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Comparison of retrograde intrarenal surgery versus a single-session percutaneous nephrolithotomy for lower-pole stones with a diameter of 15 to 30 mm: A propensity score-matching study

Gyoo Hwan Jung, Jae Hyun Jung, Tae Sik Ahn, Joong Sub Lee, Sung Yong Cho[1], Chang Wook Jeong, Seung Bae Lee[1], Hyeon Hoe Kim, Seung-June Oh

Department of Urology, Seoul National University Hospital, Seoul, [1]Department of Urology, Seoul Metropolitan Government-Seoul National University Boramae Medical Center, Seoul, Korea

Purpose: To investigate surgical outcomes between retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PNL) groups for a main stone sized 15 to 30 mm and located in the lower-pole calyx.

Materials and Methods: Patients who underwent PNL or RIRS for a main stone sized 15 to 30 mm and located in the lower-pole calyx were retrospectively reviewed. Each patient in the RIRS group was matched to one in the PNL group on the basis of calculated propensity scores by use of age, sex, body mass index, previous treatment history, stone site, maximum stone size, and stone volume. We compared perioperative outcomes between the unmatched and matched groups.

Results: Patients underwent PNL (n=87, 66.4%) or RIRS (n=44, 33.6%). After matching, 44 patients in each group were included. Mean patient age was 54.4±13.7 years. Perioperative hemoglobin drop was significantly higher and the hospital stay was longer in the PNL group than in the RIRS group. The operative time was significantly longer in the RIRS group than in the PNL group. Stone-free rates were higher and complications rates were lower in the RIRS group than in the PNL group without statistical significance. The presence of a stone located in the lower-anterior minor calyx was a predictor of stone-free status.

Conclusions: RIRS and single-session PNL for patients with a main stone of 15 to 30 mm located in the lower-pole calyx showed comparable surgical results. However, RIRS can be performed more safely than PNL with less bleeding. Stones in the lower-anterior minor calyx should be carefully removed during these procedures.

Keywords: Nephrolithiasis; Renal surgery; Ureterorenoscopy

INTRODUCTION

For active removal of renal stones, we frequently choose extracorporeal shock wave lithotripsy (SWL), retrograde intrarenal surgery (RIRS), or percutaneous nephrolithotomy (PNL). SWL remains the first option for renal stones <20

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Corresponding Author: Seung-June Oh
Department of Urology, Seoul National University Hospital, Seoul National University College of Medicine, 101 Daehak-ro, Jongno-gu, Seoul 110-744, Korea
TEL: +82-2-2072-2406, FAX: +82-2-742-4665, E-mail: sjo@snu.ac.kr

mm, whereas PNL is usually performed for large renal stones of a maximum diameter ≥20 mm [1].

However, postoperative stone-free rates (SFRs) are affected by clinical parameters such as stone location in the lower-pole calyx, obesity, large stone size, stone composition, and anatomy of the renal calyces [2-4]. In particular, stones in the lower-pole calyx are usually much more difficult to remove than are stones in the upper- or midcalyces [2], and some investigations have shown that RIRS can easily overcome some unfavorable parameters such as location of stones in the lower-pole calyx [5]. Some investigations have shown the efficacy of RIRS in the management of renal stones larger than 10 mm or 15 mm or 20 mm in diameter; however, some of the studies showed the efficacy of RIRS in a single arm [6], whereas others showed comparative results between PNL and RIRS regardless of stone location [7]. This may be because the proportion of renal stones that are located only in the lower-pole calyx is relatively low.

In the present study, we compared pre- and postoperative outcomes between PNL and RIRS groups for a main stone of more than 15 mm located in the lower-pole calyx by using a propensity score-matching method to reduce the impact of treatment-related bias. The results of the present study show that RIRS can be another option for the active removal of renal stones with a maximum diameter of more than 15 mm in the lower-pole calyx.

MATERIALS AND METHODS

1. Subjects

Between January 2008 and December 2012, consecutive patients who underwent single-session PNL or RIRS by five surgeons at three tertiary referral centers were retrospectively reviewed. Patients with a main stone sized 15 to 30 mm located in the lower-pole calyx were included in the present study. Patients with ureteral stricture, febrile urinary tract infection, coagulopathy, or congenital anomaly were excluded from the present study. Both PNL and RIRS were recommended for management of these stones. The surgical treatment was determined after the patients were informed of the advantages, disadvantages, and complications of both methods. This study was approved by the institutional review boards of our institutions.

