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ORIGINAL ARTICLE

# Comparison of retrograde intrarenal surgery, shockwave lithotripsy, and percutaneous nephrolithotomy for treatment of medium-sized radiolucent renal stones

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**Abstract**

*Objectives* To compare the outcomes of shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PNL), and retrograde intrarenal surgery (RIRS) for 10–20 mm radiolucent renal calculi by evaluating stone-free rates and associated complications.

*Patients and methods* A total of 437 patients at 7 institutions who underwent SWL ($n = 251$), PNL ($n = 140$), or RIRS ($n = 46$) were enrolled in our study. Clinical success was defined as stone-free status or asymptomatic insignificant residual fragments <3 mm. The success rates, auxiliary procedures, and complications were compared in each group.

*Results* Success rates were 66.5, 91.4, and 87 % for SWL, PNL, and RIRS ($p < 0.001$). The need for auxiliary procedures was more common after SWL than PNL and RIRS (21.9 vs 5.7 vs 8.7 %, respectively; $p < 0.001$). The overall complication rates for the SWL, PNL, and RIRS were 7.6, 22.1, and 10.9 %, respectively ($p < 0.001$). Thirteen patients in PNL group received blood transfusions, while none of the patients in RIRS and SWL groups transfused. Hospitalization time per patient was $1.3 \pm 0.5$ days in the RIRS group, while it was $2.6 \pm 0.9$ days in the PNL group ($p < 0.001$). Fluoroscopy and operation time were significantly longer in the PNL group compared to RIRS ($145.7 \pm 101.7$ vs $28.7 \pm 18.7$ s, and $57.5 \pm 22.1$ vs $43.1 \pm 17$ min, respectively).

*Conclusions* For treatment of moderate-sized radiolucent renal stones, RIRS and PNL provide significantly higher success and lower retreatment rate compared with SWL. Although PNL is effective, its biggest drawback is its invasiveness. Blood loss, radiation exposure, hospital stay, and morbidities of PNL can be significantly reduced with RIRS technique.

**Keywords** Percutaneous nephrolithotomy · Retrograde intrarenal surgery · Radiolucent renal stones · Shock wave lithotripsy

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## Introduction

The treatment for renal stone disease has changed dramatically in the last two decades with the improvements and miniaturization of instruments. Currently, shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PNL), and retrograde intrarenal surgery (RIRS) are the three main modalities for the management of upper urinary stone disease. Every year, the European Association of Urology (EAU) publishes its guidelines for stone disease treatment. The 2012 EAU guidelines on urolithiasis state clearly that SWL remains the method of first choice for stones <2 cm within the renal pelvis and upper or middle calices. Larger stones (>2 cm) should be treated by PNL or RIRS because SWL often requires multiple treatments. For the lower pole, PNL or RIRS is recommended even for stones >1.5 cm because the efficacy of SWL is limited (depending on favorable and unfavorable factors for SWL) [1].

Although these three techniques are attractive treatment options for small-to-moderate size renal calculi, difficulty visualizing of the radiolucent stones can be a restrictive factor for these approaches. In this study, we compared the outcomes of SWL, RIRS, and PNL for 1–2 cm radiolucent renal calculi, which to our knowledge has not been reported before.

## Patients and methods

### Patients

We performed a retrospective analysis of 437 evaluable patients with 1–2 cm radiolucent renal calculi, who underwent SWL ($n = 251$), PNL ($n = 140$), or RIRS ($n = 46$) in seven referral hospitals in Turkey. Patients with bleeding diathesis, abnormal renal anatomy, musculoskeletal deformities, and radiopaque stones were not included in study. Selection of treatment modality was influenced by a variety of factors, including urologist choice and patient preference. For example, we did not prefer the SWL technique in patients with step infundibular angle (<45°), long lower pole calyx (>10 mm), and narrow infundibulum (<5 mm), or we did not prefer the PNL technique in patients with chronic obstructive pulmonary disease or morbid obesity.

