Totally Ultrasound-Guided Supine Mini-PCNL Without Ureteral Catheter in Hydronephrotic Kidney; A Matched-Pair Analysis

Cengiz Çanakcı[1]*, Orkunt Özkaptan[1], Erdinç Dinçer[1], Utku Can[1], Kubilay Can Çağlar[1], Oğuz Türkyılmaz[1]

Purpose: To investigate the safety and efficacy of supine percutaneous nephrolithotomy performed completely under ultrasound guidance without fluoroscopy and ureteral catheterization in kidneys with hydronephrosis.

Materials and methods: This retrospective study analyzed the data of 30 patients (Group 1) with kidney stones larger than 2 cm and grade 2 or higher hydronephrosis who underwent ultrasound-guided supine percutaneous nephrolithotomy without ureteral catheterization and fluoroscopy between January 2022 and November 2024. The data of these patients were compared using matched-pair analysis (1:1) with patients who underwent supine percutaneous nephrolithotomy under ultrasound and fluoroscopy guidance with ureteral catheterization (Group 2) in the same period. The groups were compared regarding access time, operation time, stone-free rates, blood loss, and complications.

Results: There were no statistically significant differences between the two groups in terms of age, gender, side, stone diameter, stone volume, stone density, hydronephrosis grade, and Guy's stone score. Access time was significantly shorter in Group 1 (11.3 ± 3.9 minutes vs 13.9 ± 4.7 minutes, respectively; 95% CI, 0.3–4.9; $p = .026$). The mean operation time was 64.4 ± 19.4 minutes in Group 1 and 102.3 ± 31.2 minutes in Group 2, and this difference was statistically significant (95% CI, 24.2–51.6; $p = .001$). There was no significant difference between the two groups in terms of postoperative first-month stone-free rates (83.3% vs 86.6%, respectively; $p = .723$).

Conclusion: Compared with standard supine mini percutaneous nephrolithotomy, totally ultrasound-guided supine mini percutaneous nephrolithotomy without a ureteral catheter is an effective, safe, and feasible surgery.

Keywords: fluoroscopy; percutaneous nephrolithotomy; ultrasound; ureteral catheterization; kidney calculi

INTRODUCTION

Urolithiasis is a common urologic problem with an increasing incidence[1,2]. According to the AUA and EAU urolithiasis guidelines, percutaneous nephrolithotomy (PCNL) is the gold standard method for kidney stones larger than 2 cm. PCNL is also recommended for lower calyx stones between 1–2 cm[3,4].

One of the important steps of PCNL is access to the renal collecting system. Ultrasound, fluoroscopy, or a combination of the two are used for the control of residual stones in addition to access to the kidney[5,6]. Fluoroscopy-guided percutaneous nephrolithotomy (FG-PCNL) is typically preferred; however, it presents disadvantages such as the potential for injury to adjacent organs and radiation exposure for both the patient and the surgical team[7].

Ultrasound-guided PCNL (US-PCNL) offers advantages over FG-PCNL, including the absence of radiation exposure, the ability to visualize adjacent organs simultaneously, and the capability to identify radiolucent stones[8]. In addition, ultrasound is beneficial in instances of unsuccessful retrograde ureteral catheter placement, including difficulties in visualizing the ureteral orifices and in patients with urinary diversion[9].

In PCNL, an open-ended ureteral catheter is used to provide artificial hydronephrosis, to visualize the collecting system with contrast material, and to prevent stone migration to the ureter. In a prospective randomized study by Eryıldırım et al., ultrasound- and fluoroscopy-assisted prone PCNL was performed without ureteral catheter insertion, and it was reported that a ureteral catheter may not be necessary in a selected group of patients[10]. Tabibi et al. included patients with a single stone in their study, finding no significant difference between the groups with and without catheter insertion[11]. The prior studies assessed outcomes of non-catheterized patients undergoing standard PCNL in the prone position[10–14]. Following years of experience in supine PCNL, we initiated the practice of mini-PCNL in the supine position without ureteral catheterization in patients with hydronephrosis. To our knowledge, there is no existing literature investigating non-catheterized patients undergoing mini-PCNL in the supine position. Performing PCNL without placement of a ureteral catheter is expected to conserve time, prevent unnecessary interventions, and diminish the risk of complications linked to ureteral catheterization. However, the absence of a ureteral catheter may pose a challenge in cases of access failure (e.g., guidewire displacement, hematoma formation, or resolution of hydronephrosis), as it can impair visualization and make repeat access more difficult. In this context, we aimed to compare the data