2. PNL

Patients were placed in the prone position. A percutaneous nephrostomy tube was inserted by a single uroradiologist in all patients. If the patient had a percutaneous nephrostomy preoperatively, it was used as the access tract. Under ultrasonographic guidance, a calyceal puncture at the posterior lower-pole calyx was performed with a 22-gauge Skinny Needle (Cook Medical, Bloomington, IN, USA). A flexible 0.035-inch Terumo guidewire (Boston Scientific Corp., Miami, FL, USA) was inserted into the ureter or an upper-pole calyx through the renal pelvis. The skin and fascia were incised and a 30-Fr balloon dilatation (Nephromax; Boston Scientific Corp.) was performed. A 24-Fr Nephroscope (Karl Storz, Tuttlingen, Germany) was inserted inside the sheath and the renal stones were fragmented by a lithoclast or holmium:YAG laser with a 365- or 550-μm fiber (Trimedyne Inc., Irvine, CA, USA). Stone fragments were retrieved by use of alligator or 5-Fr grasping forceps. After the stone fragments were removed, a decision was made about whether to insert a percutaneous nephrostomy tube or a 6-Fr ureteral JJ stent. A 16-Fr urethral Foley catheter was inserted at the end of the operation. Patients were usually discharged postoperatively 2 or 3 days after the percutaneous nephrostomy and the urethral Foley catheters were removed at this time. The ureteral JJ stent was usually removed within 1 to 3 weeks postoperatively.

3. RIRS

Patients were positioned in the dorsal lithotomy position. The ureteral orifice was identified and cannulated with a 0.035-mm Terumo guidewire and an open-ended 5-Fr ureteral catheter. The Terumo guidewire was substituted with a Superstiff guidewire (Boston Scientific Corp.). A ureteral balloon dilator was inserted if there was a narrowing of the ureteral lumen. A 12- or 14-Fr ureteral access sheath (Cook Medical) was placed in position. A 7.5-Fr Flex-X2 flexible ureteroscope (Karl Storz) was inserted through the access sheath. A 200- or 365-μm laser fiber was used for treatment of the stones. The stone located in the lower-pole calyx was sometimes mobilized to the upper or mid calyx for the sake of fragmenting stones easily. Holmium laser power was set to 10 W. Fragmented stones were removed with a 1.9-Fr zero-tipped nitinol stone basket (Cook Medical). A 6-Fr JJ ureteral stent was inserted in most of the cases. A urethral Foley catheter was inserted at the end of the operation. Patients were usually discharged on the first postoperative day and the urethral Foley catheters were removed at this time. The ureteral JJ stent was usually removed within 1 to 3 weeks postoperatively.

4. Clinical parameters

Age at operation, sex, body mass index, and pre- and postoperative 2-week serum creatinine, estimated glomerular filtration rate (GFR), and hemoglobin were evaluated.

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Stone size, stone volume, laterality, stone location, major stone composition, a previous history of treatment, and perioperative parameters were also evaluated. Stone size was measured as the longest diameter on plain x-ray of the KUB (kidney, ureter, and bladder) region and noncontrast computed tomography. The stone volume was calculated to be 0.523×height×width×length (mm^3). We performed plain x-ray to assess the immediate stone-free status during the immediate postoperative period. All patients underwent plain x-ray or noncontrast computed tomography to evaluate the presence of residual stones at 1 month postoperatively. Determination of the images was based on the radiopacity on plain x-ray. The anterior and posterior divisions of the lower minor calyces were determined according to whether the division was located anterior or posterior to the frontal plane of the extension line of the major calyx [8]. For comparisons between the RIRS and PNL operations, "stone-free" status was defined as the patient being nonsymptomatic and having obstructing residual stone fragments less than 3 mm for RIRS and PNL in maximum diameter on the same images at 1 month postoperatively, respectively. Complications were assessed according to the modified Clavien classification.

