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ORIGINAL PAPER

Evaluation of the anatomical factors affecting the success of retrograde intrarenal surgery for isolated lower pole kidney stones

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Abstract
Studies which examine the factors affecting success rate in kidney stones located in the lower pole as well as the effects of infundibulopelvic angle (IPA) and infundibular length (IL) have been conducted with a small number of patients. We aimed to evaluate the cut-off points of IPA and IL parameters that effect the success of retrograde intrarenal surgery (RIRS) for isolated lower pole kidney stones. This retrospective study includes 168 patients who underwent primary RIRS due to isolated lower pole kidney stones in our clinic between January 2013 and May 2020. Pre-operative demographic data, medical history, physical examination, surgery duration as well as the post-operative hospitalization time of patients specifics were obtained. According to pre-operative computed tomography (CT), stone size, stone burden, stone density, number of stones (single and multiple), stone laterality, congenital kidney abnormality, the presence of solitary kidney, parameters of IPA and IL were measured and both included in the study. All patients were divided into two groups as the successful group and the unsuccessful group according to their post-operative success. These two groups were compared in terms of pre and post-operative data. Stone burden, IPA < 42.65°, and IL > 27.5 mm were specified as the independent risk factors for success of RIRS procedure. The patients for whom RIRS procedure is planned for lower pole kidney stones, stone burden, IPA, and IL should be taken into consideration to be able to predict success and it should be kept in mind that additional treatment may be required.

Keywords Anatomical factors · Lower pole · Nephrolithiasis · RIRS

Introduction

The stone diseases of urinary tract is an important health problem with an incidence of 1–20% worldwide [1]. Being a minimally invasive surgical procedure, retrograde intrarenal surgery (RIRS) is getting more attention in kidney stone surgery nowadays [2]. Several studies have shown that the success rate of RIRS is 50–94.2% beside a stone free rate of 91% is able to be achieved with 1.45 surgical sessions per patient even in kidney stones larger than 2 cm [3–5]. Stone size, stone burden, number of the stones, and the stones that located in the lower pole have been considered by far the most important factors that affect the success rate of RIRS procedure [6]. Therefore, scoring systems such as R.I.R.S., Modified Seoul National University renal stone complexity score (S-ReCS), and Resorlu-Unsal Stone Score (RUSS) have been evolved systematically to predict the success rates of the operation. However, none of these scoring systems are specific for stones located in the lower pole of the kidney, yet there are different opinions regarding the inclusion criteria of infundibulopelvic angle (IPA) and infundibular length (IL) parameters and the cut-off points [7–9].

Deep research of the certain literature has shown us that studies which examine the factors affecting success rate in kidney stones located in the lower pole as well as the effects of IPA and IL have been conducted with a small number of patients [2, 5, 10]. Therefore, in our study, we aimed to evaluate the effect of IPA and IL parameters and determine the cut-off points in RIRS procedure for isolated lower pole kidney stones in a large number of patients.

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Materials and methods

The Regional Research Ethics Board approved this retrospective study and waived informed consent. Totally, 686 RIRS procedures performed in our clinic between January 2013 and May 2020 were analyzed from the hospital information database retrospectively. Cases without adequate data, procedures that were performed because of non-lower pole kidney stones, and secondary cases were excluded from the study. A total of 168 patients who underwent primary RIRS because of isolated lower pole stones and who had sufficient data were included in the study.

Pre- and postoperative data of all patients included in the study were obtained from the hospital information database. All patients were evaluated for demographic data, medical history, physical examination, radiological imaging methods before surgery, surgery duration as well as the hospitalization time after surgery.

According to preoperative computed tomography (CT), stone size, stone burden, stone density, the number of the stones (single and multiple), stone laterality (right-left), the location of the stone, congenital kidney abnormality, and the presence of solitary kidney were assessed. Stone size was calculated by measuring the longest axis in preoperative radiological examination. The longest dimension for stone size was determined from any of the three image orientations. The cases that have multiple stones, the stone size was calculated as the summary of the longest axis of each stone accordingly. Stone burden was measured by the two-dimensional area determined by the multiplication of the longest and perpendicular diameters of the stone. Stone burdens were also added in case of multiple stones. IL was measured as the distance from the furthest point under the calyx containing the stone to the midpoint of the lower edge of the renal pelvis. IPA was measured as the internal angle formed by the intersection of the ureteropelvic axis and central axis of the infundibulum of the lower pole (shown in Fig. 1). IPA and IL measurements were made by selecting the coronal orientation where the infundibulum, pelvis and calyxes looked best using CT urography. All measurements were made by an author of this study who is experienced in computed tomography.

