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 mm.
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 mid-calyses [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 ultrasongraphic 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 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 19-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.
Comparison of RIRS versus a single-session PNL

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 $0.523 \times \text{height} \times \text{width} \times \text{length} \ (\text{mm}^3)$. 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...
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-

| Characteristic | Unmatched sample | Matched sample |
|---------------|------------------|----------------|
| Age (y)       | 56.1±13.2        | 56.5±14.4      |
| Gender        |                  | 53.8±13.4      |
| Male          | 52 (59.8)        | 28 (63.6)      |
| Female        | 35 (40.2)        | 16 (36.4)      |
| Body mass index (kg/m²) | 25.1±3.6 | 24.0±3.1      |
| Creatinine (mg/dL) | 1.1±0.2 | 1.0±0.2      |
| Estimated GFR (mL/min/1.73 m²) | 74.5±26.2 | 73±30.3       |
| Hemoglobin (mg/dL) | 14.0±1.7 | 13±1.7       |
| Previous SWL history | 16 (18.4) | 3 (6.8)         |
| Previous URS history | 5 (5.7) | 4 (4.5)         |
| Stone site    |                  |                |
| Right         | 51 (58.6)        | 23 (52.3)      |
| Left          | 36 (41.4)        | 21 (47.7)      |
| Stone location|                  |                |
| Pelvis        | 56 (64.4)        | 22 (50.0)      |
| Major calyx (lower) | 62 (71.3) | 28 (63.6)      |
| Minor calyx (lower anterior) | 19 (21.8) | 19 (43.2)      |
| Minor calyx (lower posterior) | 31 (35.6) | 17 (38.6)      |
| Maximal stone size (mm) | 23.7±6.4 | 21.5±3.3      |
| Total stone volume (mm³) | 1,853.6±1,187.1 | 1,332.6±955.3 |
| No. of stones | 2.5±1.6          | 2.4±1.7        |
| Main stone composition |                |                |
| Calcium oxalate monohydrate | 23 (26.4) | 10 (22.7)        |
| Calcium oxalate dehydrate | 6 (6.9) | 3 (6.8)           |
| Carbonate apatite | 3 (3.4) | 2 (4.5)           |
| Uric acid     | 2 (2.3)          | 2 (4.5)        |
| Struvite      | 5 (5.7)          | 3 (6.8)        |
| Ammonium urate| 8 (9.2)          | 0 (0.0)        |
| Cystine       | 0 (0.0)          | 0 (0.0)        |
| Calcium oxalate trihydrate | 1 (1.1) | 1 (2.3) |
| Brushite      | 1 (1.1)          | 0 (0.0)        |
| Others        | 12 (13.8)        | 3 (6.8)        |

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.
Comparison of RIRS versus a single-session PNL

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.

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 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±22.3      | 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          | PNL            | RIRS           | p-value |
| Stone-free status                            | 37 (84.1)        | 41 (93.2)      | 0.314          |
| Complications\*
| 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          |
| IIIIB 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.
\*Clavien-Dindo classification.
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
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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