Urologia Internationalis

Research Article

Urol Int 2024;108:190–197
DOI: 10.1159/000536545

Received: November 12, 2023
Accepted: January 9, 2024
Published online: January 30, 2024

Feasibility of Simultaneous Bilateral Endoscopic Surgery in Prone Split-Leg Position for Bilateral Upper Urinary Tract Calculi: A Pilot Study

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Keywords
Simultaneous manipulation · Endoscopy · Prone split-leg position · Urolithiasis

Abstract

Introduction: We explored the viability of simultaneous bilateral endoscopic surgery (SBES) in the prone split-leg position for managing bilateral calculi. ***Methods:*** We retrospectively reviewed 72 patients who underwent SBES, with procedures involving ureteroscopy (URS) and contralateral percutaneous nephrolithotomy (PNL) simultaneously, in prone split-leg position. ***Results:*** Operative times averaged 109.38 ± 30.76 min, with an average hospital stay of 7.79 ± 3.78 days. The bilateral stone-free rate (SFR) was 70.83%, while URS and PNL demonstrated comparable unilateral SFR (83.33% and 79.17%, respectively). Receiver operating characteristics curves for predicting unilateral residual fragments yielded an area under the curve of 0.84 (URS) and 0.81 (PNL) with respective cutoff values of stone diameter of 11.55 mm and 23.52 mm. Fifty-seven (79.17%) and 15 (20.83%) patients encountered grade 0–1/2 complications, with no severe complications (grade 3–5) recorded. No significant changes in blood count or renal function were observed post-SBES. ***Conclusions:*** SBES in the prone split-leg position is a viable option for managing bilateral upper tract urolithiasis. Larger scale studies are needed to further assess safety and efficacy in various positions.

Introduction

Urolithiasis is a globally prevalent condition that has witnessed a significant surge in incidence over the past 3 decades [1]. As endoscopic devices and techniques continue to advance, minimally invasive procedures have taken precedence in the treatment of upper urinary tract calculi, while the use of shockwave lithotripsy and open surgery has declined [2]. However, the management of bilateral upper urinary tract calculi, with an incidence of 10% as reported [3], remains a subject of debate.

In comparison to the traditional staged operation, same-session bilateral endoscopic surgery is favored due to its comparable stone-free rates (SFRs) and additional

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advantages such as a solitary anesthetic and operative procedure, reduced hospitalization, and enhanced cost-effectiveness [4, 5]. Nevertheless, this approach presents challenges, including the potential for extended anesthetic and operative durations that may increase the risk of severe perioperative complications [6, 7].

To circumvent these challenges, a novel procedure was introduced, wherein two teams of urologists simultaneously managed bilateral upper urinary-tract calculi. This approach, initially termed simultaneous bilateral endoscopic surgery (SBES) by Giusti et al. [8], has been performed in various positions, including lithotomy, Valdivia, or Galdakao-modified Valdivia positions, with favorable clinical outcomes reported [8–12]. In contrast to previous studies, the primary aim of our present investigation was to assess the feasibility of SBES in the prone split-leg position for the management of bilateral upper urinary tract calculi.

Materials and Methods

Patient Selection

Between March 2019 and February 2022, we retrospectively analyzed 72 consecutive patients who underwent SBES in the prone split-leg position. These procedures were exclusively performed by a skilled urological surgical team. Patients undergoing unilateral endoscopic combined intrarenal surgery or those with untreated urinary tract infections (UTIs), potential urological malignancies, or pregnancy were excluded from the study.

Ethical Approval

Our study received approval from the Institutional Ethics Committee of Beijing Chao-Yang Hospital and adhered to the Declaration of Helsinki principles. Informed consent was obtained from all eligible adult patients (age >18 years) after explaining the potential benefits and risks of simultaneous surgery.

Preoperative Assessment

Before the procedures, patient evaluation included gender, age, body mass index, medical history, serum creatinine (sCr), endogenous creatinine clearance rate (Ccr) calculated with the Cockcroft-Gault formula [13], complete blood count (CBC), urine microscopy, and culture. Non-contrast-enhanced computed tomography (NCCT) aided in stone diagnosis and grading complexity using the Guy's stone score [14]. CBC and renal function were monitored on the first postoperative day (POD1) and POD7. A follow-up NCCT at the 1-month visit defined stone-free status as the absence of stones or residual fragments <4 mm in diameter. Operative time was recorded from flexible cystoscope insertion to nephrostomy tube and bilateral double-J stent placement. Infrared spectroscopy was employed for stone composition analysis. Preoperative comorbidities were assessed using the age-adjusted Charlson comorbidity index [15, 16], and perioperative complications were categorized according to the Clavien-Dindo classification system [7].

