed under local anesthesia can further reduce treatment costs, providing a feasible approach to optimize the cost-effectiveness of FURS surgery. In terms of POP control, FURS effectively relieves short-term POP in UC plus HN patients. The high flexibility and maneuverability of the flexible ureteroscope enable precise operation in the renal pelvis and calyces, avoiding excessive extrusion and injury to urinary tract mucosa and renal tissues, thereby alleviating POP responses [25].

Postoperative elevation of BUN and Scr levels in both groups indicated that both surgical procedures may cause transient renal dysfunction, which is presumably associated with intraoperative high-pressure renal pelvic perfusion leading to tubular injury and renal interstitial edema [26]. However, FURS exerted a milder adverse effect on postoperative renal function. Routine urine test results further verified that although both surgeries can improve hematuria and inflammatory abnormalities caused by stone obstruction, FURS has superior advantages in alleviating postoperative local urinary tract inflammation and controlling hematuria. Inflammatory marker detection confirmed that FURS better inhibits surgical stress-induced inflammatory responses, with milder postoperative elevations of IL-6, CRP, and PCT. This benefit may be attributed to the indwelling ureteral sheath during FURS, which reduces intrapelvic pressure and mucosal mechanical damage, thereby mitigating systemic inflammatory reactions [27].

In terms of surgical safety, the FURS group had a significantly lower total complication rate than the URS group (15.38% vs. 46.03%). The flexible ureteroscope can adapt to the complex anatomic structure of the ureter, effectively reducing the risk of mucosal injury; in contrast, the semi-rigid ureteroscope used in conventional URS has poor flexibility, making it prone to cause mucosal abrasion and injury when passing through edematous and inflamed ureteral walls in HN patients [28]. Notably, Subiela et al. [29] reported no significant difference in complication rates between FURS and URS for upper urinary tract calculi, which is partially inconsistent with our results. The discrepancy may stem from differences in study populations: the previous study included simple renal calculi patients without ureteral edema and inflammation, while all patients in our study had secondary HN with inflamed and edematous ureteral walls. In this pathologic state, rigid ureteroscopes are more likely to aggravate urinary tract injury and induce complications, whereas flexible ureteroscopes show better safety adaptability.

This study had several limitations. First, as a single-center retrospective study, inherent selection bias cannot be completely eliminated. Future multi-center prospective studies with enlarged sample sizes are required to verify the conclusions. Second, this study lacked long-term postoperative follow-up, so long-term complication incidence and stone recurrence rates could not be evaluated. Long-term follow-up data (e.g., 5-year follow-up) should be supplemented in subsequent prospective studies to further validate the long-term clinical advantages of FURS. Third, confounding factors such as different medical insurance types and consumable selection were not controlled in the comparison of hospitalization expenses. Propensity score matching can be adopted in future studies to eliminate confounding factors and re-analyze the cost differences between the two surgical methods.

In conclusion, FURS combined with holmium laser lithotripsy is a highly effective and safe treatment for UC complicated with HN. Compared to conventional URS, it can reduce intraoperative blood loss, shorten operative time and hospital stay, alleviate early post-operative pain (POP), minimize surgical damage to renal function, inhibit postoperative inflammatory responses, reduce hematuria severity, and lower complication rates.

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Disclosure of conflict of interest

None.

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