Patient assessment included medical history, physical examination, urinalysis, urine culture, complete blood count, serum biochemistry, coagulation tests, ultrasound, and computed tomography (CT). Positive urine cultures were adequately treated with appropriate antibiotics, and all patients had a negative urine culture before surgery. Stone size was determined by measuring the longest axis on preoperative imaging; in cases of multiple calculi, stone size was defined as the sum of the longest axis of each stone.

### SWL technique

All SWL treatment was performed as an outpatient procedure using the electrohydraulic (68.9 %) or electromagnetic lithotripter (31.1 %). Targeting of the stone was done by ultrasonographically at all centers. Therapy was usually started at a low power of 12 kV and then increased gradually to 20 kV. A maximum of 3,000 shocks were delivered for each session or until complete fragmentation of the stone had occured. The patients were evaluated 1 week after the SWL session by urinary US to assess fragmentation. Repeated treatment was performed if inadequate fragmentation of the stone was observed. If no breakage of the stone had occured after 2 or 3 sessions, the case was considered a SWL failure, and the patient underwent RIRS, PNL, or observation.

### PNL technique

At all centers, the procedure started with the patient in the lithotomy position with rigid cystoscopy performed to place a ureteral catheter. After ureteral catheter insertion, patients were placed in the prone position, and percutaneous access was achieved under C-arm fluoroscopy guidance using an 18-gauge needle and guidewire. The tract was dilated with Amplatz, metal, or balloon dilators of up to 12F–30F. Fragmentation and stone removal were accomplished using a pneumatic or ultrasonic lithotripter and retrieval graspers through a rigid nephroscope. A holmium:YAG laser and nitinol basket catheter were used through a flexible nephroscope for migrated stone fragments that were unreachable with the rigid instruments. At the conclusion, a nephrostomy tube was placed in the majority of the cases (90.7 %), which was routinely removed on postoperative days 1–2, and the patient was discharged to home the next day.

### RIRS technique

All RIRS procedures were performed under general anesthesia to prevent patient movement and minimize the risk of ureteral perforation. A hydrophilic guidewire was placed into the renal pelvis under fluoroscopic guidance. Ureteral balloon dilation was performed in selected cases when the ureteroscope could not be advanced easily. The use of the ureteral access sheath was determined by surgeon preference, which indicated the possibility of multiple passages of the ureteroscope. The stones were fragmented with a holmium laser until they were deemed small enough to pass spontaneously. A Double-J stent was placed at the end of the procedure based on surgeon decision and was removed approximately 7–14 days postoperatively.

### Data analysis

Stone-free status was determined with spiral CT in an outpatient clinic setting at 1–2 months postoperatively for PNL and RIRS, at 3 months after for SWL. Treatment success was defined as stone-free or clinically insignificant residual fragments (residual fragment <3 mm). All statistical analyses were performed using SPSS 11.5. The chi-square test was applied to compare the success rates, secondary procedures, and postoperative complications of techniques. Kruskal–Wallis variance analysis was used to compare three groups in terms of age and stone size. Mann–Whitney $U$ test was used to compare the hospital stay, fluoroscopy, and operative time for PNL and RIRS. While the categorical variables were presented by frequency (%), continuous variables were presented by mean ± standard deviations (SDs) [median (minimum–maximum)]. Statistical significance was defined as $p < 0.05$.

## Results

### Patient and stone characteristics

A retrospective review identified in 437 patients, including 271 males (62 %) and 166 females (38 %). The mean patient age was 32.4 ± 17.9 years (1–76 years). The stone was on right side in 206 patients (47.2 %) and on the left side in 231 patients (52.8 %). The mean stone size was 14.9 ± 2.9 [15 (10–20)] mm in SWL group, 17.3 ± 3.6 [20 (10–20)] mm in PNL group, and 15.6 ± 3.4 [16 (10–20)] mm in the RIRS group. As delineated in Table 1, mean stone size was significantly larger in those patients who were treated with PNL ($p < 0.001$). Stone composition was available in 225 patients (51.4 %), and uric acid was the most frequent composition in each group. Table 1 lists patient demographics and stone characteristics.