[1]Department of Urology, Health Sciences University, Kartal Dr. Lütfi Kırdar City Hospital, Istanbul, Turkey.
*Correspondence: Kartal Dr. Lütfi Kırdar City Hospital, D100 Güney Yanyol, Cevizli, Kartal, İstanbul, Turkey.
Phone: +90 216 441 3900. Fax: +90 216 305 5110. E mail: cengizcanakci@hotmail.com.
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Table 1. Demographic characteristics and stone before PSM

	Group 1 (n=30)	Group 2 (n=85)	*P* value
Age (mean±SD)	46.9 ± 9.7	51.8 ± 12.7	0.056
Gender (f/m) (%)	7/23	25/60	0.638
Laterality (Right/Left)	10/20	41/44	0.201
Stone diameter (mm) (mean±SD)	25.9 ± 4.8	28.9 ± 8.4	0.073
Stone volume (mm³) (mean±SD)	3603 ± 3098	4634 ± 3654	0.082
Hounsfield Units (mean±SD)	1088 ± 225	1031 ± 321	0.372
Previous stone surgery (yes/no) (%)	7/23	53/23	0.183
Hydronephrosis (n) (%)	23 (76.6)	71 (83.6)	0.418
Grade 2	7 (23.3)	14 (16.4)	
Grade 3			
Guy's stone score (mean±SD)	1.8 ± 0.92	1.59±0.84	0.254
1	14 (46.6)	51 (60)	
2	10 (33.3)	22 (25.8)	
3	4 (13.3)	8 (9.5)	
4	2 (6.6)	4 (4.7)	
PSM: Propensity score–matched			

Abbreviations: PSM: Propensity score–matched

of patients who underwent supine mini-PCNL with and without ultrasound- and fluoroscopy-guided ureteral catheterization in kidneys with grade 2 or higher hydronephrosis.

MATERIALS AND METHODS

We retrospectively analyzed the data of patients with kidney stones ≥ 2 cm and hydronephrosis grade ≥ 2 between January 2022 and November 2024. This study was conducted in compliance with the International Standard for Good Clinical Practice and the principles of the Declaration of Helsinki. The study protocol was approved by the local ethics committee (Decision No: 2024/010.99/11/1; Decision Date: 25.12.2024). Patients were divided into two groups: Group 1 patients underwent supine mini-PCNL without ureteral catheterization and without fluoroscopy, and Group 2 patients underwent supine mini-PCNL with ureteral catheterization and fluoroscopy with ultrasound. To minimize selection bias and ensure comparability between the groups, a propensity score matching (PSM) analysis was performed. A total of 115 patients who underwent PCNL with hydronephrosis were initially evaluated, including 30 patients in the non-scopic group and 85 patients in the standard group. Propensity scores were estimated using a logistic regression model based on six baseline covariates: age, gender, stone diameter, stone volume, stone density (Hounsfield units), and hydronephrosis grade. A 1:1 nearest-neighbor matching without replacement was performed using a caliper of 0.2 standard deviations of the logit of the propensity score. This procedure yielded 30 matched pairs (n = 60) for final comparative analysis. Patients in Group 2 were operated on by different surgeons, while patients in Group 1 were operated on by a single surgeon. Patients with no hydronephrosis, anatomically anomalous kidney, active urinary tract infection, immunodeficiency, coagulation disorder, age < 18 years, or cardiopulmonary insufficiency were excluded.

Preoperative complete blood count, biochemistry, coagulation tests, and urine culture were performed. Patients with a positive urine culture were treated with appropriate antibiotic therapy. Surgery was performed after the urine culture was sterile. Preoperative computed tomography (CT) and kidney–ureter–bladder (KUB) radiography were obtained. The largest stone diameter and stone volume were measured on CT images. Stone volume was calculated using the ellipsoid formula: length × width × height × π/6.