Patients with positive urine cultures were treated with appropriate antibiotics for at least seven days. Preoperatively, urine cultures of all patients were sterile. Prophylaxis with intravenous 2 g of cefazolin was administered to all patients within 1 h before surgery. For patients using anti-coagulants, anti-coagulant therapy was stopped at least 5 days before surgery. RIRS was performed on all patients in lithotomy position under general anesthesia.

Ureterorenoscopy (URS) was performed with a 9.5 F rigid renoscope (Karl Storz, Tuttingen, Germany) for the purpose of dilatation of the ureter before RIRS. RIRS was delayed in the patients, whom we were not able to perform an URS, for two weeks by replacing a double-J catheter in the ureter. 9.5–11 F ureteral access sheath (Flexor® Uretheral access sheath, Cook Medical, USA) was replaced in the ureter in order to reduce intrarenal pressure and to provide optimal view. After the access sheath inserted in the calyceal system, renal pelvis was reached by entering through the access channel with a 7.5 F flexible ureterorenoscope (f-URS; Karl Storz, Flex X2, GmbH, Tuttlingen, Germany). In all cases, the stone which is in lower pole calyceal system was fragmented using a holmium–yttrium–aluminum–garnet (Ho:YAG) laser (200 μm) that conveyed in the working channel of the f-URS. Spontaneous irrigation by the gravity was provided with a saline at a height of 40–60 cm in order to provide a clear vision during the procedure. A 1.9 F nitinol basket catheter was used for extraction of the fragmented stones.

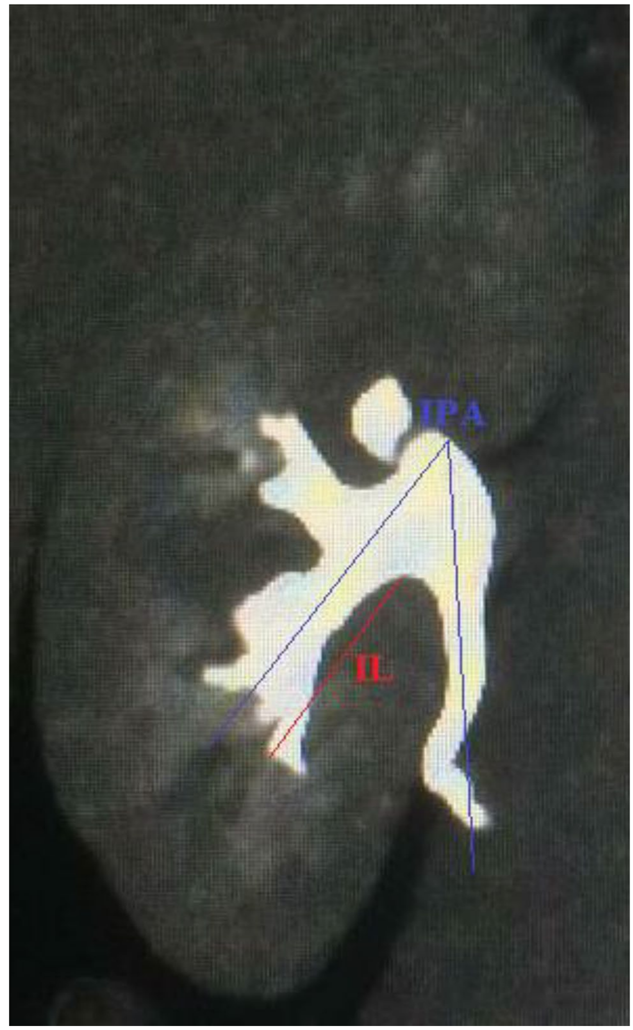

Fig. 1 Measurements of the infundibulopelvic angle (IPA), the infundibular length (IL)

After the session, the f-URS was removed with access sheat by checking ureter for possible injuries. At the end of the operation, ureteral stent and urethral catheter were inserted in all patients. All operations were performed by surgeons who have at least 5 years of RIRS experience. The patients were evaluated with kidney–ureter–bladder radiography (KUB), ultrasonography (US), or abdominopelvic CT in the postoperative first month. Success was defined as the absence of stones in the urinary tract or the presence of asymptomatic residual stones that < 2 mm in diameter. All patients were divided into two groups as the successful group and the unsuccessful group according to their post-operative success. These two groups were compared in terms of pre and post-operative data.