### Treatment characteristics and clinical outcomes

In SWL group, 113 patients (45 %) underwent a second SWL session and 61 (24.3 %) had a third session. In 35 SWL cases, the stone was unable to be visualized; 49 patients had residual fragments (≥3 mm) and they were considered treatment failures. Finally, 167 of 251 patients (66.5 %) were stone-free at the end of the SWL sessions. In PNL and RIRS groups, stone-free rates were 91.4 and 87 % following one treatment procedure ($p < 0.001$). The need for auxiliary procedures was more common after SWL than PNL and RIRS (21.9 vs 5.7 vs 8.7 %, respectively; $p < 0.001$). Success rates across modalities are seen in Fig. 1.

Hospitalization time per patient was 1.3 ± 0.5 days in the RIRS group, while it was 2.6 ± 0.9 days in the PNL group ($p < 0.001$), whereas all SWL procedures were performed in the outpatient setting. Fluoroscopy screening time and operation time were significantly longer in the PNL group compared to RIRS (145.7 ± 101.7 vs 28.7 ± 18.7 s and 57.5 ± 22.1 vs 43.1 ± 17 min). A Double-J ureteral catheter was placed in 8.4, 7.1, and 69.6 % of cases after SWL, PNL, and RIRS, respectively.

The overall complication rates for the SWL, PNL, and RIRS were 7.6, 22.1, and 10.9 %, respectively ($p < 0.001$). No major complication (Clavien III–V) occured in SWL and RIRS groups; however, there were 3 major complications (2.1 %) in PNL group. Major (Clavien grade III) complications included septicemia, renal hemorrhage requiring angiographic intervention, and pleural injury. Thirteen patients (9.3 %) in PNL group received blood transfusions, while none of the patients in RIRS and SWL groups transfused (Clavien grade II). In 4 SWL cases (1.6 %), steinstrasse developed, and they were treated successfully with SWL or ureteroscopy. In 3 patients (1.2 %), perirenal hematoma was observed after SWL and managed conservatively. In the RIRS group, complications were recorded in 5 (10.9 %) patients, including ureteral perforation in one, urinary tract infection in two, and renal colic or stent pain in two patients, respectively. All patients were treated conservatively with antibiotics and/or prolonged Double-J stent placement in the ureter of up to 4 weeks. Operative and postoperative data and stone clearance are detailed in Table 2.

## Discussion

SWL, PNL, and RIRS are the three main modalities for treating medium-sized renal stones [1–6]. Selecting the optimal treatment for these stones can be challenging, because each treatment modality has unique advantages and disadvantages. The European Association of Urology and American Urological Association guidelines for the

**Table 1** Demographic data and stone characteristics

| | SWL group | PNL group | RIRS group | $p$ value |
|---|---|---|---|---|
| No of patients (%) | 251 (57.5 %) | 140 (32.0 %) | 46 (10.5 %) | |
| Mean age ± SD (years) | 30.8 ± 15.9 [27 (1–76)] | 36.4 ± 19.7 [19 (1–71)] | 29.6 ± 20.3 [31(1–65)] | 0.004* |
| Male/female | 175/76 | 72/68 | 24/22 | 0.001* |
| Mean stone size ± SD (mm) | 14.9 ± 2.9 [15 (10–20)] | 17.3 ± 3.6 [20 (10–20)] | 15.6 ± 3.4 [16(10–20)] | <0.001* |
| Stone laterality | | | | |
| Right/left | 118/133 | 71/69 | 17/29 | |
| Stone location | | | | 0.180 |
| Pelvis | 99 (39.4 %) | 47 (33.6 %) | 15 (32.6 %) | |
| Upper/middle pole | 48 (19.1 %) | 17 (12.1 %) | 7 (15.2 %) | |
| Lower pole | 72 (28.7 %) | 54 (38.6 %) | 14 (30.4 %) | |
| Multicaliceal | 32 (12.7 %) | 22 (15.7 %) | 10 (21.7 %) | |