Stone Analysis

We used Materialise's interactive medical image control system (MIMICS) software to analyze stone parameters, including diameter, surface area, volume, mean density, and high-density (>1,000 Hounsfield units) volume. In cases with multiple stones, data were summed for each stone.

Surgical Procedure

Anticoagulant therapy was discontinued as per guidelines before SBES, and single-shot intravenous prophylactic antibiotics were administered preoperatively. SBES was performed under general anesthesia in the prone split-leg position as illustrated in Figure 1.

A ureteral catheter was placed into the kidney for percutaneous nephrolithotomy (PNL) with a 16.2 Fr flexible cystoscope (Happiness Workshop, Bengbu, China) to create artificial hydronephrosis. Contralaterally, a 7.4/8.6 Fr hydrophilic flexible ureteroscope (Happiness Workshop, Bengbu, China) was retrogradely inserted to fragment possible ureteral stones and provide optical dilation. A ureteral access sheath (Boston Scientific, Marlborough, MA, USA) was introduced over a hydrophilic guide wire. Then, a 14 Fr Foley catheter was placed before lithotripsy to prevent bladder overdistension.

The simultaneous PNL and contralateral retrograde intrarenal surgery (RIRS) was carried out, following the conventional protocols. In brief, PNL was performed under the ultrasound guidance, and multiple access tracts were required if necessary. RIRS utilized disposable flexible ureteroscopes and a Ho:YAG laser (Raykeen, Shanghai, China). Nephrostomy tubes were removed on POD3, and bilateral double-J stents were removed 4 weeks postoperation.

Statistical Analysis

We conducted statistical analysis using SPSS Statistics software (version 20, IBM Corporation, Armonk, NY, USA). Data were presented as numbers/percentages or mean ± standard deviation. Stone characteristics for different interventions (ureteroscopy [URS] or PNL) were compared using the χ^2 test and paired t test. Data were compared between stone-free and non-stone-free groups with a two-sample t test. Receiver operating characteristics (ROC) curves assessed the predictive capability of stone characteristics for stone-free status. Friedman tests compared related variables (sCr, Ccr, and CBC), with Bonferroni corrections for multiple comparisons. A p value <0.05 was considered statistically significant.

Results

We conducted a retrospective analysis of 72 patients who underwent SBES in the prone split-leg position for bilateral calculi to assess the feasibility of this novel procedure. Demographic and clinical characteristics are presented in Table 1. Of note, 45 (62.50%) patients had ureteral stents placed due to urolithiasis, while 18 (25.00%) patients had bilateral indwelling stents.

Table 2 illustrates that stone load and density in PNL significantly exceeded those in URS, with no differences

