DOI: 10.14744/iksstd.2022.25593
İKSSTD 2022;14(2):195-201

ORIGINAL INVESTIGATION / ÖZGÜN ARAŞTIRMA

The Effect of Pelvicalyceal Anatomy on the Success of Retrograde Intrarenal Surgery in the Treatment of Lower Pole Calyceal Stones

Pelvikalisiyel Anatominin Alt Pol Kaliks Taşlarının Tedavisinde Retrograd İntrarenal Cerrahinin Başarısına Etkisi

Süleyman Hilmi Aksoy[1], Basri Çakıroğlu[2], Tuncay Taş[2], Orhun Sinanoğlu[3]

[1]Department of Radiology, Hisar Intercontinental Hospital, Istanbul, Turkey
[2]Department of Urology, Hisar Intercontinental Hospital, Istanbul, Turkey
[3]Department of Urology, Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Objective: The aim of the study was to evaluate the effects of pelvicalyceal anatomy on the success of RIRS performed to treat lower pole stones.

Method: A total of 164 patients with lower calyceal stones were analyzed retrospectively. Besides demographic characteristics of the patients; size (diameter) and density (HU) of the stones, upper ureter diameter, infundibular width (IW), length (IL) and height (IH), and infundibular pelvic angle (IPA) measured in CT scans were recorded. Successful treatment was defined as absence of residual fragments or a fragment <4 mm measured at the follow-up.

Results: The mean age of the patients was 43.36±12.21. Male/female ratio was 40/124. The mean stone size was measured as 13.12 mm. The overall mean upper ureteral diameter was measured as 5.58±2.45 (min–max: 2–19) mm, IW as 6.77±2.55 (min–max: 3–18) mm, IL as 20.33±4.24 (min–max: 8–35) mm, IH as 17.99±5.22 (min–max: 9–40) mm, and IPA as 46.99±12.10 (min–max: 25–96) degrees. Stone free rate was defined as absence of stones or presence of fragments <4 mm and was found as 83.54%. The most important factors affecting treatment success and stone-free rate were found as the stone size and density and IPA.

Conclusion: There is no standardized method of measuring the pelvicalyceal anatomy, making comparison of the findings between the studies difficult. Consistently with the literature, the most important pelvicalyceal anatomy factors affecting success rate included stone size and density and IPA.

Keywords: Kidney stones, lower calyx, RIRS, stone free rate, success rate

ÖZ

Amaç: Bu çalışmanın amacı, alt pol taşlarını tedavi etmek için yapılan retrograd intrarenal cerrahinin başarısına pelvikalisiyel anatominin etkilerini değerlendirmektir.

Yöntem: Alt kaliks taşı olan toplam 164 hasta çalışmaya dahil edildi. Hastaların sosyodemografik özelliklerinin yanı sıra taşların boyutu (çap) ve yoğunluğu, üst üreter çapı, infundibular genişlik, infundibular uzunluk ve infundibular yükseklik, bilgisayarlı tomografide ölçülen infundibular pelvik açı kaydedildi. Başarılı tedavi, takipte rezidüel fragmanların olmaması veya < 4 mm fragman olması şeklinde tanımlandı.

Bulgular: Hastaların yaş ortalaması 43,36±12,21 yıldır. Erkek/kadın oranı 40/124'tür. Ortalama taş boyutu 13,12 mm olarak ölçüldü. Ortalama üst üreter çapı 5,58±2,45 (min-maks: 2–19) mm, infundibular genişlik 6,77±2,55 (min-maks: 3–18) mm, infundibular uzunluk 20,33±4,24 (min-maks: 8–35) mm, infundibular yükseklik 17,99±5,22 (min-maks: 9–40) mm ve infundibular pelvik açı 46,99±12,10 (min-maks: 25–96) derece olarak ölçüldü. Taşsızlık oranı taş yokluğu veya <4 mm fragman varlığı olarak tanımlandı ve %83,54 olarak bulundu. Tedavi başarısını ve taşsızlık oranını etkileyen en önemli faktörlerin, taşın boyutu ve yoğunluğu ile infundibular pelvik açı olduğu bulundu.

Sonuç: Pelvikalisiyel anatomiyi ölçmek için standart bir yöntem yoktur, bu da çalışmalar arasındaki bulguların karşılaştırılmasını zorlaştırmaktadır. Başarı oranını etkileyen en önemli pelvikalisiyel anatomi faktörleri literatürle uyumlu olarak taş boyutu ve yoğunluğu ile infundibular pelvik açıdır.