Statistical analysis

The coding and statistical analyses of the data were performed on the computer, using the SPSS 22 software (IBM SPSS Statistics, IBM Corporation, Chicago, IL) package program. The compatibility of the variables to normal distribution was examined using Shapiro–Wilk tests. Mann–Whitney *U* test was used to compare non-categorical parameters between groups. Chi-squared or Fisher's exact tests were used for categorical variables. The decision-making properties of stone burden, stone density, IPA, and IL in predicting RIRS success in lower pole stones were analyzed with receiver-operating characteristic (ROC) curve at 95% confidence interval (CI). Risk factors for RIRS success in lower pole stones were determined by univariate logistic regression analysis. Whether the factors determined in this analysis were independent risk factors was evaluated by using the Backward LR method with multivariate analysis. The conditions with a p value of < 0.05 were considered statistically significant.

Results

The mean age of 168 patients who were included in the study and who underwent RIRS was 45.7 ± 13.8 years; 105 (62.5%) were male, and 63 (37.5%) were female. The success rate after the first session was 62.5%. No significant difference were detected between the successful and unsuccessful groups in terms of age, gender, number of stones, hospitalization time, lateralization, history of stone surgery, history of extracorporeal shockwave lithotripsy, and the presence of congenital and solitary kidney abnormalities. Stone size, stone burden, stone density, and hospitalization time were higher in the unsuccessful group, and this difference was statistically significant ($p < 0.001$, $p < 0.001$, $p = 0.001$ and $p < 0.001$, respectively). In the unsuccessful group, IPA was narrower and IL was longer at a statistically significant level ($p < 0.001$ and $p = 0.003$, respectively). The demographic, clinical, and anatomical characteristics of patients who underwent RIRS procedure for renal lower pole stones are shown in Table 1.

In our study, ROC curves were defined with 95% CI to determine whether stone burden, stone density, IPA, and IL were decisive factors for RIRS success in regard as well as the cut-off points were significated accordingly (Table 2). Afterward, risk factors for success in RIRS procedure for lower pole stones were determined by univariate and multivariate logistic regression analyses by using the significated cut-off points. According to univariate logistic regression analysis; stone burden, stone density, surgery duration, IPA, and IL were found as risk factors for success of RIRS procedure, whereas, in multivariate logistic regression analysis, stone burden (OR 7.958; 95% CI 3.459–18.307; $p < 0.001$), IPA < 42.65° (OR 5.473; 95% CI 2.238–13.387; $p < 0.001$), and IL > 27.5 mm (OR 2.763; 95% CI 1.212–6.302; $p = 0.016$) were stated as the independent risk factors (Table 3).

Discussion

In this study, factors that affect the success rate of RIRS procedure for isolated renal stones located in the lower pole were investigated and as a result, important findings were obtained. According to the result of multivariate analysis of our study, stone burden > 132.5 mm^2, IPA < 42.65°, and IL > 27.5 mm were determined as independent risk factors causing a reduce in success of surgery. Moreover, this study has the highest patient series according to the up to date literature evaluating the anatomical factors affecting the success of RIRS for isolated lower pole stones.

Although these factors are previously included in stone scoring systems evolved for surgery success, there are limited studies about the effect of these factors on isolated stones located in the lower pole. The success rate, mentioned in these studies, is 73–94.4% [2, 5, 10–13]. The study which has the highest number of patients was conducted by Sari et al. with 132 patients [5]. In the R.I.R.S scoring system, IPA and IL are measured by using CT images and 30° is assigned as the cut-off point for IPA. For IL, the cut-off point is determined as 25 mm but this measurement is not defined for lower pole kidney stones. In RUSS, IPA calculated < 45° in lower pole kidney stones is included in the scoring system as a factor that increases the risk of failure [7, 8]. In another study evaluating the pelvicalyceal anatomy in lower pole stones, Kilicarslan et al. found that the success rate was 57.9% among the patients with IPA < 70° and also reported that this rate was 100% among patients with IPA ≥ 70° [10]. They stated that if IL was < 3 cm, the success rate increased from 62.5 to 90% but this result was

Table 1 Demographic, clinical and anatomical characteristics of patients who underwent RIRS for lower pole kidney stones