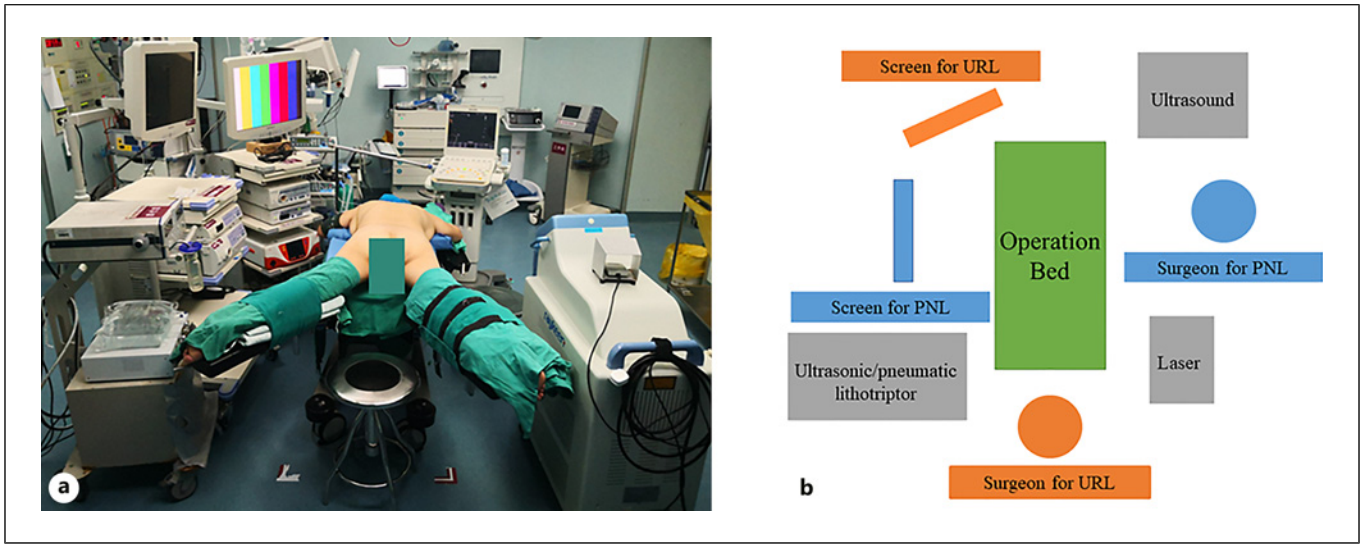

Fig. 1. Operation room setup. Before the initiation of the procedure, patients were kept in the prone split-leg position to avoid the extra time for repositioning. The real (**a**) and virtual (**b**) operation room setup was shown to perform an SBES in prone split-leg position of right PNL and left URS. SBES, simultaneous bilateral endoscopic surgery; PNL, percutaneous nephrolithotomy; URS, ureteroscopic lithotripsy.

Table 1. Demographic and clinical characteristics of the patients (n = 72)

Age, years	56.25±13.84
Male/female, *n* (%)	54/18 (75.00/25.00)
BMI, kg/m^2	25.29±3.03
aCCI, *n* (%)	
0–2	51 (70.83)
3–5	18 (25.00)
>5	3 (4.17)
ASA score, *n* (%)	
I–II	57 (79.17)
III	15 (20.83)
Previous history of stenting, *n* (%)	45 (62.50)

Data were reported as numbers/percentages or mean ± SD. BMI, body mass index; aCCI, age-adjusted Charlson comorbidity index; ASA, American Society of Anesthesiologists; SD, standard deviation.

observed in terms of side and location. Eighteen (25.00%) cases were classified as grade III according to the Guy's stone score, primarily due to the presence of stones in calyceal diverticula in 6 cases and partial staghorn calculi in 12 cases; no patients with grade IV (complete staghorn) calculi were included.

In URS, ureteral calculi were diagnosed in 33 (45.83%) cases and were effectively disintegrated using flexible ureteroscopes. In every case, a ureteral access sheath was utilized (12/14 Fr in 69 patients, 11/13 Fr in 3 patients). Contralaterally, 69 (95.83%) patients underwent PNL with a single tract, with only 3 (4.17%) patients requiring a second tract. The mean operative time was 109.38 ± 30.76 min, and the average hospital stay was 7.79 ± 3.78 days. Further details regarding the outcomes of SBES are outlined in Table 3.

One month post-surgery, an NCCT scan indicated that 51 (70.83%) patients achieved bilateral stone-free status, with comparable unilateral SFR reported in URS (83.33%) and PNL (79.17%). Among the 21 patients with significant residual fragments, 15 underwent second-stage RIRS, while active surveillance was offered to the 6 patients with asymptomatic, non-obstructing calyceal stones. Stone composition results, analyzed with samples collected during PNL, revealed that calcium oxalate was the most common substance in 57 (79.17%) patients.

Patients with residual stones exhibited significantly larger stone diameter, surface area, and volume but not higher density or larger high-density (>1,000 Hounsfield units) volume, compared to patients reported as bilateral stone-free (Table 4; Fig. 2). To predict unilateral residual fragments based on stone diameter, ROC curves were calculated, yielding an area under the curve of 0.84 (95% CI: 0.64, 1.00, $p < 0.05$) for URS and 0.81 (95% CI: 0.61, 1.00, $p < 0.05$) for PNL. The corresponding cutoff values were 11.55 mm (sensitivity 100% and specificity 60%) and 23.52 mm (sensitivity 100% and specificity 53%),

Table 2. Clinical characteristics of stones (n = 72)