Patients were operated on under general anesthesia in Bart's flank-free position. In Group 1, after a Foley catheter was inserted, access was made to the collecting system under direct ultrasound guidance. The access length was measured using the access needle, and dilatation was conducted up to 20 French with an Amplatz dilator, followed by placement of the access sheath. Only ultrasound was used during dilatation and residual stone control. In Group 2, a 5F ureteral catheter was

Table 2. Demographic and stone characteristics after PSM

	Group 1 (n=30)	Group 2 (n=30)	*P* value
Age (mean±SD)	47.8 ± 9.9	52.3 ± 13.4	0.142
Gender (f/m) (%)	7/23	10/20	0.567
Laterality (Right/Left)	10/20	17/13	0.119
Stone diameter (mm) (mean±SD)	25.9 ± 4.84	28.3 ± 6.76	0.130
Stone volume (mm³) (median–IQR)	2792 (2 225–4163)	3854 (2090–6208)	0.224
Hounsfield Units (mean±SD)	1088 ± 225	1049 ± 359	0.617
Previous stone surgery (yes/no) (%)	7/23	11/19	0.399
Hydronephrosis (n) (%)	23 (76.6)	25 (83.3)	0.748
Grade 2	7 (23.3)	5 (16.6)	
Grade 3			
Guy's stone score (mean±SD)	1.8 ± 0.92	2.03 ± 1.09	0.652
1	14 (46.6)	13 (43.3)	
2	10 (33.3)	7 (23.3)	
3	4 (13.3)	6 (20)	
4	2 (6.6)	4 (13.3)	

PSM: Propensity score–matched

Table 3. Operative and postoperative data

	Group 1 (n=30)	Group 2 (n=30)	*P* value
Access time (min) (mean±SD)	11.3 ± 3.9	13.9 ± 4.7	0.026
Operative time (min) (mean±SD)	64.4 ± 19.4	102.3 ± 31.2	0.001
Site of puncture (n) (%) Upper	2 (6.6)	3 (10)	0.225
Site of puncture (n) (%) Mid	24 (80)	18 (60)	
Site of puncture (n) (%) Lower	4 (13.3)	9 (30)	
Hemoglobin drop (g/dL) (median–IQR)	1.6 (0.8–2.2)	1.4 (0.4–1.9)	0.182
Hematocrit drop (%) (median–IQR)	3.5 (2.4–7.3)	4.25 (1.67–5.92)	0.171
Lithotriptor type (pneumatic/laser) (n)	22/8	18/12	0.412
Clavien–Dindo classification (n) (%) Minor	3 (10)	4 (13.3)	0.788
Clavien–Dindo classification (n) (%) Major	2 (6.6)	1 (3.3)	
Postoperative first-day stone-free (n) (%)	23 (76.6)	25 (83.3)	0.748
Postoperative first-month stone-free (n) (%)	25 (83.3)	26 (86.6)	0.723

inserted into the ipsilateral ureter using a cystoscope, and a Foley catheter was inserted. Access was achieved using ultrasound and fluoroscopy guidance, followed by dilatation to 20 French with an Amplatz dilator, and the access sheath was subsequently placed. Fluoroscopy was used during dilatation and residual control. Both groups utilized a sensor-type guidewire. A 12 French nephroscope was employed in conjunction with an 18 French working sheath. A laser lithotripter or pneumatic lithotripter was used for fragmentation of stones. Depending on the surgeon's decision, in certain cases, a double-J (D/J) stent was employed. A 14 Fr nephrostomy catheter was placed at the end of the operation for both groups.

Patients were compared in terms of access time, operation time, stone-free status, bleeding, and complications. On postoperative day 1, residual control was performed with KUB radiography. Stone-free status was evaluated by KUB and ultrasonography at the first postoperative month, and patients with residual stones < 4 mm were considered stone-free. Complications were evaluated according to the Clavien–Dindo classification. Grade 1–2 complications were considered minor (postoperative fever, blood transfusion, additional pharmacological treatment); Grade 3 (intervention under local or general anesthesia) and above (Grade 4: sepsis, septic shock, organ failure; Grade 5: death) were considered major complications.