Anahtar kelimeler: Alt kaliks, başarı oranı, böbrek taşları, retrograd intrarenal cerrahi, taşsızlık oranı

Cite as: Aksoy SH, Çakıroğlu B, Taş T, Sinanoğlu O. The Effect of Pelvicalyceal Anatomy on the Success of Retrograde Intrarenal Surgery in the Treatment of Lower Pole Calyceal Stones. İKSSTD 2022;14(2):195-201

Address for Correspondence/Yazışma Adresi: Süleyman Hilmi Aksoy, Department of Radiology, Hisar Intercontinental Hospital, Istanbul, Turkey
E-mail: mdshilmiaksoy@gmail.com **ORCID ID:** 0000-0002-2356-0268

Received/Geliş tarihi: 14.03.2022
Accepted/Kabul tarihi: 29.03.2022

Medical Journal of Istanbul Kanuni Sultan Suleyman published by Kare Publishing. İstanbul Kanuni Sultan Süleyman Tıp Dergisi, Kare Yayıncılık tarafından basılmıştır.

INTRODUCTION

Renal stones, also called calculi, are firm mineral materials formed within the kidney or urinary tract. Kidney stones may grow so as to impair usual renal function.[1] These stones frequently lead to hematuria and severe pain in the abdomen, flank, or groin. The prevalence and incidence of kidney stones have increased among both adults and children in the past decades. Lifetime prevalence of renal stones has been reported as approximately 10% in adults.[2] Most renal calculi are located in the lower pole calyx (in about 35% of cases).[3] Stones in the lower lobe have been reported to be the most difficult to treat due to anatomical complexity.[4] The risk of developing lower pole stones has been associated with a narrow infundibulum and large calyceal volume.[5]

Computed tomography (CT) is considered the gold standard for the pre-operative investigation of renal calculi and to assist clinicians for the choice of surgical strategy.[6] In addition to the size and location of the stone, pre-operative CT also provides information about the density of the stone in Hounsfield units (HU), which is related to the density of the tissue or stone. The primary goal of kidney stone treatment is to achieve a longest stone-free duration with the lowest rate of morbidity as much as possible.[7] Treatment options for lower pole calyceal stones include extracorporeal shockwave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), and retrograde intrarenal surgery (RIRS).[8] Recent technological advancements in the field of endourology have popularized RIRS for the treatment of kidney stones.[9,10] Studies have reported RIRS to be a safe and efficient procedure associated with minimal complications for renal stones.[11]

The most important parameter that affects the success of renal calculi treatment has been reported as the stone size.[12] In addition, anatomic features of the lower calyx, including the infundibular pelvic angle (IPA), infundibular length (IL), and infundibular width (IW), may also influence success of treatment, which is measured with the ability to access the calculi, stone-free rate or period, and residual fragments. Procedure length, radiation exposure, and hospital stay are the other indicators of the treatment success.

Although the effect of renal anatomy on the treatment of lower pole stones with SWL method has been well-established, studies reporting this with RIRS method are limited.[13] Therefore, the objective of this study was to evaluate the effects of pelvicalyceal anatomy on the success of RIRS performed to treat lower pole stones.

METHOD

Study Design and Patients

In the present study, a total of 164 patients, aged 19–81 years, who were referred to our radiology clinic for CT scans due to the presumed diagnosis of kidney stones, and who underwent RIRS in the urology clinic between January 2016 and January 2020, were retrospectively evaluated. Patients with single or multiple stones localized in the lower calyx systems and with complete CT data of the pelvicalyceal anatomy and operational variables were included in the study. Patients with upper urinary system stones, urinary system anomaly, a history of the previous urinary system surgery and those with missing data were excluded from the study. Inclusion criteria were: Patient's preference, other treatment failures, and American Society of Anesthesiologists score of ≤2. In addition, pediatric patients and patients with abnormal creatinine levels were also excluded from the study.

All patients' serum biochemistry, urine analysis, urine culture, plain kidney-ureter-bladder radiography, renal ultrasonography, and/or CT records of all patients were recorded before and after the surgery. Patients who had positive urine cultures were treated with the antibiotics before surgery.

Successful treatment was defined as absence of residual fragments or a fragment <4 mm measured at the follow-up.