* Significant at 0.05 level

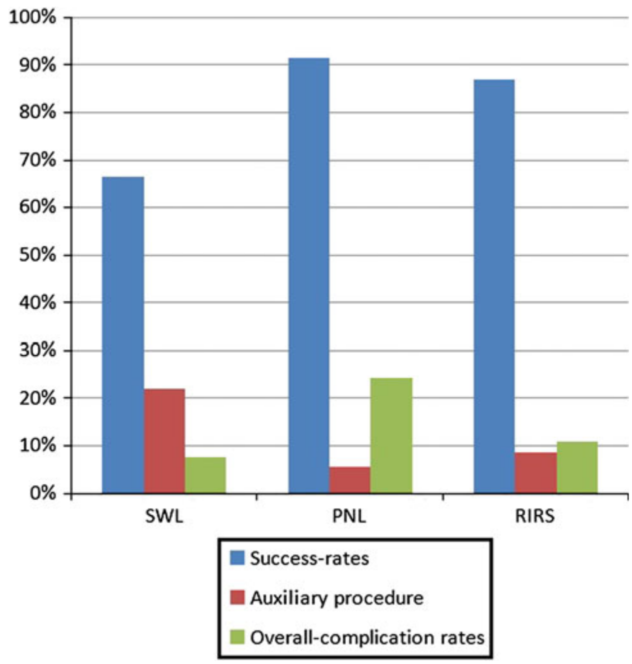


**Fig. 1** Comparison of success rates, complication rates and auxiliary treatments in SWL, PNL, and RIRS patients

treatment of intrarenal calculi <2 cm recommend SWL as the first-line therapy because of its noninvasive nature, low complication rate, and high level of patient acceptance [1, 6]. A variety of factors can affect the success rate of SWL, and several investigators have tried to define those patients who more likely to have an unsuccessful outcome [7–14]. They demonstrated the significance of stone size, stone location, stone shape, number of stones, patient age, renal morphology, and congenital anomalies [10–15]. However, there is no recommendation in these studies or guidelines for treatment of radiolucent stones, because no previous study has specifically examined and compared the clinical outcomes of treatment approaches in this cohort of patients.

The visualizing of radiolucent stones with fluoroscopic imaging is difficult during SWL and therefore requires either US-guided localization or the addition of retrograde or intravenous contrast to localize calculus. But intravenous contrast medium administration bears known risks, and retrograde contrast medium administration requires general anesthesia. US-guided targeting significantly reduces the radiation exposure to the patient and operator, particularly desirable in the children. In our study, targeting was done by ultrasonographically at all centers. But our stone-free rates were lower than reported in the literature, perhaps due to the fact that difficulty monitoring of the radiolucent calculi [3, 4, 10].

In the present study, stone-free rates were significantly lower in patients treated with SWL than in those patients who were treated with PNL or RIRS. Moreover, auxiliary treatment rates were significantly higher for patients in the SWL arm. These poor outcomes, patient discomfort, and need for further treatment have led us to question SWL as the most appropriate therapy for moderate-sized (1–2 cm) radiolucent renal stones.

Percutaneous nephrolithotomy has significantly higher stone-free and lower requirements for ancillary compared to SWL, and this technique allows for the rapid removal of stones, regardless of composition and size [16, 17]. The stone-free rate after PNL in this present series was similar to previous studies (75–98 %), with success rates of approximately 91.4 % [2, 16–18]. On the other hand, overall complication rates were significantly higher in the PNL group when compared with RIRS and SWL. In our study, we observed only minor complications after SWL and RIRS, but there were three major complications in PNL arm (septicemia, renal hemorrhage requiring angiographic intervention, and pleural injury). If we classify our complications regarding the modified Clavien system [19], we can see only grade I–II complications in SWL and

