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STONE-FREE RATE AND PREDICTORS OF SUCCESS AFTER RETROGRADE INTRARENAL SURGERY FOR RENAL STONES

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ABSTRACT
Background: Retrograde intrarenal surgery is widely used for the minimally invasive management of renal stones.
Objective: To determine the stone-free rate following retrograde Intrarenal surgery and identify predictors of successful stone clearance.
Methodology: This prospective observational study was conducted at Hayatabad medical complex Peshawar from June 2024 to June 2025 and included 155 adult patients with renal stones undergoing retrograde intrarenal surgery. Demographic characteristics, comorbidities, stone size, burden, number, location, density, operative time, laser time, perioperative complications, hospital stay, and secondary interventions were recorded.
Results: The mean age of the patients was 46.8 ± 12.7 years, and 96 (61.9%) were male. The mean stone size was 15.2 ± 4.8 mm, mean stone burden was 182.6 ± 71.5 mm², and mean stone density was 1046 ± 286 HU. Stone-free status was achieved in 132 (85.2%) patients, while 23 (14.8%) had residual fragments. The mean hospital stay was 1.6 ± 0.8 days. Postoperative fever occurred in 10 (6.5%) patients, urinary tract infection in 8 (5.2%), readmission in 5 (3.2%), and major Clavien–Dindo grade III or higher complications in 3 (1.9%). Compared with patients with residual stones, stone-free patients had smaller stones (14.3 ± 4.2 vs. 20.4 ± 4.8 mm), lower stone burden (169.2 ± 64.7 vs. 259.4 ± 58.6 mm²), lower stone density (998 ± 251 vs. 1322 ± 273 HU), and shorter operative time (68.7 ± 16.2 vs. 93.8 ± 17.5 minutes); all p-values were <0.001.
Conclusion: It is concluded that retrograde intrarenal surgery provides a high stone-free rate with low major morbidity. Smaller stone size, lower density, single-stone disease, and shorter operative time were associated with successful clearance, whereas lower-pole location reduced procedural success.

KEYWORDS: Retrograde intrarenal surgery; renal stones; stone-free rate; flexible ureteroscopy; predictors

INTRODUCTION
Renal stone disease is one of the most frequent urological diseases around the world; its incidence has been steadily rising over the years, and this is attributed to the alteration of dietary habits, obesity, metabolic syndrome and diabetes mellitus, and sedentary lifestyles [1]. The prevalence of urolithiasis is 5%-15% and near to 50% of the patients will recur within 10 years if no preventive measures are undertaken [2]. The treatment of renal stone is a significant burden on healthcare due to its recurrent painful episodes, the burden of urinary infections, repeated admissions to the hospital, and surgery treatment [3]. The treatment of renal stones relies on the size of the stone, location, composition, anatomical considerations and patient factors [4]. There are some other surgical options such as shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL) and open and laparoscopic surgery, but technological advancements have made retrograde intrarenal surgery (RIRS) a minimally invasive and highly effective method in treating small- and medium-sized renal calculi [5]. Recent advances in flexible ureteroscopes, high power holmium: YAG and thulium fiber lasers, ureteral access sheaths, and advances in stone retrieval devices have further improved the safety and efficiency of RIRS [6]. Retrograde intrarenal surgery includes the direct visualization of pelvicalyceal system through the flexible ureteroscopy for laser fragmentation and extraction of renal stones, which can preserve renal parenchyma [7]. RIRS is less invasive than PCNL, and the patient will experience less postoperative pain, shorter hospital stay, faster recovery, less bleeding, and fewer major complications, which makes it ideal for patients with significant medical comorbidities, solitary kidney, obesity and bleeding disorders [8]. As such, RIRS has emerged as

one of the most preferred methods of treatment for stones up to 20 mm in size and is gaining popularity in the treatment of select larger stones in a staged approach [9].

The stone-free rate or the absence of stones or the presence of stones less than 2-4 mm in diameter on postoperative imaging is the main outcome parameter for procedural success after receiving RIRS [10]. There are many factors affecting SFR, such as the stone size, stone burden, location of the lower pole, Hounsfield unit density, infundibulopelvic angle, multiple stones, time of surgery, surgeon experience and preoperative use of ureteral stents [11]. Predictors of successful stone clearance are important to identify for selecting patients, counselling and surgical planning. Although the equipment and laser technology of the endoscopy room have been continuously upgraded, there are still many patients in the clinic who cannot completely get rid of stones because of the large stone burden, unfavorable lower calyceal anatomy, or hard calculi [12]. Residual fragments can serve as a nidus for further stone formation, recurrence of symptoms, and infection, and subsequent procedures [13]. Thus, the factors influencing stone-free status after surgery are clinically significant for better long-term clinical results and reduce retreatment rates [14].