	For the stone in URS	For the stone in PNL
Side (left/right), *n* (%)	27/45 (37.50/62.50)	45/27 (62.50/37.50)
Location, *n* (%)		
Kidney only	39 (54.17)	48 (66.67)
Ureter only	15 (20.83)	12 (16.67)
Kidney and ureter	18 (25.00)	12 (16.67)
Diameter, mm	16.56±14.88	30.44±14.14*
Surface area, mm^2	291.22±372.72	899.93±745.03*
Volume, mm^3	365.32±699.37	1,515.19±1,559.51*
Mean density, HU	742.87±256.24	871.35±249.16*
High-density (>1,000 HU) volume, mm^3	63.90±109.01	572.75±660.58*
Guy's stone score, *n* (%)		
The absence of kidney stone	–	12 (16.67)
1	–	15 (20.83)
2	–	27 (37.50)
3	–	18 (25.00)
4	–	0 (0.00)

Data were reported as numbers/percentages or mean ± SD. URS, ureteroscopy; PNL, percutaneous nephrolithotomy; HU, Hounsfield unit; SD, standard deviation. *Indicated significant difference when compared with stone receiving URS.

Table 3. Clinical outcome of SBES in prone split-leg position (n = 72)

Operative time, min	109.38±30.76
Hospital stay, days	7.79±3.78
SFR, *n* (%)	
Bilateral	51 (70.83)
For the stone in URS	60 (83.33)
For the stone in PNL	57 (79.17)
Complications, *n* (%)	
Grade 0–1	57 (79.17)
Grade 2	15 (20.83)
Grade 3–5	0 (0.00)
Stone composition, *n* (%)	
Calcium oxalate monohydrate	30 (41.67)
Calcium oxalate dihydrate	27 (37.50)
Uric acid	9 (12.50)
Carbonated apatite	6 (8.33)

Data were reported as numbers/percentages or mean ± SD. SBES, simultaneous bilateral endoscopic surgery; SFR, stone-free rate; URS, ureteroscopy; PNL, percutaneous nephrolithotomy; SD, standard deviation.

respectively. Detailed ROC curve analysis data are provided in Table 5.

In terms of complications, 57 (79.17%) patients experienced grade 0–1 complications according to the Clavien-Dindo classification system, including mild pain, frequency, urgency, gross hematuria, transient fever, and others. Grade 2 complications were observed in 15 (20.83%) patients who were diagnosed with febrile UTI and required additional intravenous antibiotics; no blood transfusions were necessary in this series. Fortunately, no severe complications (grade 3–5) were recorded in our study. The Friedman test revealed significant differences among time points regarding sCr, Ccr, white blood cell count, and hemoglobin. However, no significant difference was found in CBC and renal function between baseline and POD7 (Fig. 3).

Discussion

Various approaches to bilateral endoscopic stone management have been explored to achieve optimal stone removal while minimizing complications. Same-session surgery, where bilateral procedures are performed sequentially, has gained popularity as an alternative to traditional staged bilateral lithotripsy.

A novel procedure, defined as SBES, was recently introduced by Giusti et al. [8]. SBES offers several advantages over the same-session surgery, particularly in reducing prolonged operative duration and anesthetic exposure, which can increase the risk of complications [6, 7]. The concept of simultaneous bilateral URS in the lithotomy position was first reported in 2005 [17]. Subsequently, Giusti et al. [8, 9] proposed SBES in the Valdivia position, involving RIRS and contralateral PNL [12]. In our study, we present data on the feasibility of

Table 4. Clinical characteristics of stones in the stone-free group (n = 51) and non-stone-free group (n = 21)

	Total (n = 72)	Stone-free group (n = 51)	Non-stone-free group (n = 21)
Diameter, mm	47.01±21.06	39.22±11.87	65.92±27.12*
Surface area, mm^2	1,181.15±858.83	942.37±451.86	1,761.06±1,314.95*
Volume, mm^3	1,880.52±1,723.35	1,393.00±927.97	3,064.50±2,603.75*
Mean density, HU	851.65±253.14	834.95±264.38	892.19±237.77
High-density (>1,000 HU) volume, mm^3	593.54±664.76	493.28±633.59	837.03±725.13

Data were reported as numbers/percentages or mean ± SD. HU, Hounsfield unit; SD, standard deviation. *indicated significant difference between the stone-free and non-stone-free groups.

