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FULL PAPER

The effects of stone density on surgical outcomes of retrograde intrarenal stone surgery

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Objective: Several pre-operative parameters have been studied to estimate stone-free rate (SFR) following retrograde intrarenal surgery (RIRS) procedures. The objective of this study was to evaluate the effects of stone density on surgical outcomes of RIRS.
Methods: This retrospective study included 30 stone-free patients (Group SF) and 30 patients with residual fragments (Group RF). Patients' age and gender, laterality, non-contrast CT findings, including size and density of the kidney stones, infundibular pelvic angle (IPA), operational time, and post-operative pain were recorded and compared between the two groups. The stone density was measured by free hand region of interest (ROI) determination coincident with the stone borders and expressed as Hounsfield units (HUs).
Results: The rate of single stones was significantly higher in Group SF compared to Group RF ($p < 0.001$). The mean stone size was found as 11.93 ± 7.81 mm in Group SF and 16.27 ± 7.29 mm in Group RF with the difference being statistically significant ($p < 0.001$). The mean IPA was 53.87 degrees in Group SF and 50.33 degrees in Group RF. The mean density was measured as 748.17 ± 318.14 HU in Group SF and 945.90 ± 345.30 HU in Group RF. The mean stone density was statistically significantly higher in patients with residual fragments compared to the stone-free patients ($p < 0.001$).
Conclusion: This study revealed that stone density as measured as HU affects the treatment outcomes with RIRS procedure and the mean density is significantly higher in patients with residual stone fragments.
Advances in knowledge: Studies about the effects of HUs on stone-free rate are limited in the literature. Stone density affects the treatment outcomes with RIRS procedure and the mean density is significantly higher in patients with residual stone fragments.

INTRODUCTION

Renal calculi, namely kidney stones, is one of the most common problems of the urinary system associated with significant pain, suffering and healthcare costs.[1] Approximately, 10% of the general population suffer from kidney stones at least one during their lifetime.[2] The prevalence and incidence of kidney stones has increased among both adults and children in the last decades. About 35% of all kidney stones are located in the lower calyx, which is more difficult to treat due to anatomical complexity.[3]

The primary goal of kidney stone treatment is to achieve a longest stone-free duration with the lowest rate of residual fragments and morbidity as much as possible.[4] The recent advancements in technology and surgical tools has resulted in evolution in the treatment of renal calculi. According to the European Association of Urology (EAU) guidelines, retrograde intrarenal surgery (RIRS), extracorporeal shock wave lithotripsy (SWL) and percutaneous nephrolithotomy (PNL) are first-line therapies for kidney stones.[5] However, RIRS using a flexible ureteroscope and laser has recently become the preferred treatment option in the management of kidney stones. Although at first, RIRS was used for treatment of kidney stones <2 cm, today, it is used also for treatment of >2 cm stones.[6] Several studies in the literature have reported RIRS as a safe and effective method associated with minimal complications in the treatment of intrarenal stones.[7]

Non-contrast computed tomography (NCCT) has become the gold-standard for the diagnosis of kidney stones.[8] NCTT provides information about the precise location, size, volume and density of the stone that are relevant for making clinical decisions. Several parameters obtained through NCTT have been studied to estimate stone-free rate (SFR) following RIRS procedures. Stone size and volume have been reported as predictors of spontaneous stone passage, operational time and stone-free rate following RIRS.[8]

Stone density as measured on CT by Hounsfield units (HUs) has been studied for the prediction of operational time and stone composition.[1] Although there are studies reporting that stone density affects success of percutaneous nephrolithotomy,[9] studies about the effects of HU on SFR are limited in the literature. Oztekin et al reported that a stone density >1100 HU as an independent predictor of RIRS failure.[10] In this study, we aimed to evaluate the effects of stone density on surgical outcomes of RIRS.