**Table 2** Comparison of operative and postoperative data

| | SWL group | PNL group | RIRS group | *p* value |
|---|---|---|---|---|
| Mean fluoroscopy time ± SD (s) | – | 145 ± 101 [120 (10–600)] | 28.7 ± 18.7 [25 (5–90)] | <0.001* |
| Mean operative time ± SD (min) | – | 57.5 ± 22.1 [55 (18–120)] | 43.1 ± 17 [38 (18–90)] | <0.001* |
| Mean hospitalization time ± SD (day) | – | 2.6 ± 0.9 [3 (1–7)] | 1.3 ± 0.5 [1 (1–3)] | <0.001* |
| Stone-free rate (%) | 66.5 % | 91.4 % | 87.0 % | <0.001* |
| Auxiliary procedure (%) | 21.9 % | 5.7 % | 8.7 % | <0.001* |
| Complication rates (%) | | | | |
| Minor complications | 19 (7.6 %) | 28 (20 %) | 5 (10.9 %) | <0.001* |
| Major complications | – | 3 (2.1 %) | – | |
| Blood transfusion rate | – | 13 (9.3 %) | – | 0.024* |
| Nephrostomy tube | – | 90.7 % | – | |
| Double-J catheter | 8.4 % | 7.1 % | 69.6 % | <0.001* |

* Significant at 0.05 level

RIRS groups and grade I–III complications in PNL group. Thirteen patients (9.2 %) required blood transfusions in PNL group, while none of the patients in SWL and RIRS groups required transfusion. Overall complications in PNL according to Clavien classification were reported as 43.8 % by de la Rosetta et al. and 29.2 % by Tefekli et al. [19, 20].

Careful selection of the patients for this technique is very important for decreasing these complications. Unsal et al. [16] reported on the prediction of morbidity and mortality of PNL using the Charlson comorbidity index (CCI). They showed 0.2 % mortality and a direct relationship between preoperative comorbidity. Also, they found that patients with higher CCI scores had a significantly greater rate of perioperative bleeding and postoperative medical complications than those with lower CCIs. Therefore, SWL, RIRS, or conservative management of kidney stones may be a safe alternative to PNL in patients with high CCI scores.

Improvements in flexible ureteroscopes, instruments, and laser technology have made retrograde stone removal more attractive. However, this procedure has some limitations in treatment efficacy. Resorlu et al. [21] evaluated the stone-related factors and pelvi-calyceal anatomy on the success of RIRS and determined which of these factors could be used to select patients. They found that stone size and lower pole infundibulopelvic angle (IPA) were important factors affecting stone clearance after RIRS. The presence of an IPA of >45° was strongly related to a high success rate for RIRS (91 vs 65 %). In another study, Bozkurt et al. [5] compared the outcomes of PNL and RIRS for 15–20 mm lower pole renal stones. They found that the stone-free rate and complications were higher with the percutaneous approach, although the difference was not statistically significant. However, no previous study specifically examined the PNL and RIRS in the radiolucent renal calculi and compared the clinical outcomes of these approaches. The above data suggest that the efficacy of retrograde technique is comparable to that of percutaneous surgery for approaching to medium-sized radiolucent renal calculi. Furthermore, mean duration of fluoroscopy and operative time and hospital stay were found to be longer in the PNL arm relative to the RIRS. Creation of percutaneous renal access under fluoroscopic guidance was the most important factor for this long fluoroscopy and operative time.

The present study has several limitations owing to its multicentric and retrospective nature. The first is that we did not perform a cost analysis for these procedures. Second, analgesic and postoperative pain scores were not evaluated. Another limitation is that different surgical techniques were used in this study owing to its multicentric nature. Finally, the most important limitation of the present study was that there were some criteria for the selection of treatment modality. Despite these shortcomings, this is an important study, as there are no data in the literature regarding the relative merits of SWL, PNL, and RIRS in a contemporary cohort of patients.

## Conclusion

Shock wave lithotripsy has always attracted because of its noninvasive nature. However, for treatment of moderate-sized radiolucent renal stones, RIRS and PNL provide significantly higher success rate and lower retreatment rate compared with SWL. But the biggest drawback of PNL is its invasiveness and possibility of some blood loss. RIRS technique may allow decreased morbidity, radiation exposure, and hospital stay with similar success rates compared with PNL.

**Conflict of interest** We have no conflict of interest.

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