Statistical analysis

Quantitative variables are presented as mean ± standard deviation or median (interquartile range), depending on the distribution. Qualitative variables are expressed as numbers and percentages. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess normality. Additionally, graphical methods such as Q–Q plots were used to visually confirm distribution patterns. For example, the Q–Q plot for stone diameter z-scores showed that the data were approximately normally distributed(**Figure 1**). Before matching, continuous varia-

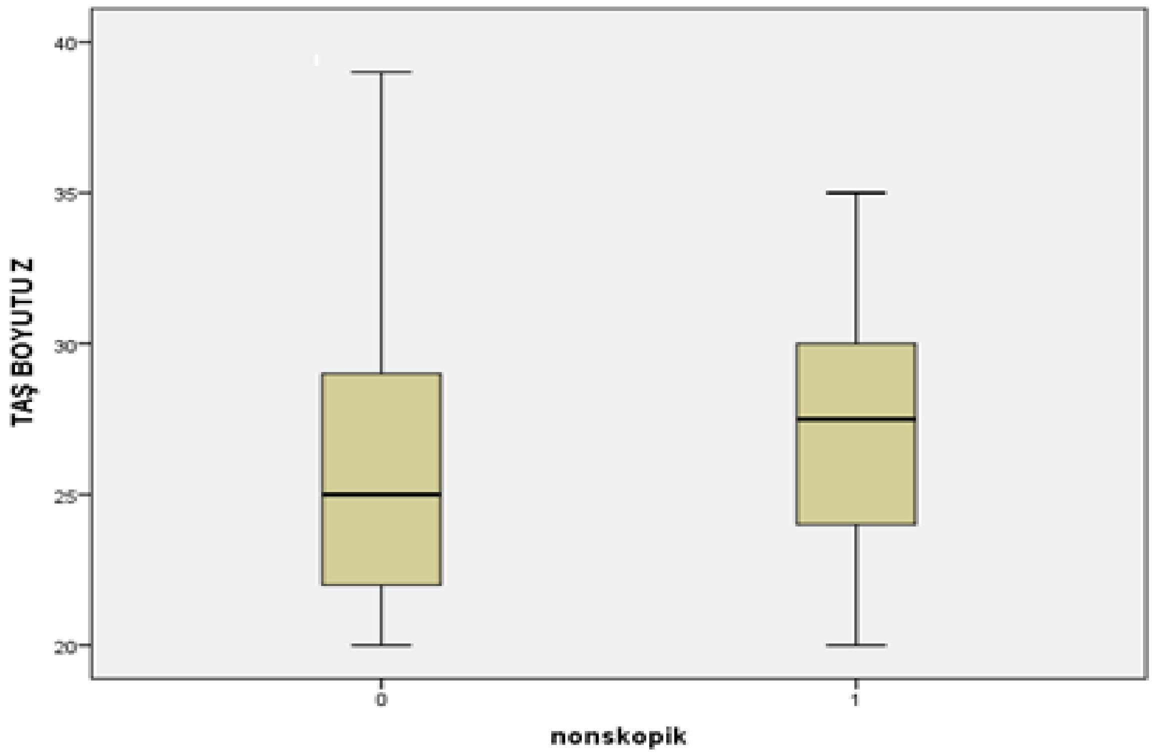

Figure 1. Graphical assessment of normality for stone diameter using a Q–Q plot.

bles with normal distribution were compared using the independent-samples t test, while non-normally distributed variables were analyzed using the Mann–Whitney *U* test. Categorical variables were compared using the chi-square test. After 1:1 propensity score matching, comparisons between groups were performed using the paired-samples t test for normally distributed continuous variables and the Wilcoxon signed-rank test for non-normally distributed variables. Categorical variables were compared using the McNemar test. All analyses were conducted using SPSS software version 23.0 (SPSS Inc., Chicago, IL, USA), and a p value < .05 was considered statistically significant.