METHODS AND MATERIALS

Study population

A total of 60 patients, aged 19–75 years, who were referred to our radiology clinic for NCCT investigation and who underwent underwent RIRS in the urology clinic due to kidney stones between 2018 and 2021 were retrospectively included in this retrospective study. 30 patients with residual fragments <4 mm at follow-up examination were assigned to Group RF and 30 consecutive stone-free patients were included as the controls (Group SF). Patients with single or multiple renal calculi localized in the lower calyx who had complete NCCT parameters and operational variables were included in the study. Patients with upper urinary system stones, urinary system anomalies, skeletal deformities, morbid obesity (>35 kg/m^2) a history of urinary system surgery, patients with contraindications for RIRS, residual fragments >4 mm after RIRS procedure and those with missing NCCT or operational data were excluded from the study.

DATA ACQUISITION

Patients' demographic data such as age and gender, laterality, NCCT findings, including size and density of the kidney stones, infundibular width (IW), length (IL) and height (IH), infundibular pelvic angle (IPA), operational time, type of anesthesia, and post-operative pain were retrospectively recorded and compared between the two groups. Operational success was based on operational time, ability to remove the stone and residual fragments <4 mm. Post-operative stone-free status was evaluated by NCCT performed in the first month after RIRS. Data used in this study were obtained from the hospital information system and patient files.

NCCT

Non-contrast computed abdominopelvic tomography was performed with Toshiba Aquilion One 320-detector row 640-slice dynamic volume CT system (160 × 0.5 vol scanning mode). The size and HU of the stone, IW, IL, IH and IPA values were measured on NCCT images. The longest measurements in the axial, sagittal and coronal planes were used to calculate the stone size. IPA was measured as the angle between the ureteropelvic axis and central axis of the lower pole infundibulum. The stone density was measured by free-hand ROI determination coincident with the stone borders (between 2 and 5 pixel points depending on the stone area) and expressed as HU. The NCCT images retrieved from picture archiving and communication systems (Sectra PACS System) were examined by the same experienced radiologist.

RIRS procedure

First, a double-J (DJ) stent (4.8 Fr 26 cm, Boston Scientific Corp., Boston, MA) or urinary catheter (5 Fr, 0.038 cm, Cook Medical CLL, Bloomington, IN) was placed in all patients 2 weeks before the RIRS procedure was performed. RIRS operations were performed under general anesthesia alone or combined with regional anesthesia with the patient in dorsal lithotomy position. First, the catheter was removed and a 7.5 Fr semi-rigid ureterorenoscope (URS) (Karl Storz Flex-X2, Tuttlingen, Germany) was advanced to the kidney over a hydrophilic guidewire of 0.97 mm under fluoroscopy guidance. The stones were fragmented with 200 µm VersaPulse Holmium:YAG laser (Sphinx, LISA Laser Products GmbH, Katlenburg-Lindau, Germany) until they were considered small enough for spontaneous passage. Removal of all the stone fragments was attempted using a 1.5 Fr N-Circle nitinol tipless basket (Cook Medical CLL, Bloomington, IN). At the end of the operation, the lower calyx was inspected with a flexible ureterorenoscope. A DJ catheter was inserted again in all patients at the end of the procedure and removed 1 month after the surgery during follow-up visits. Post-operative pain was assessed using the visual analog scale (VAS) score. For this purpose, the patients were asked to mark their perception of pain on a 10 cm ruler where 0 point indicates no pain and 10 points shows the worst possible and unbearable pain. All RIRS procedures were performed by the same experienced urologist.

Ethical approval

The study protocol was approved by the local ethics committee of our hospital Istinye University with the (2017-KAEK-120)/2021.G-135 decision. The necessary permission was received from the hospital management to use the archives of patient files. Written consent from patients was waived as the study was conducted retrospectively. The study was performed in line with the ethical principles of the Declaration of Helsinki.

Statistical analysis

Data obtained in this study were statistically analyzed using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL) v. 22. Software. Normality of the data was analyzed with the Saphiro–Wilk test. The Student's *t*-test, Mann–Whitney *U* test, and Pearson's χ^2 test were used for the comparison of continuous and categorical variables, as appropriate. Continuous variables were expressed with descriptive statistics such as mean ± standard deviation, minimum, maximum and categorical variables as frequency and percentage. The relationships between radiological measurements on CT and success of RIRS operations were investigated. $p < 0.05$ values were considered statistically significant.