	Total ($n=168$)	Successful ($n=105$, 62.5%)	Unsuccessful ($n=63$, 37.5%)	p
Age (years) (mean ± SD)	45.7 ± 13.8	45.4 ± 12.8	46.2 ± 15.5	0.799[m]
Sex				0.902[c]
Male, *n* (%)	105 (62.5)	66 (62.9)	39 (61.9)	
Female, *n* (%)	63 (37.5)	39 (37.1)	24 (38.1)	
Stone size (mm) (mean ± SD)	15.3 ± 6.8	13.2 ± 5.3	19 ± 7.6	**< 0.001**[m]
Cumulative stone burden (mm^2) (mean ± SD)	154.2 ± 119.2	110.7 ± 60.5	226.7 ± 153.6	**< 0.001**[m]
Stone density (HU) (mean ± SD)	1028.2 ± 322.6	968.9 ± 328.8	1127 ± 288.2	**0.001**[m]
Number of stones				0.605[c]
One, *n* (%)	116 (69)	71 (67.6)	45 (71.4)	
Multiple, *n* (%)	52 (31)	34 (32.4)	18 (28.6)	
Surgery duration (min) (mean ± SD)	52.1 ± 16.9	48.1 ± 14.8	58.7 ± 18.2	**< 0.001**[m]
Hospitalization (day) (median) (min–max)	1 (1–15)	1 (1–10)	1 (1–15)	0.296[m]
Stone laterality				0.84[c]
Right, *n* (%)	71 (42.3)	45 (42.9)	26 (41.3)	
Left, *n* (%)	97 (57.7)	60 (57.1)	37 (58.7)	
Previous stone surgery				0.6[c]
Yes, *n* (%)	71 (42.3)	46 (43.8)	25 (39.7)	
No, *n* (%)	97 (57.7)	59 (56.2)	38 (60.3)	
ESWL				0.887[c]
Yes, *n* (%)	39 (23.2)	24 (22.9)	15 (23.8)	
No, *n* (%)	129 (76.8)	81 (77.1)	48 (76.2)	
Congenital kidney anomaly				0.713[f]
Yes, *n* (%)	7 (4.2)	5 (4.8)	2 (3.2)	
No, *n* (%)	161 (95.8)	100 (95.2)	61 (96.8)	
Solitary kidney				0.199[f]
Yes, *n* (%)	6 (3.6)	2 (1.9)	4 (6.3)	
No, *n* (%)	162 (96.4)	103 (98.1)	59 (93.7)	
IPA (degree) (mean ± SD)	50.3 ± 12.9	54.2 ± 12.1	43.8 ± 11.5	**< 0.001**[m]
IL (mm) (mean ± SD)	26.1 ± 6.1	25.1 ± 5.6	27.6 ± 6.6	**0.003**[m]

Bold values indicate statistical significance

RIRS retrograde intrarenal surgery *HU* Houndsfield unit, *ESWL* extracorporeal shock wave lithotripsy, *IPA* infundibulopelvic angle, *IL* infundibular length, *SD* standard deviation

[m]Mann–Whitney *U* test

[c]Chi-squared test

[f]Fisher's exact test

mentioned that it was not statistically significant ($p = 0.103$). We believe that this result may be related to the low number of patients. In a study conducted by Inoue et al., they found that the mean IPA and IL were 44° and 27.2 mm, respectively, in the success group and 26.7° and 33.6 mm, respectively, in the failure group [14]. In a different study with 132 patients, Sari et al. found the mean IPA as 85.8 ± 16.9° in the success group and 54.7 ± 11.5° in the failure group and reported that IPA being < 69.4 is an independent risk factor that affects negatively to the success (OR 50.261; 95% CI 8.395–300.920; $p < 0.001$). They emphasized that when IL > 2.73 cm, success rates increases but this is not considered as an independent risk factor (OR 2.11; 95% CI 0.289–15.41; $p = 0.462$) [5]. In our study IPA < 42.65° and IL > 27.5 were found as independent risk factors that increase the success rates in lower pole kidney stones.

It has been stated in the literature that stone burden and stone size are the most important factors for predicting RIRS outcomes and the possibility of residual stone and the need for additional sessions increases as the stone size increases [15, 16]. In another study by Sari et al., it was reported that if the size of the stone is larger than ≥ 17 mm, risk of failure of the RIRS procedure increases by approximately nine times in kidney stones located in lower pole [5]. Moreover,

Table 2 The best cut-off points for stone burden, stone density, infundibulopelvic angle and infundibular length distinguishing the successful group from the unsuccessful group with 95% confidence according to the area under the ROC curve

	Cumulative stone burden	Stone density	IPA	IL
AUC	0.812	0.657	0.74	0.635
95% CI	0.747–0.876	0.571–0.743	0.664–0.815	0.539–0.73
p value	< 0.001	0.001	< 0.001	0.004
Cut-off point	132.5	1232	42.65	27.5
Sensitivity	0.752	0.771	0.848	0.8
Specificity	0.746	0.46	0.508	0.556