5. Statistical analysis

All variables were expressed as mean±standard deviation or number (%). Differences in patient demographics were analyzed by using the independent t-test between the two operative groups. Categorical variables were compared by the chi-square and Fisher exact test. Propensity score matching was used to reduce the impact of treatment-related bias in estimating the treatment effects using observational data. Each patient in the RIRS group was matched to one in the PNL group on the basis of calculated propensity scores by using multiple logistic-regression analysis including age, sex, body mass index, previous treatment history, stone site, maximum stone size, and total stone volume. Continuous and categorical parameters were combined to yield a propensity score for each patient in both operation groups. The means and standard deviations related to matching covariates were equivalent between groups. We calculated and compared the perioperative parameters and the surgical outcomes of the stone-free rates and complication rates between the unmatched and matched groups. Univariate and multivariate logistic regression analyses with backward stepwise selection were used to show predictors of stone-free status. Statistical significance was considered at $p<0.05$. All statistical analyses were performed by using commercially available software (SAS 9.2; SAS Institute Inc., Cary, NC, USA).

RESULTS

1. Patient characteristics

As shown in Table 1, patients who underwent PNL (n=87, 66.4%) or RIRS (n=44, 33.6%) were analyzed in the present study. After propensity matching, 44 patients in each group were included in the analysis. The patients' mean age was 54.4±13.7 years. In matched samples, there were no significant differences in body mass index, serum creatinine, estimated GFR, hemoglobin, previous SWL history, previous history of ureteroscopy, or stone location between the PNL and RIRS groups.

2. Perioperative findings

As shown in Table 2, perioperative hemoglobin drop and estimated blood loss were significantly higher in the PNL group than in the RIRS group. The hospital stay was longer in the PNL group than in the RIRS group. In contrast, the operative time was significantly longer in the RIRS group than in the PNL group and ureteral JJ stents were more frequently inserted in the RIRS group than in the PNL group. There were no significant differences in the rates of occurrence of anesthetic complications.

3. Surgical outcomes according to operation method

As shown in Table 3, RIRS showed higher stone-free rates than did PNL; however, this difference was not statistically significant. All remnant stones were less than 6 mm in maximum diameter and no ancillary procedure was needed during the 1 year of follow-up. Complications occurred in 15.9% of the PNL group and in 4.5% of the RIRS group; however, this difference was not statistically significant. In most cases, minor complications occurred and two cases of embolization and wound dehiscence occurred in the PNL group. Intraoperative ureter injury occurred in five cases in the RIRS group and two of them showed ureteral dye leakage; however, no ureteral stricture was found during the 1 year of follow-up. The rest of the cases showed only contusion or hematoma.

4. Analysis for prediction of stone-free status

As shown in Table 4, univariate and multivariate logistic regression analyses showed that the presence of a stone located in the lower-anterior minor calyx was a predictive factor for stone-free status. Chi-square tests showed that stones in the lower-anterior minor calyx were more difficult to remove than were those in the lower-posterior minor