RESULTS

A total of 60 patients who underwent NCCT investigation and RIRS operation due to kidney stones were included in our study. The patients were divided into stone-free (Group SF) and residual stones (Group RS) groups with 30 patients in each. The mean age of the patients was found as 45.8 ± 12.76 (max-min:19–75)

Table 1. Demographic characteristics of the patients

	Group SF		Group RF		
Age (years)	Mean	±SD	Mean	±SD	*p* values
	45.3	12.6	46.3	13.12	0.384a
Gender	**n**	**%**	**n**	**%**	
Female	22	73.33	23	76.67	0.562**
Male	8	26.67	7	23.33	

[a]Student *t* test, ** χ^2 test

years. The mean age was found as 45.3 ± 12.60 (min-max: 19–67) years in Group SF and 46.3 ± 13.12 (min-max: 28–75) years. Of all patients, 46 (76.67%) were male and 14 (23.33%) female. No statistically significant difference was found between both groups in terms of age and gender (both $p > 0.05$). Demographic data of the groups are shown in Table 1.

16 (53.33%) patients in Group SF had a single stone and 14 (46.67%) multiple stones, while 7 (23.3%) patients in Group RF had a single stone and 23 (76.67%) multiple stones. The rate of single stones was significantly higher in Group SF compared to Group RF ($p < 0.001$). When laterality of the stones was evaluated; the renal calculi were localized in the left lower lobe in 12 (40.00%), the right lower lobe in 13 (43.33%) and bilateral in 5 (16.67%) patients in Group SF. The kidney stones were left-sided in 12 (40.00%), right-sided in 9 (30.00%) and bilateral in 9 (30%) patients in Group RF. The distribution of stone localization in all patients is shown in Figure 1.

The mean stone size was measured as 14.1 ± 7.80 (3-32) mm in all patients. The mean stone size was found as 11.93 ± 7.81 (min-max: 3–30) mm in Group SF and 16.27 ± 7.29 (min-max: 4–32) mm in Group RF. The mean stone size was significantly higher in Group RF compared to the stone-free group ($p < 0.001$). The mean infundibular weight (IW) was measured as 8.82 ± 6.63 mm, infundibular length (IL) as 22.57 ± 3.75 mm, infundibular height (IH) as 19.28 ± 3.38 mm and IPA as 52.10 ± 11.24 degrees. The mean infundibular measurements according to the groups are given in Table 2.

The mean stone density was found as 847.03 ± 345.30 HU in all. Patients. The mean density was measured as 748.17 ± 318.14 HU in Group SF and 945.90 ± 345.30 HU in Group RF. The mean stone density was statistically significantly higher in patients with residual fragments compared to the stone-free patients ($p < 0.001$).

Figure 1. Distribution of the stone localizations in all patients included in the study