Data Collection

Patients' demographic data such as age and gender, CT scan findings, including size (diameter) and density (HU) of the stones, upper ureter diameter, IW, IL and IH, IPA, and residual stones were recorded and analyzed. The IPA was measured digitally (Agfa HealthCare IMPAX Software) as described by El-Bahnasy.[14] Accordingly, IPA was measured between the ureteropelvic axis and central axis of the lower pole infundibulum. In addition, prophylactic agents, type of anesthesia, status of access to the stone, and operational time were also recorded. Operational success was based on operational time, ability to remove the stone, and residual fragments <4 mm.

CT Scans

All patients underwent unenhanced abdominal CT with Toshiba Aquilion One 320-detector row 640-slice dynamic volume CT system (160×0.5 volume scanning mode). Abdomen CT images retrieved from picture archiving and communication systems (Sectra PACS System) were examined by the same experienced radiologist (SHA).

RIRS Procedure

RIRS operations were performed under general anesthesia alone or combined with regional anesthesia with the patient in dorsal lithotomy position. First, the catheter was passed into the renal pelvis with a 7.5 Fr semi-rigid ureterorenoscope (URS) (Karl Storz Flex-X2, Tuttlingen, Germany) over a 0.97 mm hydrophilic guide wire under fluoroscopy guidance. After a hydrophilic guidewire was passed into the renal pelvis, a ureteric access sheath (UAS), with an inner to outer size of 11/13 F, was placed. Afterwards, a 8.5-F flexible URS was placed through the UAS and the stones were fragmented and/or dusted using a holmium (Ho): yttrium-aluminum-garnet (YAG) laser with a 272-µm laser fiber set at 0.2–2 J×10–40 Hz (Sphinx, LISA Laser Products GmbH, Katlenburg-Lindau, Germany). Visualized stone fragments were extracted with a 1.7- and 2.2-mm Nitinol stone extractor (NGage®; Cook Urological Inc., Bloomington, IN, USA). After RIRS, a double-J (DJ) stent (4.8 Fr 26 cm, Boston Scientific Corp., Boston, MA, USA) or urinary catheter (5 Fr, 0.038 cm, Cook Medical CLL, Bloomington, IN, USA) was inserted in all patients. The inserted DJ catheters were removed after 2–4 weeks.

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 show the worst possible and unbearable pain.

Ethics Consideration

Before the beginning of the study, approval was received from the Local Ethics Committee of Istanbul University of Health Science Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital with the December 16, 2020 dated and 2020/53 numbered decision. The necessary permission was received from the hospital management to use the archives of patient files. The study was performed in accordance with the ethical principles of the Declaration of Helsinki.

Table 1. Demographic characteristics of the patients

Parameter	Minimum	Maximum	Mean±SD
Age (years)	19	81	43.36±12.21
Gender			
Female, n (%)	40 (24.39)		
Male, n (%)	124 (75.51)		
Stone size (mm)	1	30	12.00±6.72

Data Analysis

Data obtained in this study were analyzed using Statistical Package for the Social Sciences Inc., Chicago, Illinois, USA version 22. software. 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. No further statistics were used.

RESULTS

A total of 164 patients with lower pole calyceal stones were included in the study. The mean age of the patients was 43.36±12.21 (min–max: 19–81) years. Of all patients, 40 (24.39%) were female and 124 (75.61%) were males. The mean age was found as 42.43±12.11 (min–max: 21–71) in the female and 43.66±12.21 (min–max: 19–81) years. Demographic features of the patients are given in Table 1.

Localization of the stones was examined and accordingly, 49 (29.89%) stones were localized in the right lower calyx, and 54 (32.93%) in the left lower calyx, while 61 (37.20%) stones were bilateral (Fig. 1).