RESULTS

The demographic characteristics and stone-related variables of the groups before propensity score matching are presented in (**Table 1**). Demographic and stone characteristics of the matched patients are shown in (**Table 2**). The mean age of the patients was 47.8 ± 9.9 years in Group 1 and 52.3 ± 13.4 years in Group 2 (p = .142). There were 7 females and 23 males in Group 1 and 10 females and 20 males in Group 2, with no significant difference between the two groups (p = .567). Stone characteristics (stone diameter, stone volume, stone density) were similar in both groups (p = .130, p = .224, p = .617, respectively). Guy's stone score was 1.8 ± 0.92 in Group 1 and 2.03 ± 1.09 in Group 2, with no statistically significant difference (p = .652). Perioperative and postoperative data of the patients are shown in (**Table 3**). The mean access time was 11.3 ± 3.9 minutes in Group 1 and 13.9 ± 4.7 minutes in Group 2, indicating a statistically significant difference (95% CI, 0.3–4.9; p = .026). Mean operation time was significantly shorter in Group 1 (64.4 ± 19.4 minutes vs 102.3 ± 31.2 minutes; 95% CI, 24.2–51.6; p = .001). The median decrease in hemoglobin was 1.6 g/dL (IQR, 0.8–2.2) in Group 1 and 1.4 g/dL (IQR, 0.4–1.9) in Group 2, with no statistically significant difference (p = .182). Similarly, the median decrease in hematocrit was 3.5% (IQR, 2.4–7.3) in Group 1 and 4.25% (IQR, 1.67–5.92) in Group 2, which also did not reach statistical significance (p = .171). Postoperative day-1 stone-free rates were 76.6% (n = 23) in Group 1 and 83.3% (n = 25) in Group 2 (p = .748); this result was not statistically significant. Complications were evaluated according to the Clavien–Dindo classification. In Group 1, 2 patients required D/J stent insertion under local anesthesia as a major complication. In Group 2, 1 patient required D/J stent placement under local anesthesia. Transfusion was required in 1 patient in Group 1, while none of the patients in Group 2 received transfusion. No statistically significant difference was observed between the two groups concerning complications (p = .788).

DISCUSSION

In this study, we investigated the necessity of ureteral catheterization in dilated systems. The outcomes demonstrated that patients with kidney stones and hydronephrosis achieved favorable results in terms of complications and stone-free rates without the need for ureteral catheterization.

In the standard PCNL technique, a ureteral catheter is inserted and removed sometimes perioperatively, sometimes in the early postoperative period. PCNL is traditionally performed in the prone position. It provides a larger space for access and facilitates manipulation of the nephroscope. However, it has disadvantages in patients with cardiac and skeletal deformities and obesity, and position changes and anesthetic interventions may be difficult when there is a respiratory or circulatory problem[15]. Supine PCNL was first described by Valdivia et al. in 1998[16]. Later, various supine PCNL positions were described, such as Galdakao-modified Valdivia, Barts-modified Valdivia, and Barts flank-free modified positions[17]. Supine PCNL has the advantages of allowing simultaneous retrograde access, shorter operative time, and less radiation exposure of the surgeon's hand[15,17]. Previous studies on PCNL without ureteral catheterization were conducted in the prone position, whereas the study by Tabibi et al. did not specify the position employed[10–14]. In our study, Bart's flank-free position was preferred. Thus, retrograde access can be instantly facilitated in the case of a potential access failure.

In PCNL, both access and residual stone control are usually performed with fluoroscopy. The most important disadvantage of fluoroscopic access is exposure of the patient and the surgical team to ionizing radiation[2,18]. To reduce radiation exposure, combined ultrasound with fluoroscopy or fully US-PCNL has been described. In addition, US-PCNL provides real-time guidance during access, enabling evaluation of neighboring organs (such as spleen, colon, pleura)[19]. However, the inability to visualize Amplatz dilators in real time, the requirement for a higher level of surgical expertise compared with fluoroscopy, and the potential loss of visualization in cases of access failure are notable disadvantages[9,20]. In a prospective study, Falahatkar et al. compared supine PCNL under fluoroscopy guidance with full ultrasound guidance and found no difference between the two groups in terms of stone-free rates and complications[20]. El-Shaer et al. compared prone and supine ultrasound-guided standard PCNL in a prospective randomized study and observed no significant difference in stone-free rates[7]. In another prospective randomized study, 450 patients underwent mini-PCNL with ultrasound guidance, fluoroscopy guidance, and a combination of the two. Ultrasonography-guided mini-PCNL was safe and effective in simple kidney stones with a S.T.O.N.E. score of 5–6, but fluoroscopy and the combination were more effective in complicated stones with a S.T.O.N.E. score of 7–8[21]. In meta-analyses, US-PCNL has similar success rates compared with FG-PCNL and is more advantageous in terms of complications[2,19]. Our study used ultrasound-guided and combined-guidance techniques, revealing no significant differences between the two groups regarding stone-free and complication rates. In case of unsuccessful access under ultrasound guidance, a C-arm fluoroscopy unit was always available in the operating room to allow immediate fluoroscopic intervention if needed.