Objective

To determine the stone-free rate following retrograde intrarenal surgery and identify predictors of successful stone clearance.

METHODOLOGY

This prospective observational study was conducted at Hayatabad medical complex Peshawar from June 2024 to June 2025 and included 155 patients with renal stones who underwent retrograde intrarenal surgery. The purpose of this study was to evaluate the stone free rate and to identify patient, stone, and procedure-related factors associated with stone free success after the procedure. They included patients older than 18 years of either sex with stones in one or both kidneys up to 25 mm that were to be treated with retrograde intrarenal surgery as an elective procedure. Patients with X-ray proven renal stones, who had no urinary infection before operation and had no infection after operation with complete peri- and postoperative records were eligible for study. Patients with active urinary tract infection, uncorrected coagulopathy, pregnancy, congenital renal anomaly, ureteral stricture and that did not allow for endoscopic access, severe renal impairment, untreated obstruction, staghorn calculi requiring percutaneous nephrolithotomy, previous ipsilateral renal surgery within three months and incomplete follow-up imaging have been excluded.

Data Collection

Eligible patients were enrolled with non-probability consecutive sampling techniques after getting approval from the Institutional Ethical Review Committee and written informed consent. Baseline data consisted of age, gender, body mass index, comorbidities, previous stone history, previous stone surgery, ureteral stenting before surgery, serum creatinine, urine culture and American Society of Anesthesiologists physical status. Stone size, number, location, total stone burden, laterality, density in Hounsfield units, hydronephrosis, infundibular length, infundibular width and infundibulopelvic angle were determined by non-contrast computed tomography (CT). The stones were classified based on the maximum diameter, position of the lower pole, number of distribution and density. The procedures were carried out by the well-trained endourologists under general or spinal anesthesia through a flexible ureteroscope. Where possible, a ureteral access sheath was placed, and stones were crushed with holmium:YAG or thulium fiber laser. Fragmentation, dusting or basket extraction was done based on the characteristics of stone and surgeon's preferences. Intraoperative variables were operative time, laser time, use of access sheath, ureteral injury, bleeding, stone migration and requirement for ureteral stent placement. Patients were following surgery for pain, the presence of hematuria, fever, urinary tract infection, sepsis, length of hospital stay, readmission and secondary intervention. The time of stone clearance after surgery was evaluated using non-contrast computed tomography or ultrasonography in conjunction with plain radiography at 4 to 6 weeks. The main outcome was the stone-free rate, which was defined as complete stone clearance or as stones that became smaller than 4 mm and did not obstruct or cause symptoms. Secondary outcomes were operative time, hospital stay, postoperative complications, retreatment rate and independent predictors of successful stone clearance.

Statistical Analysis

The data were subjected to the analysis by SPSS version 26.0. Data from continuous variables were expressed as mean ± SD and data from categorical variables as frequencies and percentages. The patients were subclassified into stone free and residual stone groups. Independent t-test or Mann–Whitney U test was used to compare continuous variables, and Chi-square or Fisher's exact test was used for categorical variables. Multivariable logistic regression was performed to determine independent factors associated with stone-free status and variables that were significant at univariate analysis were entered. Odds ratios with 95% confidence intervals were determined and significance was determined as p value ≤ 0.05.

RESULTS

The study included 155 patients with a mean age of 46.8 ± 12.7 years and a mean BMI of 27.3 ± 4.2 kg/m². There were 96 (61.9%) males and 59 (38.1%) females. Diabetes mellitus was present in 34 (21.9%) patients and hypertension in 47 (30.3%). A previous history of renal stones was reported by 58 (37.4%) patients, while 31 (20.0%) had undergone an earlier stone intervention. Preoperative ureteral stenting was performed in 44 (28.4%) patients. The mean serum creatinine level was 1.02 ± 0.26 mg/dL.

Table 1. Baseline demographic and clinical characteristics of the study participants (n=155)

Characteristic	Value	n (%) / Mean ± SD
Age (years)	Mean ± SD	46.8 ± 12.7
Male gender		96 (61.9)
Female gender		59 (38.1)
BMI (kg/m²)	Mean ± SD	27.3 ± 4.2
Diabetes mellitus	Yes	34 (21.9)
Hypertension	Yes	47 (30.3)
Previous history of renal stones	Yes	58 (37.4)
Previous stone intervention	Yes	31 (20.0)
Preoperative ureteral stent	Yes	44 (28.4)
Serum creatinine (mg/dL)	Mean ± SD	1.02 ± 0.26

The mean stone size was 15.2 ± 4.8 mm, with a mean cumulative stone burden of 182.6 ± 71.5 mm². A single stone was present in 103 (66.5%) patients, while 52 (33.5%) had multiple stones. Lower-pole stones were identified in 48 (31.0%) patients. The mean stone density was 1046 ± 286 HU. The mean operative and laser times were 72.4 ± 18.6 minutes and 31.8 ± 10.9 minutes, respectively. A ureteral access sheath was used in 132 (85.2%) procedures, and postoperative ureteral stenting was performed in 126 (81.3%) patients.