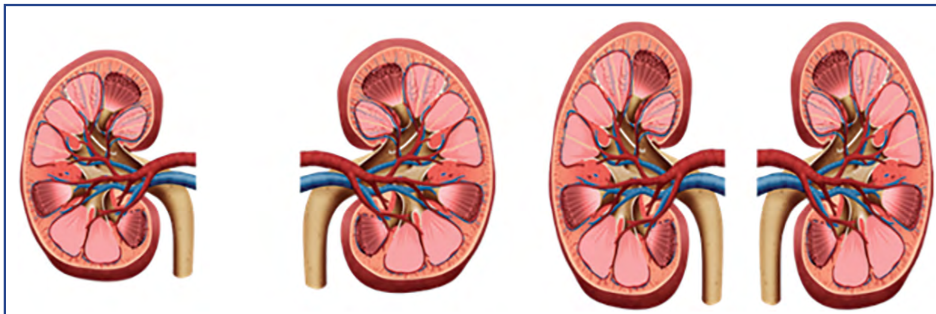

Figure 1. Schematic illustration of the kidney stones' localizations

Table 2. Ureteral and infundibular parameters of the right and left kidney

	Right			Left		
	Mean±SD	Min	Max	Mean±SD	Min	Max
Upper ureteral diameter (mm)	5.40±2.07	2	12	5.76±2.83	2	17
IW (mm)	6.87±2.45	3	14	6.67±2.64	3	18
IL (mm)	20.86±4.33	13	35	19.79±4.15	8	30
IH (mm)	17.54±5.09	10	35	18.43±5.35	9	40
IPA (degrees)	46.76±11.90	27	96	47.21±12.29	25	85

IW: Infundibular width, IL: Infundibular length, IH: Infundibular height, IPA: Infundibular pelvic angle

Fifty-four (32.93%) had a single kidney stone and the remaining 110 (67.07%) patients had multiple lower pole calyceal stones. Density of the stones was measured on CT images in HU and the mean density was found as 752.57±327.76 (min–max: 125–1580) HU. The overall mean upper ureteral diameter was measured as 5.58±2.45 (min–max: 2–19) mm, IW as 6.77±2.55 (min–max: 3–18) mm, IL as 20.33±4.24 (min–max: 8–35) mm, IH as 17.99±5.22 (min–max: 9–40) mm, and IPA as 46.99±12.10 (min–max: 25–96) degrees. The mean ureteral and infundibular parameters of both kidneys measured on CT images are shown in Table 2. Figure 2 shows the measurement of the IPA angle of a stone localized in the lower calyx-infundibulum region on a coronal section CT image.

Figure 2. Coronal section CT image shows a stone in the lower calyx-infundibulum region. Infundibular pelvic angle is measured as 62.7°. The image also shows dilatation in the right kidney pelvicalyceal system due to a stone at the lower end of the right ureter (not shown in this section)

A DJ stent was inserted in 142 (86.59%) patients and ureteral catheter in 22 (13.41%) patients. Before the RIRS operations, 143 (87.20%) patients were administered Aksef 500 mg PO (Nobel, Umraniye, Istanbul, Turkey), 18 (10.98%) patients Sefazol 1000 mg IM (Mustafa Nevzat Ilac Sanayii A.S., Yenibosna, Istanbul, Turkey), 2 (1.22%) patients Cefaks 500 mg PO (Deva Holding A.S., Kucukcekmece, Istanbul, Turkey), and 1 patient (0.61%) Iesef IV (Ibrahim Etem Ulagay Ilac Sanayi Turk A.S., Topkapi, Istanbul, Turkey) for prophylaxis.

Of the patients included in this study, 149 (90.85%) were operated under general anesthesia and 15 (9.15%) under a combination of general and regional anesthesia. Intra-operative ureteral laceration occurred in 24 (16.63%) patients. The mean operational time was found as 69.46±36.19 (min–max: 15–220) min. The mean operational time was measured as 61.09±36.19 min in stone-free patients and 108.49±36.47 min. Post-operative pain was evaluated through VAS scores. The most common VAS pain score was found as "0" point in 91 (55.49%) patients followed by "3" points in 33 (20.12%) patients, "4" points in 18 (10.98%) patients, and "5" points in 10 (6.10%) patients. At the post-operative follow-up, residual stones <4 mm were detected in 29 (17.68%) patients. Primary procedure failed in 2 (1.22%) patients and the overall success rate of the treatment was found as 98.78%. Post-operative stone free rate (SFR) was calculated as 83.54%. The pelvicalyceal anatomy parameters of the stone-free and non-stone free patients included in this study are presented in Table 3.

It was found that operational time was directly proportional to IPA. As is shown in Figure 3, operational time prolonged as the IPA value increased.