Table 1. Patient characteristics

Characteristic	Unmatched sample			Matched sample		
	PNL (n=87)	RIRS (n=44)	p-value	PNL (n=44)	RIRS (n=44)	p-value
Age (y)	56.1±13.2	53.8±13.4	0.370	56.5±14.4	53.8±13.4	0.365
Gender			0.495			0.823
Male	52 (59.8)	29 (65.9)		28 (63.6)	29 (65.9)	
Female	35 (40.2)	15 (34.1)		16 (36.4)	15 (34.1)	
Body mass index (kg/m^2)	25.1±3.6	24.1±3.7	0.114	24.0±3.1	24.1±3.7	0.952
Creatinine (mg/dL)	1.1±0.2	1.0±0.2	0.876	1.0±2.5	1.0±0.5	0.850
Estimated GFR (mL/min/1.73 m^2)	74.5±26.2	82.5±29.0	0.112	73.6±30.3	82.5±29.0	0.163
Hemoglobin (mg/dL)	14.0±1.7	13.2±2.0	0.012*	13.6±1.7	13.2±2.0	0.294
Previous SWL history	16 (18.4)	5 (11.4)	0.300	3 (6.8)	5 (11.4)	0.713
Previous URS history	5 (5.7)	4 (9.1)	0.483	2 (4.5)	4 (9.1)	0.676
Stone site			0.959			0.520
Right	51 (58.6)	26 (59.1)		23 (52.3)	26 (59.1)	
Left	36 (41.4)	18 (40.9)		21 (47.7)	18 (40.9)	
Stone location						
Pelvis	56 (64.4)	26 (59.1)	0.556	22 (50.0)	26 (59.1)	0.392
Major calyx (lower)	62 (71.3)	9 (20.5)	0.001*	28 (63.6)	9 (20.5)	<0.001*
Minor calyx (lower anterior)	19 (21.8)	18 (40.9)	0.022*	19 (43.2)	18 (40.9)	0.829
Minor calyx (lower posterior)	31 (35.6)	16 (36.4)	0.934	17 (38.6)	16 (36.4)	0.826
Maximal stone size (mm)	23.7±6.4	20.0±4.1	0.001*	21.5±3.3	20.0±4.1	0.098
Total stone volume (mm^3)	1,853.6±1,187.1	1,491.5±1,384.1	0.122	1,332.6±955.3	1,491.5±1,384.1	0.532
No. of stones	2.5±1.6	2.0±1.0	0.019*	2.4±1.7	2.0±1.0	0.166
Main stone composition			0.098			0.127
Calcium oxalate monohydrate	23 (26.4)	20 (45.4)		10 (22.7)	20 (45.4)	
Calcium oxalate dehydrate	6 (6.9)	1 (2.3)		3 (6.8)	1 (2.3)	
Carbonate apatite	3 (3.4)	0 (0.0)		2 (4.5)	0 (0.0)	
Uric acid	2 (2.3)	2 (4.5)		2 (4.5)	2 (4.5)	
Struvite	5 (5.7)	1 (2.3)		3 (6.8)	1 (2.3)	
Ammonium urate	8 (9.2)	0 (0.0)		0 (0.0)	0 (0.0)	
Cystine	0 (0.0)	1 (2.3)		0 (0.0)	1 (2.3)	
Calcium oxalate trihydrate	1 (1.1)	0 (0.0)		0 (0.0)	0 (0.0)	
Brushite	1 (1.1)	0 (0.0)		1 (2.3)	0 (0.0)	
Others	12 (13.8)	0 (0.0)		3 (6.8)	0 (0.0)	
Missing	37 (42.5)	19 (43.2)		21 (47.7)	19 (43.2)	

Values are presented as mean±standard deviation or number (%).
Comparison after propensity-score matching for age, sex, body mass index, previous treatment history, stone site, maximal stone size, and total stone volume.
PNL, percutaneous nephrolithotomy; RIRS, retrograde intrarenal stone surgery; GFR, glomerular filtration rate; SWL, shock wave lithotripsy; URS, ureteroscopic stone surgery.
*p<0.05, statistically significant difference.

calyx.

In the PNL group, seven cases had one or more remnant stones. The renal stones were located in the lower-anterior calyx in five cases (71.4%), the lower-posterior calyx in a single case (14.3%), and the lower anterior and posterior calyces in a single case (14.3%). In the RIRS groups, three cases had remnant stones in the lower-anterior minor calyx.

DISCUSSION

1. Removal of renal stones in the lower-anterior and lower-posterior calyces

The present study compared the perioperative outcomes between the PNL and RIRS groups for a main stone sized 15 to 30 mm and located in the lower-pole calyx by use of a propensity score matching method. Although previous studies have demonstrated the efficacy of PNL or micro-

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Table 2. Perioperative findings

Variable	Unmatched sample			Matched sample		
	PNL	RIRS	p-value	PNL	RIRS	p-value
Operative time (min)	90.7±47.5	123.0±57.4	0.069	85.5±41.1	123.0±57.4	0.005*
Postoperative creatinine (mg/dL)	1.0±0.2	1.1±0.5	0.240	1.0±2.2	1.1±0.5	0.235
GFR increase (postoperative minus preoperative)	2.9±22.3	11.1±20.1	0.092	5.0±21.0	11.1±20.1	0.242
Hemoglobin drop (postoperative minus preoperative)	–1.0±1.3	–0.2±0.9	0.003*	–1.0±1.2	–0.2±0.9	0.008*
Estimated blood loss (mL)	73.2±89.3	10.6±22.2	0.001*	81.5±95.4	10.6±22.2	0.001*
Transfusion (%)	2 (2.3)	0 (0)	0.550	2 (4.5)	0 (0)	0.494
Ureteral JJ stent insertion (%)	48 (55.2)	37 (86.0)	0.001*	23 (52.3)	37 (86.0)	0.001*
Removal of urethral catheter (d)	1.5±0.9	1.5±0.8	0.012*	1.5±0.9	1.5±0.8	0.018*
Discharge (d)	4.0±1.5	2.0±2.6	0.001*	3.9±1.7	2.0±2.6	0.001*
Removal of ureteral JJ stent (d)	18.8±12.6	12.2±7.1	0.020*	17.4±14.3	12.2±7.1	0.242