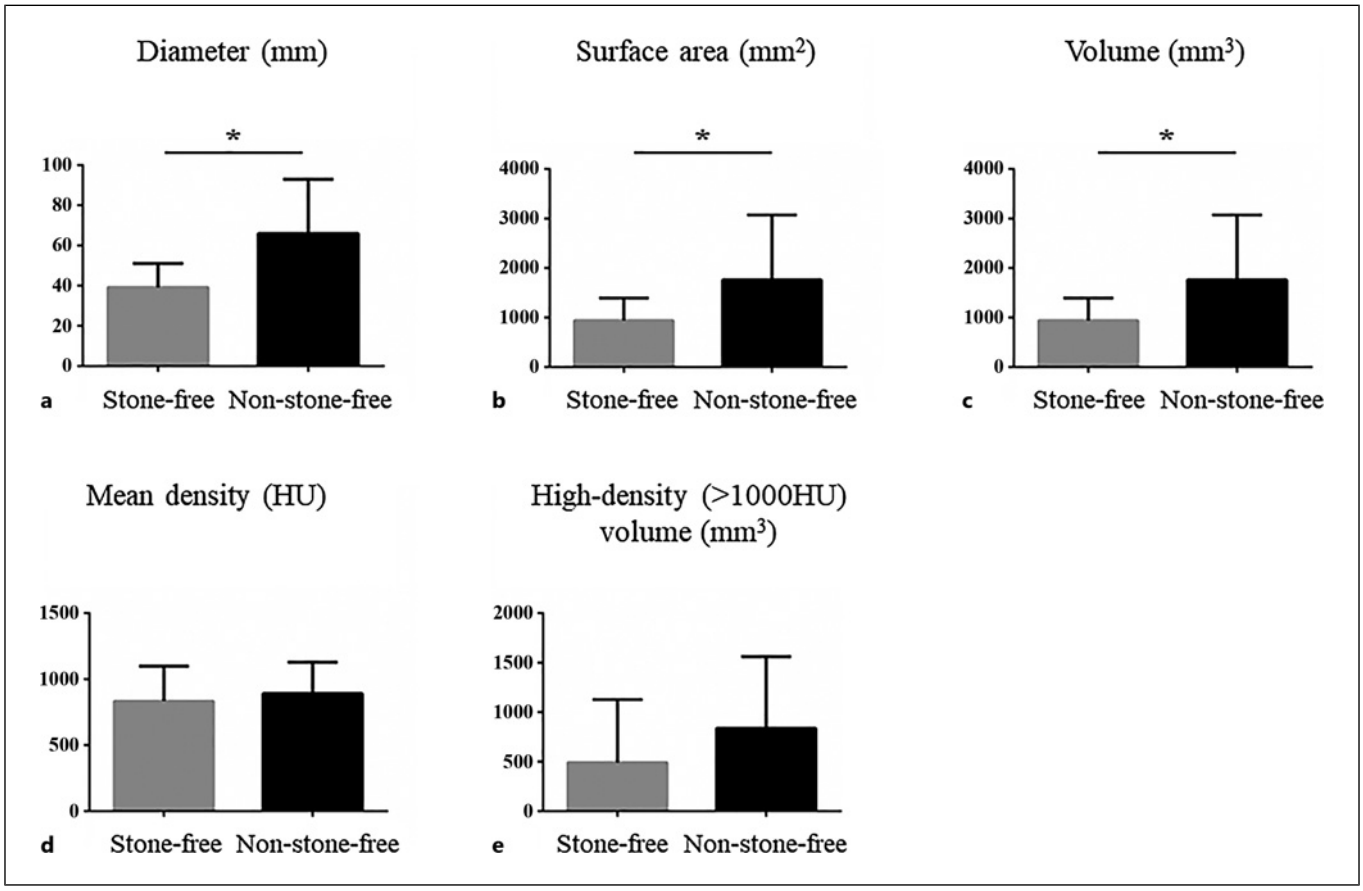

Fig. 2. Comparison of clinical characteristics of stones in the stone-free group (n = 51) and non-stone-free group (n = 21). Patients in the non-stone-free group (n = 21) had significantly larger diameter (**a**), surface area (**b**), and volume (**c**) but not higher density (**d**) or larger high-density (>1,000 HU) volume (**e**), compared to patients in the stone-free group (n = 51). *Indicates statistically significant difference.

SBES in the prone split-leg position for the first time. Our initial analysis includes 72 cases of SBES in this position, with a bilateral SFR of 70.83%, which is comparable to that reported for supine SBES [8, 10, 12].