DISCUSSION

Minimally invasive techniques like RIRS, SWL, and PCNL are being increasingly used for the treatment of renal stones,

Table 3. Pelvicalyceal anatomy parameters of the stone-free and non-stone free patients

	Stone free (n=135) Mean±SD	Non-stone free (n=29) Mean±SD
Stone size (mm)	11.39±6.72	14.84±6.89
Upper ureteral diameter (mm)	5.36±1.79	6.57±1.82
IW (mm)	6.60±2.05	7.55±2.05
IL (mm)	20.14±3.54	21.16±3.46
IH (mm)	18.01±4.58	18.00±4.65
IPA (degrees)	47.17±10.91	46.14±11.19
Density (HU)	705.66±327.76	857.85±333.06

IW: Infundibular width; IL: Infundibular length; IH: Infundibular height; IPA: Infundibular pelvic angle; HU: Hounsfield units

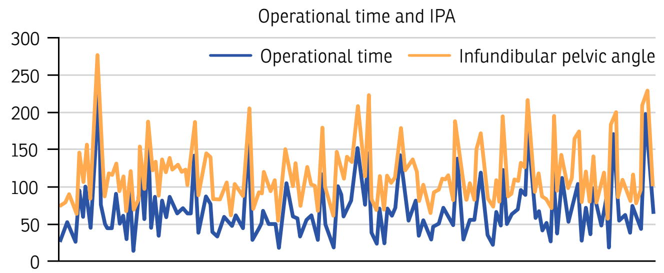

Figure 3. Relationship between operational time and IPA

IPA: Infundibular pelvic angle

despite the increasing incidence and rates of recurrence.[15] These techniques have developed continuously since the past three decades with introduction and sustainable improvement of new procedures. Among these methods, RIRS has gained popularity with the introduction of Ho: YAG laser stone breaking system in the 1990s.[16] In general, RIRS technique is less invasive compared to the other techniques. In the present study, all patients underwent RIRS procedure for the treatment of lower pole calyceal stones.

In our study, SFR was defined as absence of stones or presence of fragments <4 mm and was found as 83.54%. However, there is a controversy in the definition of SFR among various studies, which is considered to be resulted from the variations in the type of imaging modality used to evaluate the presence of stones postoperatively and timing of the evaluation.[17] This controversy has reflected on the results reported by several studies. SFR was defined as complete removal of the stones and was found as 50% with RIRS procedure in a study by Pearle et al.[18] Gokce et al.[19] defined SFR as complete removal or residual fragments <3mm and found the mean SFR as 73.9% with RIRS. The finding closest to our result was reported by Aboutaleb et al.[20] as 84.6% with a SFR definition of residual stones 3 mm.

It is known that treatment success and SFR are influenced by renal anatomy. In our study, among the pelvicalyceal anatomy parameters, the most important factors affecting treatment success and stone-free rate were found as the stone size and density and IPA. Similarly, in a systematic review of relevant literature, Karim et al.[13] also reported the IPA as the most important determinant of the treatment success in the lower pole stones. On the other hand, there was a direct proportional relationship between IPA values and operational times as clearly shown in Figure 2. It could be attributed to prolonged operation with increasing IPA values. IPA angle was more acute in non-stone free patients. In a study by Resorlu et al.,[21] the mean IPA value was found as 49.37±11.83 mm in stone-free patients. In our study, the mean IPA value was measured as 47.17±10.90, consistently with the literature.

In the systematic review by Karim et al.,[13] patients who were not stone-free had larger stone sizes and longer operational times. In our study, residual stones were observed in 29 (17.68%) patients who had larger stone sizes compared to the stone free patients (14.84 vs. 11.39 mm) and longer operational times (108.49 vs. 62.09 min). Based on our results and those of the other studies, it could be said that stone size significantly affects SFR.

Infundibular width is among the reported radiological parameters that may affect treatment success. Studies in the literature have reported that an IW value between 6 and 9 mm predicts treatment success. In our study, the mean IW was 6.60±2.05 mm in stone-free patients, which falls within this range. However, there was no significant difference between the stone-free and non-stone free patients in terms of the IW values (6.60 vs. 7.55).

An IL value between 22 and 27 mm has been reported to indicate treatment success.[22] In our study, the mean IL was measured as 20.14±3.54 in stone-free patients. In our study, IL was not significantly different between the patients with and without residual stones. However, there are studies reporting that IL may be a significant determinant of operational success.[23] Differences between the studies might be caused by the procedures used and definition of operational success or treatment success.

In the present study, the mean overall success rate of RIRS procedures was found as 98.78% as measured by absence of stones or residual fragments <4 mm at follow-up imaging investigations and with a mean stone size of 13.12 mm. In a study by Guler et al.,[24] the overall success rate was reported as 70% with RIRS in pediatric patients based on ≤2 cm upper urinary tract stones. Treatment success was reported as 100% by Gamal et al.[25] with mean stone size 12.2 mm and by Yuruk et al.[26] with mean stone size 13.6 mm. The definition of success rate with RIRS widely differs among the studies due to the use of different inclusion and success criteria, making an exact comparison difficult.