IPA infundibulopelvic angle, *IU* infundibular length, *AUC* area under curve, *CI* confidence interval

Resorlu et al., found that 63% of patients who became stone-free, have a kidney stone size reported < 15 mm, whereas the size of the stone was ≥ 15 mm in all patients in the failure group [2]. Kilicarslan et al., contradicting with the literature, reported in their study that the size of the stone was larger in the failure group but this was not statistically significant ($p = 0.825$). They explained this situation by the sizes of the stones being smaller compared with other studies in the literature [10]. In our study, in addition to the stone size, stone burden was also calculated as the area in two-dimensional mm^2, determined by multiplying the longest diameter and the perpendicular diameter of the stone. It was shown that stone burden > 132.5 mm^2 was an independent risk factor that negatively affects the success and increases the probability of failure approximately by eightfolds.

In a study of 219 patients in which the effect of stone density on stone-free status was examined, no relationship was found but it was detected that stone density was inversely correlated with the surgery duration and fragmentation efficiency [17]. In a study by Gucuk et al., it was shown that, although the stone density had no effect on the stone-free rate in RIRS procedure, those with stone density < 677 HU has significantly reduced stone-free status in the mini percutaneous nephrolithotomy group [18]. Although it was shown in our study that stone density was different at statistically significant level between success and failure groups, it was considered not to be an independent risk factor.

There are several studies examining the effects of number of stones on RIRS success; the presence of multiple stones directly affects the score in RUSS and modified S-ReCS, which predict the success rate of RIRS [7–9]. In a study conducted on this subject, the average number of stones in the stone-free group was 1.53 ± 0.6, whereas it was 2.8 ± 1.3 in the group with residual stones ($p < 0.05$) [19]. However, in a study on RIRS performed only on lower pole kidney stones, it was shown that the number of stones was not a risk factor, which is in accordance with our results [5]. We believe that this result may be related to the inclusion of patients with multiple stones located only in the lower pole in both studies.

In our study, age and gender were not found as risk factors for the success rate of RIRS in lower pole kidney stones. Cannon et al. found that success rate of RIRS was similar in patients with pre- and post-pubertal kidney stones and also stated that age is not a risk factor for RIRS success, similar to our results [20].

There are some limitations to our study. Our study was conducted retrospectively and USG and KUB, which have less sensitivity, were used along with abdominopelvic CT for the evaluation of residual kidney stones. In similar studies in the literature, it is seen that infundibular width and pelvicalyceal height, which we did not include in our current study, are also evaluated. However, we believe that our study will contribute to the literature, as more patients were included in our study compared with other studies on this subject.

Conclusion

In conclusions, stone burden > 132.5 mm^2 along with IPA < 42.65° and IL > 27.5 mm are independent risk factors that affect the success rate of RIRS procedure in lower

Table 3 Evaluation of the parameters associated with success in patients who underwent retrograde intrarenal surgery in lower pole kidney stones

	Univariate		Multivariate	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Cumulative stone burden > 132.5 mm^2	8.925 (4.345–18.334)	**< 0.001**	7.958 (3.459–18.307)	**< 0.001**
Stone density > 1232 HU	2.879 (1.469–5.643)	**0.002**	2.159 (0.939–4.963)	0.07
Operative time (min)	1.04 (1.019–1.062)	**< 0.001**	1.013 (0.987–1.04)	0.333
IPA < 42.65°	5.742 (2.778–11.869)	**< 0.001**	5.473 (2.238–13.387)	**< 0.001**
IL > 27.5 mm	5 (2.509–9.965)	**< 0.001**	2.763 (1.212–6.302)	**0.016**

Bold values indicate statistical significance

HU Houndsfield unit, *IPA* infundibulopelvic angle, *IU* infundibular length pole kidney stones. In patients for whom RIRS procedure is planned for lower pole kidney stones, stone burden, IPA, and IL should be taken into consideration to be able to predict success and it should be kept in mind that additional treatment may be required. So, percutaneous nephrolithotomy may be preferred instead of RIRS if IPA < 42.65°, IL > 27.5 mm or stone burden > 132.5 mm^2 in patients who have surgery plan due to isolated lower pole stones.

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Data availability Available.

Code availability Not applicable.

Declarations

Conflict of interest The authors report no conflicts of interest.

Ethics approval The present study protocol was reviewed and approved by the Institutional Review Board of ### Hospital (approval number: E2-21-110).

Consent to participate Not applicable.

Consent for publication Not applicable.

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