While there is no consensus on the superiority of PNL SFR in different positions, we typically favor prone PNL as the standard procedure for complex stones. Our extensive experience with over 3,000 prone PNL procedures has

Table 5. Area under the ROC curve of stone characteristics

	AUC	95% CI
URS		
Diameter, mm	0.84*	0.64, 1.00
Surface area, mm^2	0.73	0.45, 1.00
Volume, mm^3	0.71	0.42, 1.00
Mean density, HU	0.50	0.16, 0.84
High-density (>1,000 HU) volume, mm^3	0.56	0.23, 0.88
PNL		
Diameter, mm	0.81*	0.61, 1.00
Surface area, mm^2	0.67	0.34, 1.00
Volume, mm^3	0.67	0.35, 1.00
Mean density, HU	0.57	0.31, 0.83
High-density (>1,000 HU) volume, mm^3	0.64	0.34, 0.95

ROC, receiver operating characteristics; URS, ureteroscopy; PNL, percutaneous nephrolithotomy; HU, Hounsfield unit; AUC, area under the curve; CI, confidence interval. *Indicated significant difference.

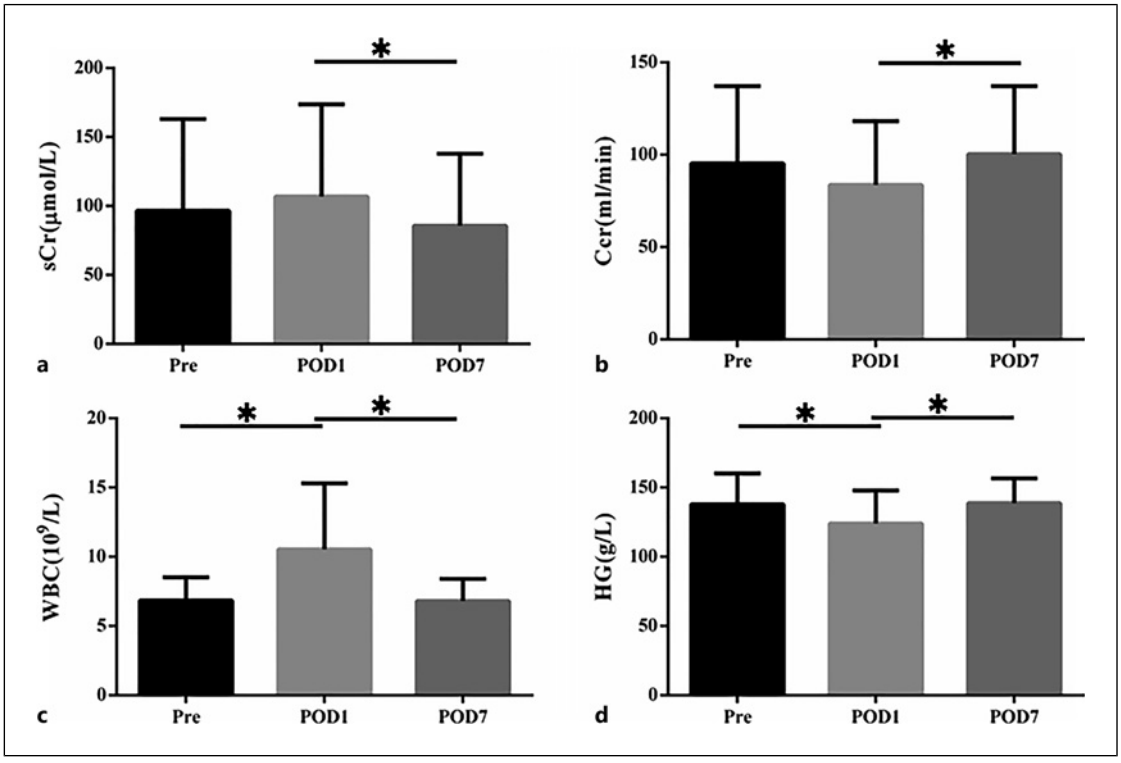

Fig. 3. Comparison of complete blood count (CBC) and renal function during the perioperative period. The postoperative renal function, including sCr (**a**) and Ccr (**b**), deteriorated insignificantly, followed by a remarkable improvement to the baseline level. Significant but transient increase of white blood cell count (**c**) as well as decrease of hemoglobin (**d**) was observed on POD1, compared with pre-SBES, and was restored to the baseline level on POD7. sCr, serum creatinine; Ccr, creatinine clearance rate; WBC, white blood cell count; HG, hemoglobin; POD, postoperative day. *Indicates statistically significant difference.