Study Limitations

This study was executed respectively and in a single-center, as the mean limiting factors. The number of our patients was relatively small for such a study. In addition, more detailed statistical analysis could be conducted. However, given the scarcity of studies investigating the effect of pelvicalyceal anatomy on the success of RIRS, we hope that our results will be guiding more comprehensive studies to be conducted in the future with larger patient series and will provide significant contribution to the existing literature findings.

CONCLUSION

The results of this study indicate that the stone size and density and IPA are the most important determinants of operational success. Although IPA seems to be recognized in the literature as an anatomical measurement affecting stone-free rate, the other parameters of pelvicalyceal anatomy are yet to be further studied to draw more definitive conclusions. In addition, there is no standardized method of measuring the pelvicalyceal anatomy, making comparison of the findings between the studies difficult. Therefore, further prospective and comprehensive multi-center studies are warranted to clarify the association of renal anatomy and treatment success in lower pole calyceal stones. Furthermore, studies especially investigating the effects of stone density as measured in Hounsfield units are also needed.

Disclosures

Ethics Committee Approval: The study was approved by The Istanbul University of Health Science Sancaktepe Sehit Prof. Dr. Ilhan Varank Training and Research Hospital Scientific Research Ethics Committee (No: 2020/53, Date: 16/12/2020).

Informed Consent: Written informed consent was obtained from all patients.

Peer-review: Externally peer reviewed.

Authorship Contributions: Concept: S.H.A., B.Ç., T.T.; Design: S.H.A., B.Ç., T.T., O.S.; Supervision: S.H.A.; Funding: None; Materials: S.H.A., T.T.; Data Collection or Processing: B.Ç., O.S.; Analysis or Interpretation: S.H.A.; Literature Search: S.H.A., B.Ç., T.T.; Writing: S.H.A., O.S.; Critical review: S.H.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Deepika RM, Ravisankar P, Priya JD, Surekha P, Sushmitha G, Tejaswi V, et al. Renal calculi: A comprehensive review. Indian J Res Pharm Biotechnol 2018;6:30–4.
2. McClinton S, Starr K, Thomas R, MacLennan G, Lam T, Hernandez R, et al. The clinical and cost effectiveness of surgical interventions for stones in the lower pole of the kidney: The percutaneous nephrolithotomy, flexible ureterorenoscopy and extracorporeal shockwave lithotripsy for lower pole kidney stones randomised controlled trial (PUrE RCT) protocol. Trials 2020;21:479. [CrossRef]
3. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, et al. EAU guidelines on interventional treatment for urolithiasis. Eur Urol 2016;69:475–82. [CrossRef]
4. Geraghty R, Burr J, Simmonds N, Somani BK. Shock wave lithotripsy outcomes for lower pole and non-lower pole stones from a university teaching hospital: Parallel group comparison during the same time period. Urol Ann 2015;7:46–8. [CrossRef]
5. El-Assmy A, Abo-Elghar ME, El-Nahas AR, Youssef RF, El-Diasty T, Sheir KZ. Anatomic predictors of formation of lower caliceal calculi: Is it the time for three-dimensional computed tomography urography? J Endourol 2008;22:2175–9. [CrossRef]
6. Gallioli A, De Lorenzis E, Boeri L, Delor M, Zanetti SP, Longo F, et al. Clinical utility of computed tomography Hounsfield characterization for percutaneous nephrolithotomy: A cross-sectional study. BMC Urol 2017;17:104. [CrossRef]
7. Süelözgen T, İşoğlu CS, Karabıçak M, Yalçın MY, Yeni S, İlbey YÖ. Our retrograde intrarenal surgery experience with horseshoe kidney. J Urol Surg 2017;4:106–8. [CrossRef]
8. Inoue T, Okada S, Hamamoto S, Fujisawa M. Retrograde intrarenal surgery: Past, present, and future. Investig Clin Urol 2021;62:121–35.
9. Rukin NJ, Siddiqui ZA, Chedgy ECP, Somani BK. Trends in upper tract stone disease in England: Evidence from the hospital episodes statistics database. Urol Int 2017;98:391–6. [CrossRef]
10. Van Cleynenbreugel B, Kılıç Ö, Akand M. Retrograde intrarenal surgery for renal stones - Part 1. Turk J Urol 2017;43:112–21. [CrossRef]
11. Xiao Y, Li D, Chen L, Xu Y, Zhang D, Shao Y, et al. The R.I.R.S. scoring system: An innovative scoring system for predicting stone-free rate following retrograde intrarenal surgery. BMC Urol 2017;17:105. [CrossRef]
12. Boonyapalanant C, Saksirisampant P, Taweemonkongsap T, Leewansangtong S, Srinualnad S, Chotikawanich E. Factors impacting stone-free rate after retrograde intrarenal surgery for calyceal diverticular calculi. Res Rep Urol 2020;12:345–50. [CrossRef]
13. Karim SS, Hanna L, Geraghty R, Somani BK. Role of pelvicalyceal anatomy in the outcomes of retrograde intrarenal surgery (RIRS) for lower pole stones: Outcomes with a systematic review of literature. Urolithiasis 2020;48:263–70. [CrossRef]
14. Elbahnasy AM, Shalhav AL, Hoenig DM, Elashry OM, Smith DS, McDougall EM, et al. Lower caliceal stone clearance after shock wave lithotripsy or ureteroscopy: The impact of lower pole radiographic anatomy. J Urol 1998;159:676–82. [CrossRef]