PNL, percutaneous nephrolithotomy; RIRS, retrograde intrarenal stone surgery; GFR, glomerular filtration rate.
*p<0.05, statistically significant difference.

Table 3. Surgical outcomes according to surgical method

Variable	PNL	RIRS	p-value
Stone-free status	37 (84.1)	41 (93.2)	0.314
Complications[a]			
I			
Transient increase in creatinine > 1.4 ng/dL	0 (0)	1 (2.3)	0.315
Prolonged tract leakage	1 (2.3)	0 (0)	1.000
II			
Transfusion	2 (4.5)	0 (0)	0.494
Fever more than 38.0 with antibiotics	2 (4.5)	0 (0)	0.494
IIIA			
Sepsis	0 (0)	1 (2.3)	0.315
Embolization due to bleeding	1 (2.3)	0 (0)	1.000
Wound dehiscence	1 (2.3)	0 (0)	1.000
IIIB			
Open conversion	0 (0)	0 (0)	
Ureteral stricture treated by a procedure	0 (0)	0 (0)	
Total	7 (15.9)	2 (4.5)	0.157

Values are presented number (%).
PNL, percutaneous nephrolithotomy; RIRS, retrograde intrarenal stone surgery.
[a]:Clavien-Dindo classification.

PNL and RIRS for renal stones with a maximum diameter of 10 to 40 mm [7,9], only a few studies have retrospectively investigated the advantages and disadvantages of surgical methods for renal stones located only in the lower-pole minor calyx irrespective of the presence of stones in the renal pelvis [10,11]. Furthermore, all previous studies used retrospective analyses without matching, and they usually classified the renal stone location into only the upper-, middle-, and lower-pole calyces without consideration of the presence of the lower anterior or posterior calyx. All things considered, the present study analyzed the surgical outcomes of PNL and RIRS for only renal stones with a maximum diameter of 15 to 30 mm in the lower-pole minor calyx by using a propensity score matching method, and we classified the lower-pole minor calyx into the anterior and posterior calyces, which enabled us to analyze the clinical parameters more accurately than in previous studies. The present study included the largest series of renal stones in the lower-pole minor calyx with a maximum diameter of 15 to 30 mm.

Bozkurt et al. [11] and Aboutaleb et al. [10] compared surgical outcomes between PNL and RIRS for renal stones sized less than 20 mm, and they showed that the PNL and RIRS procedures were safe and effective methods for medium-sized renal stones in the lower-pole calyces. Similar

Table 4. Uni- and multivariate logistic regression analysis to predict stone-free status

Variable	Univariate			Multivariate		
	p-value	OR	95% CI	p-value	OR	95% CI
Age	0.499	0.989	0.958–1.021			
Sex (male vs. female)	0.970	0.983	0.394–2.454			
Body mass index	0.123	1.112	0.972–1.272			
Preoperative SWL history	0.888	0.897	0.200–4.035			
Preoperative URS history	0.920	1.094	0.189–6.340			
Laterality (right vs. left)	0.571	0.776	0.322–1.868			
Number of stones	0.104	0.765	0.555–1.056			
Maximal diameter of stone	0.785	0.984	0.875–1.106			
Total stone volume	0.665	1.000	1.000–1.000			
Stone in lower minor calyx						
Posterior versus anterior	0.017*	0.258	0.085–0.787	0.002*	0.017	0.001–0.226
Posterior versus both	0.004*	0.155	0.043–0.555	0.003*	0.051	0.007–0.365

OR, odds ratio; CI, confidence interval; SWL, extracorporeal shock wave lithotripsy; URS, ureteroscopic stone surgery.