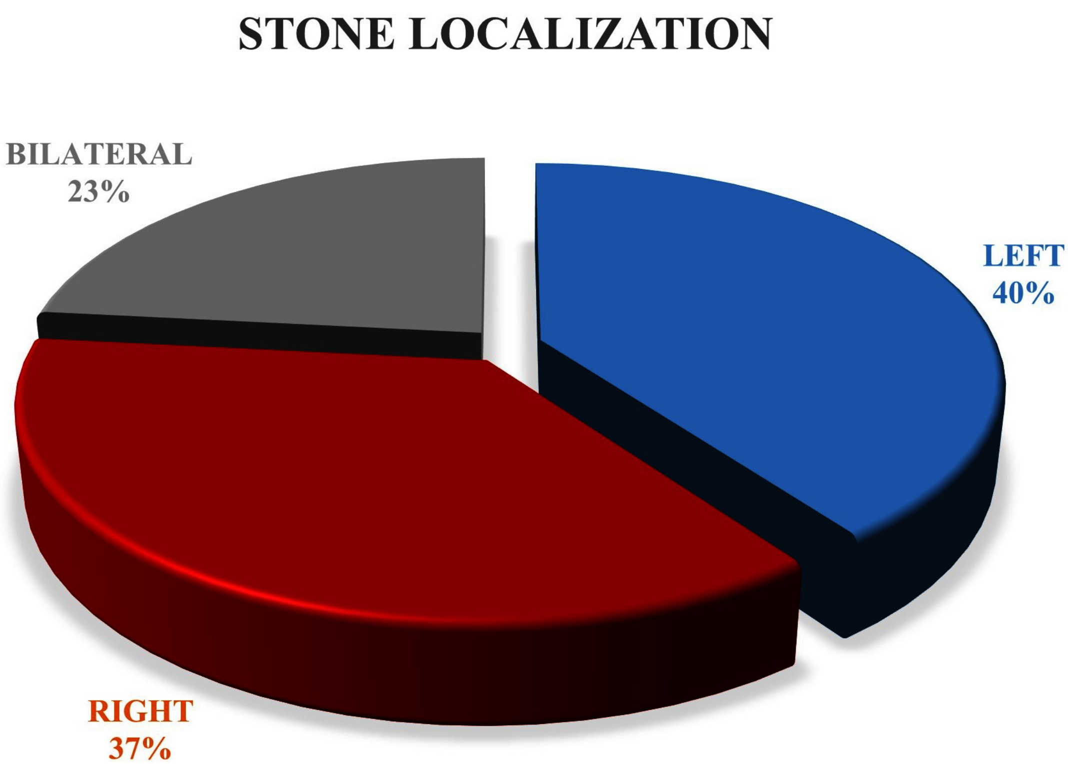

Table 2. Infundibular measurements of the patients on pre-operative NCCT

	GROUP SF			GROUP RF		
	Mean	±SD	Min-Max	Mean	±SD	Min-Max
IW (mm)	7.17	1.98	3–13	9.13	3.2	3–15
IL (mm)	22.37	3.73	18–31	22.77	3.83	14–30
IH (mm)	19.47	3.37	13–26	19.1	3.44	10–26
IPA (degrees)	53.87	12.12	29–81	50.33	10.17	33–81

IH, infundibular height; IL, infundibular length; IPA, infundibular pelvic angle; IW, infundibular width; SD, standard deviation.

Of all patients included in the study, only 5 (8.33%) patients were operated under combined anesthesia, while the remaining 52 (86.87%) patients underwent RIRS operations under general anesthesia. The mean operational time was found as 87.78 ± 43.94 (min-max:20–220) min. The mean operation duration was measured as 61.9 ± 27.17 (min-max:20–140) min in Group Sf and 105.67 ± 46.90 (min-max:25–220) min in Group RF, and the difference between the two groups was statistically significant ($p < 0.001$). Post-operative pain of the patients was measured using the VAS. Accordingly, the mean VAS score was found as 2.32 ± 2.00 (min-max:0–7) in all patients. The mean VAS score was measured as 1.87 ± 2.06 (min-max:0–7) in Group SF and 2.77 ± 187 in Group RF. The mean post-operative pain was significantly higher in Group SF compared to Group RF ($p = 0.047$).

DISCUSSION

The most important indicator of success following surgical treatment of kidney stones is SFR. SFR is measured during post-operative follow-up with imaging modalities, including ultrasonography and CT, and residual fragments <4 mm are usually considered clinically insignificant. Since pre-operative factors such as renal anatomy, obesity, presence of comorbidity and risk factors for recurrent affect the performance of surgical treatment, numerous parameters have been studied for the prediction of surgical outcomes to guide clinicians for making appropriate decisions in choosing the treatment method and achieving desired targets.

The effects of pre-operative parameter on treatment success have been investigation in the most commonly used surgical treatment methods for kidney stones, including Extracorporeal Shockwave Lithotripsy (ESWL), RIRS and percutaneous nephrolithotomy (PNL) that were recommended as first-line therapy options for kidney stones by the European Association of Urology (EAU).[5] In the present study, we investigated the effect of stone density as measured as HUs in CT on SFR following RIRS procedure. We retrospectively recruited totally stone-free patients and those with fragments <4 mm.