15. Arda E, Cakiroglu B. Bilateral same-session flexible ureterorenoscopy for renal and/or ureteric stone disease treatment. Arab J Urol 2018;16:441–5. [CrossRef]
16. Chung DY, Kang DH, Cho KS, Jeong WS, Jung HD, Kwon JK, et al. Comparison of stone-free rates following shock wave lithotripsy, percutaneous nephrolithotomy, and retrograde intrarenal surgery for treatment of renal stones: A systematic review and network meta-analysis. PLoS One 2019;14:e0211316. [CrossRef]
17. Ghani KR, Wolf JS Jr. What is the stone-free rate following flexible ureteroscopy for kidney stones? Nat Rev Urol 2015;12:281–8. [CrossRef]
18. Pearle MS, Nadler R, Bercowsky E, Chen C, Dunn M, Figenshau RS, et al. Prospective randomized trial comparing shock wave lithotripsy and ureteroscopy for management of distal ureteral calculi. J Urol 2001;166:1255–60. [CrossRef]
19. Gokce MI, Tokatli Z, Suer E, Hajiyev P, Akinci A, Esen B. Comparison of shock wave lithotripsy (SWL) and retrograde intrarenal surgery (RIRS) for treatment of stone disease in horseshoe kidney patients. Int Braz J Urol 2016;42:96–100. [CrossRef]
20. Aboutaleb H, El-Shazly M, Badr Eldin M. Lower pole midsize (1-2 cm) calyceal stones: Outcome analysis of 56 cases. Urol Int 2012;89:348–54.
21. Resorlu B, Sancak EB, Resorlu M, Gulpinar MT, Adam G, Akbas A, et al. Retrograde intrarenal surgery in pediatric patients. World J Nephrol 2014;3:193–7. [CrossRef]
22. Kilicarslan H, Kaynak Y, Kordan Y, Kaygisiz O, Coskun B, Gunseren KO, et al. Unfavorable anatomical factors influencing the success of retrograde intrarenal surgery for lower pole renal calculi. Urol J 2015;12:2065–8.
23. Jessen JP, Honeck P, Knoll T, Wendt-Nordahl G. Flexible ureterorenoscopy for lower pole stones: Influence of the collecting system's anatomy. J Endourol 2014;28:146–51. [CrossRef]
24. Guler Y, Erbin A. Comparison of extracorporeal shockwave lithotripsy and retrograde intrarenal surgery in the treatment of renal pelvic and proximal ureteral stones ≤2 cm in children. Indian J Urol 2020;36:282–7.
25. Gamal WM, Hussein MM, Rashed EN, Mohamed AD, Mmdouh A, Fawzy F. Pediatric retrograde intra-renal surgery for renal stones <2 cm in solitary kidney. Indian J Urol 2016;32:296–300. [CrossRef]
26. Yuruk E, Binbay M, Sari E, Akman T, Altinyay E, Baykal M, et al. A prospective, randomized trial of management for asymptomatic lower pole calculi. J Urol 2010;183:1424–8. [CrossRef]