to the results of the present study, these previous studies showed that the risk of hemorrhage or hemoglobin drop was higher in the PNL group than in the RIRS group; in contrast, the operative time was longer in the RIRS group than in the PNL group. However, those studies did not find differences in surgical outcomes between the lower-anterior and lower-posterior minor calyces. In the present study, the results of the multivariate logistic regression analysis showed that the presence of stones located in the lower-anterior minor calyx was a significant predictor of a higher SFR. We did not analyze parameters related to the lower-pole minor calyx such as infundibular length, infundibular width, lower-pole infundibulopelvic angle, or pelvicaliceal height in the present study [12], because there must have been a significant amount of individual variation in these parameters during measurement. However, on the basis of the results of a recently published investigation (S-ReSC scoring system) [8], the present study divided the lower-pole calyx into anterior and posterior divisions and reported that the presence of a renal stone in the lower-anterior minor calyx was a significant predictor of the SFR after PNL or RIRS. Therefore, researchers should consider performing differentiation of the location of the lower-anterior calyx from the lower-posterior minor calyx in future investigations.

2. SFR for PNL and RIRS for stones located in the lower-anterior minor calyces

Previous studies showed a higher SFR in the PNL group (92% to 98%) than in the RIRS group (89% to 95%) [7,8]. In contrast, the present study showed a higher SFR in the RIRS group than in the PNL group without statistical significance, as shown in Table 3. The SFR of the PNL group in the present study was relatively lower than in previous studies; however, most of the remnant stones were smaller than 6 mm and the authors do not think that RIRS was an absolutely superior procedure to PNL. The results may have been due to differences in the surgeons' skill or may have reflected selection bias. The important thing is that we should endeavor to increase the SFR of a single-session PNL procedure without any ancillary procedures, which is usually performed in South Korea. We can use a flexible nephroscope or ureteroscope intraoperatively to remove remnant stones [13]; however, a small amount of bleeding may provide the surgeon with a limited view of the operating field delivered by the endoscope. Furthermore, many remnant stones were located in the lower-anterior minor calyx, and in a fluoroscopic exam, the radiopacity of the nephrostomy tube can hide the stones, causing surgeons to miss stones in the lower-anterior minor calyx. Therefore, a careful examination is important for removing single small stones. Additionally, performing postoperative computed tomography is necessary so as not to miss the presence of remnant stones in the lower-anterior minor calyx, because remnant stones can be covered with a nephrostomy tube or the stones can be radiolucent.

Another important point is that RIRS is a good option for the removal of renal stones in the lower-pole calyx without bleeding risk as shown in previous studies [6]. The presence of remnant stones usually depends on the deflection of the distal tip of a flexible ureteroscope. The Flex-X2 ureteroscope has 270 degrees of deflection; however, the intraoperative deflection can be significantly decreased when a laser fiber is put into the working channel. Therefore, we should

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endeavor to maximize the deflection of the distal tip by using a laser fiber that is as thin as possible and a nitinol stone basket with maximal elasticity. Furthermore, the intravesical pressure should be decreased with an access sheath so as not to tighten the ureteroscope. Previous studies have already demonstrated some advantages of RIRS such as no necessity for a renal puncture and a smaller drop in hemoglobin [14]. A longer operative time and the risk of ureteral injury may be disadvantages; however, the present study showed no significant complications. The occurrence of complications may depend on the surgeon's experience.

3. Limitations of this study

The present study performed propensity score matching to reduce the impact of treatment-related bias in estimating the treatment effects of PNL and RIRS. However, this study was retrospective and the small number of patients may result in some errors in the observed data. Although the present study had these limitations, this is one of the largest series of renal stones located in the lower-pole minor calyces with a maximum diameter of 15 to 30 mm, and our results may be helpful for surgeons to determine the most appropriate surgical procedure for management of stones located in the lower-pole calyx.

CONCLUSIONS

RIRS and single-session PNL in patients with a main stone sized 15 to 30 mm located in the lower-pole calyx showed comparable surgical results. However, RIRS might be performed more safely than PNL with less bleeding. Stones in the lower-anterior minor calyx should be carefully examined and surgeons should try to remove all renal stones including stones in the lower-anterior minor calyx.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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