demonstrated several advantages, including easier access to the posterior calyces, reduced risk of iatrogenic visceral injury, a larger surface area for puncture, and sufficient space for endoscopic manipulation [18–20]. Additionally, the prone position facilitates a potential pattern of SBES involving bilateral PNL. To further minimize the operative

duration and avoid respiratory as well as cardiac risks, patients were kept in the prone split-leg position throughout the endoscopic manipulation. Our proficiency in prone retrograde URS from routine endoscopic combined intrarenal surgery procedures significantly shortened the learning curve for prone SBES. The use of flexible endoscopes, such as cystoscopes and ureteroscopes, rather than traditional rigid or semirigid instruments, allowed for improved manipulation during guide wire placement, accessing the ureteral orifice, and ureteral lithotripsy. Female patients, the absence of ureteral calculi, and pre-stenting facilitated URS in the prone position, but cases with steinstrasse or impacted ureteral stones required special attention.

Our observation that patients achieving bilateral stone-free status had significantly smaller stone diameter, surface area, and volume highlights the association between stone load and SFR. A study by Angerri et al. [10] reported an SFR of 70% after SBES in either the supine or lithotomy position, with residual stones primarily found on the side treated for high-volume (complete) staghorn calculi. In the previous literature, ideal SBES candidates were described as patients with bilateral small-to medium-sized stones to improve SFR, but specific criteria were lacking [8, 12]. A unique aspect of our study is the elaboration of ROC curve, confirming that stone diameter is the best predictor of residual stones. We identified cutoff values of 11.55 mm for URS and 23.52 mm for PNL, above which there is a high risk of residual stones.

No significant differences in CBC and renal function were found between baseline and POD7, consistent with previous data on supine SBES [8]. However, special attention should be given to patients with preoperative comorbidities, such as renal function impairment and anemia, when undergoing bilateral endoscopic surgeries [21]. Infectious complications following SBES should also be noted. In our study, 15 out of 72 cases developed febrile UTI after surgery and required additional intravenous antibiotics, but no urosepsis occurred. The higher incidence of infectious complications in our analysis, compared to other studies [8, 12], may be attributed to the larger stone load and longer operative times in our cohort. Prolonged operation duration has been recognized as a risk factor for postoperative UTI [22–25]. In our series, we strictly limited lithotripsy to 120 min. The prone position has been associated with more septic complications due to the upwardly oriented access sheath, which can impair drainage and increase intrarenal pressures, compared to supine PNL [26]. During bilateral irrigation in SBES, maintaining minimized intrarenal pressure is crucial, achieved by avoiding excessive flow rates and maintaining a low endoscope-sheath diameter ratio whenever possible. Patients with positive urine nitrite or urine cultures were categorized as "high risk" and excluded from our study.

Our study has some limitations, including a small sample size and its retrospective, non-comparative design. The strict selection criteria were established to prioritize procedure safety, but this may introduce bias into the complication data. Further prospective investigations with larger sample sizes are ongoing to confirm the safety and efficacy of SBES in the prone split-leg position. Nevertheless, our pilot study demonstrates the feasibility of prone SBES and provides initial insights into candidate selection, surgical techniques, and complication prevention.

Conclusion

For managing bilateral upper tract urolithiasis, simultaneous treatment is a recommended approach, offering reduced operative time, minimized anesthetic exposure, and fewer complications. Depending on optimized candidate selection and perioperative management, SBES in the prone split-leg position emerges as a promising alternative.

Statement of Ethics

This protocol was reviewed and approved by Institutional Ethics Committee of Beijing Chao-Yang Hospital, approval number (2023-769). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from each patient to participate in the study and for publication of the details of their medical case and any accompanying images.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

This work was supported by Beijing Municipal Administration of Hospitals Incubating Program, Code: PX2024013.

Author Contributions

Yihang Jiang and Yali Sheng: writing original draft and review and editing. Junhui Zhang and Hui Shan: review and editing. Yuguang Jiang: software. Ning Kang: conceptualization and review and editing.

Data Availability Statement

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.

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