Kidney stones may occur in any age and sex, but more frequently in males than in females within 20–49 years of age.[11] The mean age of our patients was found as 45.8 years with male predominance (45/15). Sarikaya et al reported the mean age as 45.3 years with 66.3% being male.[12] Similarly, in their study comparing RIRS and PNL operations, Gucuk et al reported the mean age of the patients as 46.3 years with male predominance (44/16).[13] Our demographic data were consistent with the previous studies.

Multiple kidney stones have been reported in 20–25 of patients.[14] Treatment of multiple stones is more challenging and treatment success has been reported to be lower compared to single stones of the same size with RIRS.[6] In our study, the rate of single stones was significantly higher in the stone-free group (53.33% vs 23.30%). Caglayan et al found single stones in 68.5% of stone-free patients and 29.4% in patients with residual stones.[15] Ozgor et al reported that treatment success decreased as the number of stones increased with SWL procedure.[16]

Most renal calculi are unilateral and are not favored to either side of the urinary tract.[17] Similarly in our study, the distribution of the stones was similar with unilateral predominance.

Stone size is one of the most commonly studied parameters in relation with treatment outcomes. Ito et al reported stone size as an independent predictor of SFR following RIRS.[18] Similarly, in their study with 207 patients, Resorlu et al stated that stone size was one of the significant factors affecting the success rates.[19] Likewise, in the present study, the mean stone size was significantly higher in the stone-free patients compared to the patients with residual fragments (11.93 vs 16.27 mm). Ergani et al reported the mean stone size as 15 mm in patients undergoing RIRS.[20] Tonyali et al retrospectively analyzed 43 stone-free patients and 57 patients with residual fragments and found the mean stone size as 14.2 mm and 15.2 mm, respectively with no significant difference between them ($p = 0.490$).[21] Different results between the studies could be a result of different measurement techniques and assumptions.

Among the renal anatomical parameters, IPA has been reported to affect treatment success.[22] Studies have indicated that steep angles <30 degrees are predictive of treatment failure.[23] Resorlu et al, reported the mean IPA value as 49.37 degrees in stone-free pediatric patients.[19] In our study, the mean IPA was measured as 53.87 degrees in stone-free patients and 50.33 in patients with residual fragments. Karim et al found the mean IPA as 38.1 degrees in stone-free patients and 32.4 degrees in non-stone-free patients ($p = 0.05$).[24] Different results might be attributed to the inclusion criteria and measurements.

Stone density as measured by HU on CT has been investigated as a potential predictor of treatment outcomes in various methods. Gucuk et al compared PNL and RIRS method and reported stone density to be effective in SFRs and selection of treatment modality. In their study, a mean density <677 HU reduced the

SFR from 100 to 55.6% in patients undergoing PNL procedure due to kidney stones <2 cm.[13] On the other hand, Oztekin et al stated that a stone density >1100 HU is an independent predictor of failure with RIRS procedure.[10] In parallel with the literature, in the present study, we found the mean stone density as 748.17 HU in stone-free patients and 945.90 HU in patients with residual fragments and the difference was statistically significant ($p < 0.001$).

Finally, as expected in our study the mean operation time and VAS pain score were significantly lower in the stone free group, similar to the other studies in the literature.[13,19,21]

Study limitations

First of all, our number of patients was small and the study had a retrospective design. In addition, we could not perform a correlation or regression analysis due to the small number of patients. Since studies on the effect of stone density are rare in patients undergoing RIRS procedures and a consensus has not yet been achieved, our results may be guiding for further prospective and large studies to be performed in the future.

CONCLUSIONS

This study revealed that stone density as measured as HU affects the treatment outcomes with RIRS procedure and the mean density is significantly higher in patients with residual stone fragments. In addition, several parameters including stone size, number of stones, operational time, and VAS score also were higher in these patients. Some pre-operatively determined features such as stone size, density, and number of stones can help clinicians to guide management of kidney stones, especially those localized in the lower calyx.

CONFLICT OF INTEREST

The authors declare no conflict of interest to disclose.

FUNDING

This study did not receive financial support.

CONSENT TO PARTICIPATE

All participants were informed in detail about the objectives of the study and granted informed consent.

ETHICS APPROVAL

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University (2017-KAEK-120/2021 .G-135).

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