Table 2. Stone characteristics and intraoperative findings (n=155)

Variable	Category	n (%) / Mean ± SD
Stone size (mm)	Mean ± SD	15.2 ± 4.8
Stone burden (mm²)	Mean ± SD	182.6 ± 71.5
Single stone		103 (66.5)
Multiple stones		52 (33.5)
Lower pole stone		48 (31.0)
Stone density (HU)	Mean ± SD	1046 ± 286
Operative time (minutes)	Mean ± SD	72.4 ± 18.6
Laser time (minutes)	Mean ± SD	31.8 ± 10.9
Ureteral access sheath used	Yes	132 (85.2)
Postoperative ureteral stent	Yes	126 (81.3)

Stone-free status was achieved in 132 (85.2%) patients, while residual fragments remained in 23 (14.8%). The mean hospital stay was 1.6 ± 0.8 days. Postoperative fever occurred in 10 (6.5%) patients, urinary tract infection in 8 (5.2%), hematuria requiring intervention in 4 (2.6%), and readmission in 5 (3.2%). A secondary procedure was required in 14 (9.0%) patients, while major Clavien–Dindo grade III or higher complications occurred in only 3 (1.9%).

Table 3. Postoperative outcomes following retrograde intrarenal surgery (n=155)

Outcome	Value	n (%) / Mean ± SD
Stone-free status	Yes	132 (85.2)
Residual fragments	No	23 (14.8)
Hospital stay (days)	Mean ± SD	1.6 ± 0.8
Postoperative fever		10 (6.5)
Hematuria requiring intervention		4 (2.6)
Urinary tract infection		8 (5.2)
Readmission		5 (3.2)
Secondary procedure required		14 (9.0)
Clavien–Dindo complication grade ≥III		3 (1.9)

Patients who became stone-free were younger than those with residual stones, with mean ages of 45.9 ± 12.3 and 51.8 ± 13.5 years, respectively (p=0.041). The stone-free group had smaller mean stones (14.3 ± 4.2 vs. 20.4 ± 4.8 mm; p<0.001), lower stone burden (169.2 ± 64.7 vs. 259.4 ± 58.6 mm²; p<0.001), and lower stone density (998 ± 251 vs. 1322 ± 273 HU; p<0.001). Lower-pole stones were present in 33 (25.0%) stone-free patients compared with 15 (65.2%) patients with residual stones (p<0.001), while multiple stones occurred in 37 (28.0%) and 15 (65.2%), respectively (p=0.001).

Table 4. Comparison between stone-free and residual-stone groups

Variable	Stone-Free (n=132)	Residual Stone (n=23)	p-value
Age (years), Mean ± SD	45.9 ± 12.3	51.8 ± 13.5	0.041
Stone size (mm), Mean ± SD	14.3 ± 4.2	20.4 ± 4.8	<0.001
Stone burden (mm²), Mean ± SD	169.2 ± 64.7	259.4 ± 58.6	<0.001
Lower pole stones	33 (25.0%)	15 (65.2%)	<0.001
Multiple stones	37 (28.0%)	15 (65.2%)	0.001
Stone density (HU), Mean ± SD	998 ± 251	1322 ± 273	<0.001
Operative time (minutes), Mean ± SD	68.7 ± 16.2	93.8 ± 17.5	<0.001

Stone density below 1000 HU increased the odds by 2.96 times (95% CI: 1.29–6.81; p=0.010), a single stone by 2.71 times (95% CI: 1.16–6.35; p=0.021), and operative time below 80 minutes by 2.43 times (95% CI: 1.08–5.47; p=0.032). Lower-pole location reduced the likelihood of successful clearance by 66% (AOR=0.34, 95% CI: 0.14–0.79; p=0.012). Preoperative ureteral stenting showed a positive but statistically non-significant association with stone-free status (AOR=1.88, 95% CI: 0.91–3.89; p=0.086).