Retrograde ureteral catheterization is the first stage of standard PCNL. The aims of ureteral catheterization are calyx selection by retrograde pyelography, providing artificial hydronephrosis, and preventing migration of stone fragments into the ureter[12]. Complications such as ureteral perforation, renal perforation, bleeding, and mucosal damage may develop during ureteral catheterization. In addition, retrograde access may not be possible in patients in whom the orifice cannot be seen or in those with urinary diversion. In 2005, in a preliminary study, Tabibi et al. placed a ureteral catheter in one group and placed only a guidewire in the other group. This study utilizing fluoroscopic access found no significant difference between the groups regarding stone-free rates; however, a greater decrease in hemoglobin levels was observed in the group with ureteral catheter placement[11]. The research performed by Eryıldırım et al. involving patients undergoing prone PCNL revealed that the operation time was reduced in the group without ureteral catheter placement, while no significant differences were observed in stone-free rates or complications[10].

A prospective study conducted in 2024 compared 50 patients who underwent tubeless ultrasound-guided mini-PCNL without ureteral catheterization and without hydronephrosis to 49 patients who underwent traditional prone mini-PCNL. No difference was observed in stone-free rates; however, the operation time was shorter, costs were reduced, and hospitalization duration was decreased. This technique has been demonstrated to be effective and reliable[12]. In a retrospective study by Li et al., prone mini-PCNL performed under ultrasound guidance without the use of a ureteral catheter did not show any difference in terms of stone-free rates and complications; nevertheless, the operation time was reduced[14]. In our study, we found a statistically significant shorter operation time. There was no apparent difference between the groups when complications were assessed.

US-PCNL can be successfully performed in the supine and flank-free positions. There are case reports demonstrating its successful application in pregnant patients[22,23]. One of the most significant morbidities associated with PCNL is colonic injury, which may occur in both positions. In a study by Hur et al., the risk of colonic injury was found to be higher in the prone position compared with the supine position[24]. Similarly, in a study by Maghsoudi et al., colonic injury was reported in patients who underwent PCNL in the prone position[22]. In our study, no colonic injuries were observed. We believe that both the use of the supine position and ultrasound guidance during access contributed to minimizing the risk of colonic injury.

In our study, the duration of access was statistically shorter in the ultrasound-only group. Zhu et al. similarly observed that combined guidance resulted in longer access times compared with fluoroscopic or ultrasonic access alone[21]. The study performed by Hosseini et al. compared fluoroscopic access and combined access, revealing no significant difference in access duration between the two groups[9]. In another randomized study, fluoroscopic access was compared with ultrasonic access in supine PCNL and no significant difference was observed in terms of access time[20]. In a meta-analysis by Wang et al., ultrasonic and fluoroscopic access were compared and no significant difference was found between access times[2]. The reduced duration of ultrasonic access observed in our study may be attributed to heterogeneity of the combined group with respect to the operator.

The most important limitations of this study are the modest sample size and its retrospective design. To confirm the results, prospective randomized studies are needed. Another limitation is the lack of documentation of the duration of ureteral catheterization in the ureteral catheterization group. However, the matched group underwent procedures under fluoroscopy and ultrasound guidance. The fact that the matched group was not composed of cases performed completely under ultrasound guidance with ureteral catheter insertion may affect the results. Another limitation is that surgeons with different degrees of experience operated on patients in the combined group, whereas a single highly experienced surgeon operated on patients in the ultrasound group.

CONCLUSIONS

Ultrasound-guided supine mini-PCNL can be performed effectively and safely without the necessity of a ureteral catheter in kidney stones with hydronephrosis. Experienced physicians may perform mini-PCNL without ureteral catheterization in the supine position to minimize surgical steps while preserving stone clearance rates and not increasing complication rates. These data should be supported by prospective randomized studies.

SUMMARY

In patients with hydronephrosis, a less invasive, ultrasound-guided supine mini-PCNL without a ureteral catheter shortened surgery and access times while keeping stone-clearance and complication rates similar to standard care.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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