Table 5. Multivariable logistic regression analysis of predictors of stone-free status after RIRS

Variable	Adjusted Odds Ratio (95% CI)	p-value
Stone size <20 mm	3.94 (1.62–9.61)	0.002
Single stone	2.71 (1.16–6.35)	0.021
Lower pole location	0.34 (0.14–0.79)	0.012
Stone density <1000 HU	2.96 (1.29–6.81)	0.010
Operative time <80 minutes	2.43 (1.08–5.47)	0.032
Preoperative ureteral stenting	1.88 (0.91–3.89)	0.086

DISCUSSION

In this study, we assessed the stone-free rate and factors associated with success in stone-free rates among 155 patients who underwent retrograde intrarenal surgery with renal stones. The mean age of the study population was 46.8 ± 12.7 years with a male predominance of 61.9%. The mean BMI was 27.3 ± 4.2kg/m², and 21.9% and 30.3% of patients had diabetes mellitus and hypertension, respectively. Among the patients, 37.4% had a previous history of renal stones, and 20.0% had been treated for a previous renal stone intervention. Previous studies have also revealed that renal stone formation is more prevalent in the middle-aged male population and that it also tends to recur, and that there is a significant amount of patients who needed a repeated endourological procedure [15]. The mean stone size was 15.2 ± 4.8 mm, the mean stone burden was 182.6 ± 71.5 mm², and the mean stone density was 1046 ± 286 HU. Sixty six.5% of patients had single stones, with 33.5% having multiple stones and lower-pole calculi were present in 31.0% of patients. It took 72.4 ± 18.6 minutes to complete the mean operative time and 31.8 ± 10.9 minutes to complete the mean laser time. Previous studies have also reported similar stone size, operation time and stone density in patients who had undergone retrograde intrarenal surgery for small to medium size renal stones [16]. Overall, 85.2% of patients in the present study were stone-free, and 14.8% had stones remaining. This finding showed that retrograde intrarenal surgery was effective in dealing with the appropriately selected renal stones with high effectiveness. Previous studies have also shown rates of stone free from about 80% to 95% based on the definition of stone-free status, the type and when the postoperative imaging is performed, stone burden, stone location and surgeon experience [17]. Recovery and safety after surgery were good. The mean hospital stay was 1.6 ± 0.8 days, and 6.5% of patients had postoperative fever, 5.2% had urinary tract infection, 2.6% had hematuria that required intervention, and 3.2% were readmitted. Major Clavien–Dindo grade III or higher complications were seen in 1.9% while secondary procedure was necessary in 9.0%. The results of previous studies have also indicated that retrograde intrarenal surgery results in short hospital stay, low risk of complications and a low requirement for secondary intervention when compared with more invasive renal stone surgery [18].

The stone characteristics were significantly better in patients who were stone-free compared with those who had stones remaining. Their mean stone size was 14.3 ± 4.2 mm compared with 20.4 ± 4.8 mm, while mean stone burden was 169.2 ± 64.7 mm² compared with 259.4 ± 58.6 mm². The stone-free group also had lower stone density (998 ± 251 HU) than the other group (1322 ± 273 HU). Additionally, lower-pole stones and multiple stones were significantly more prevalent in the patients with residual fragments, as were longer operative time. Larger stone size, increased stone burden, higher Hounsfield units, multiple calculi, and stone location in the lower part of the kidney have also been shown to be associated with lower success rates for complete stone clearance following retrograde intrarenal surgery [19]. The stone size <20 mm was the most significant positive predictor (3.94-fold) in the multivariable analysis in achieving stone-free status. A density < 1000 HU, one stone and operative time < 80 minutes each increased the odds by 2.96, 2.71, and 2.43 times, respectively. Lower-pole location, on the other hand, had a 66% reduction in successful clearance. The same results have been noted previously and stone size, stone density, number of stones, lower calyceal location and operative duration are all clinically significant factors affecting stone-free status after surgery [20]. Lower pole location may be responsible for this negative effect because of the acute infundibulopelvic angle, length of infundibular, and lower calyx's gravitation. Similarly, higher density stones may need more energy from the laser and longer fragmentation time, causing the operation to be more difficult and the stones which remain to be more. Previous studies have also focused on the technical difficulties encountered with dense calculi in the lower pole and unfavorable calyceal anatomy [21]. The odds of stone-free outcome were positive but not statistically significant with preoperative ureteral stenting. This indicates that although pre-stenting might make access of the ureter and access-sheath easier, it does not seem to have any particular value when stone and anatomical characteristics are taken into account for stone clearance after stenting. The advantages of routine preoperative stenting have been mixed in the past with some studies reporting better access and others reporting no significant impact on stone-free rates [22]. The limitations of this study include the single-center, observational design, which might limit generalizability of the results. The small number of patients in the sample size and the limited postoperative follow-up prevented evaluation of long-term stone recurrence and renal functional outcomes. Moreover, the anatomical parameters of the pelvicalyceal system have not been analyzed in detail in all patients, and not the composition of the stone.

CONCLUSION

It is concluded that retrograde intrarenal surgery is a safe and highly effective minimally invasive treatment for renal stones, achieving a high stone-free rate with a low incidence of major complications. Smaller stone size, lower stone density, single-stone disease, and shorter operative time were significant predictors of successful stone clearance, whereas lower-pole stone location reduced the likelihood of achieving a stone-free status. Comprehensive preoperative evaluation of stone characteristics can improve patient selection, optimize surgical planning, and enhance procedural success.

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