Retrograde Intrarenal Surgery for Renal Stones

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ABSTRACT

The main aim in the treatment of renal stones is to clean the stones completely with the least morbidity. Parallel to the improvements in technology during recent years, new flexible ureterorenoscopes and effective lithotripthors like holmium laser have been developed, thus Retrograde Intrarenal Surgery **(RIRS)** has become an efficient and safe option in stone treatment. Therewithal, innovations in auxiliary equipment such as guide-wires, ureteral access sheath and stone baskets have made this procedure more effective. With this modality, nowadays, the vast majority of renal stones can be treated successfully without need of open surgery or Percutaneous Nephrolithotomy **(PCNL).** RIRS can be used as a primary treatment in patients with renal stones smaller than 2 cm, prior unsuccessful Shock Wave Lithotripsy **(SWL),** infundibular stenosis, renoureteral malformation, skeletal-muscular deformity, bleeding diathesis as well as obese patients. The efficiency of this procedure has been also proved in pediatric patients. In this chapter, recent advances in flexible ureteroscopes and auxiliary equipment as well as indications, surgical technique and complications will be discussed with up-to-date literature.

Keywords: Kidney stone; Flexible ureteroscopy; Retrograde intrarenal surgery; Laser lithotripsy; Ureteral access sheath

INTRODUCTION

With the aid of the recent technological developments, there have been rapid increasing options in the treatment of kidney stones. Historically treated with open surgery, recently kidney stones are often managed by SWL and endoscopic surgeries. Nowadays minimally invasive modalities such as SWL, ante grade fashion (PCNL-conventional, mini, ultra-mini and micro), Retrograde Fashion **(RIRS)** and laparoscopic surgeries are commonly used for the treatment of kidney stones.

The most important one of the various clinical parameters that can affect the success of stone treatment is the stone size [1-2]. It has been shown that SWL has a good Stone-Free Rate **[SFR]** for the stones that are up to 20 mm, and PCNL is considered as a primary treatment for the stones greater than 20 mm [3]. The negative factors affecting the SFR in SWL include lower pole calyx, acute Infundibulo Pelvik Angle **(IPA),** calyx neck longer than 10 mm, narrow infundibulum (≤5 mm), hard stones, and obesity. Multiple sessions and additional treatments may be needed in case of these factors [4,5]. Even PCNL has high SFRs, hemorrhage, perioperative decrease in hemoglobin and renal injury can occur as the renal parenchyma is penetrated in this modality [6].

Although SWL and PCNL are mentioned in the guidelines as gold standard treatment for the management of kidney stones, RIRS is accepted as another treatment modality in the European Association of Urology **(EAU)** guidelines [7]. The more commonly use of RIRS depends on not only the digital improvements in flexible Ureteroscopy **(fURS)** technology, but also the developments in deflection mechanism, mobility, ergonomics and durability. Meanwhile, with the addition of the developments in auxiliary devices – such as miniaturized holmium laser fibers, nitinol baskets, guide-wires and ureteral access sheath – and increase in surgical experience and compliance, higher success rates have been achieved with RIRS in the management of kidney stones. There are some papers with increasing numbers that show RIRS can be performed for stones >2 cm [3,8-10]. Today, reaching the stone via a natural route and achieving a high success rate with a lower morbidity have led RIRS to become a commonly used and important treatment modality.

HISTORY

In 1964, Marshall has reported the first use of fURS, and has been able to see a ureteral stone with a ureteroscope passing through a 26 Fr cystoscope [11]. At the end of 1980s, use of flexible ureteroscopes has gained acceleration with the production of devices that have an irrigation channel and a flexible tip (active and passive deflection) [12]. Bagley et al. [13] published their first fURS study in 1987, thereafter Kavoussi et al. [14] reported their series including 76 fURS in 68 patients in 1989, and Fuchs [15] published their experience in 1990. The developments in flexible ureteroscopes in this time have mainly been on decreasing the diameter of the devices and increasing the deflection angles. In 1994, Grasso and Bagley [16] reported their early-term experience with ureteroscopes with working channels of 7.5 Fr and 3.6 Fr, where they noted that no dilatation was needed in 48% of the patients due to use of a device with a narrower diameter.

In 2001, an ureteroscope with 2-way deflection (270°) has been manufactured which allowed to reach all pelvicalyseal system [17]. The durability of flexible ureteroscopes has been increased, so that it has been able to use them without any maintenance up to 50 cases [18].

With the regeneration of the endoscopic technology, digital flexible ureteroscope has been manufactured in 2006. However, because of its wider diameter, use of Ureteral Access Sheath **(UAS)** has increased [19]. Later on, Zilberman et al. [20] published their series with the use of newer digital ureteroscopes with a higher resolution and color quality that can show 5.3 folds bigger than standard flexible ureteroscopes. As the improvements have emerged, it has been possible to develop new flexible ureteroscopes with a smaller caliber when compared to older conventional flexible ureteroscopes [21]. Another development has been achieved with the addition of a second working channel that enabled an increase in irrigation power [22].

Sun et al. [23] reported the first combination of rigid and flexible ureteroscope – "the Sun's ureteroscope" – in 2010. This device is consisted of a retractable rigid shaft and a flexible tip that enable to treat both ureteral and renal stones without changing the endoscopes. In their series of 175 patients, shorter operation duration and a SFR of 83% have been reported [23]. Lastly, some researchers have described robotic RIRS system [24,25]. The effects of these systems on outcomes of surgery are not clear at the moment. The potential advantages of this robotic system seem to be improved ergonomics and stability of the instruments.

INDICATIONS

In the beginning, the indications of RIRS included failure of previous SWL, lower calyx stones and stones smaller than 1.5 cm. However, the limitations in the indication of RIRS has been reduced recently, where it can be used for stones smaller than 2 cm as a first line treatment option besides SWL, and can be an alternative of PCNL for the stones in lower calyx and greater than 2 cm. The relatively lower morbidity of RIRS has caused it to be used increasingly [26]. Although its absolute indications have not been reported, the potential indications can be listed as below [26-28]:

- Medium-sized stones those are not suitable for SWL or PCNL
- SWL-resistant stones
- Non-opaque stones
- Existence of anatomic abnormalities (acute IPA, long lower pole calyx, narrow infundibulum)
- Co-existence of renal and ureteral stones
- Need of treating bilateral renal stones successfully in a single session
- Multiple kidney stones including nephrocalcinosis
- Bleeding disorders

- People who have to be treated completely stone-free (like pilots, etc.)
- Percutaneous antegrade approach for ureteral stones in patients with urinary diversion
- Combined or ancillary procedures following PCNL
- Renoureteral malformations
- Patient habitus (obese, musculoskeletal deformities)
- Stones >3 cm (may require two or more sessions)

RIRS is an efficient and reliable treatment method for patients with obesity, musculoskeletal deformities, renoureteral malformations, infundibular stenosis, bleeding disorders in whom other treatment options risky or insufficient [29,30].

PREOPERATIVE EVALUATION

The patient has to be informed about the style, success rate and possible complications of the operation, and informed consent has to be taken. The patients are evaluated preoperatively with physical examination, routine blood tests, urine test and culture, Kidney-Ureter-Bladder **(KUB)** x-ray, renal Ultrasound **(US),** Intravenous Urography **(IVU)** and/or Non-Contrast Computed Tomography **(NCCT).**

ANTIBIOTIC PROPHYLAXIS

Even if prophylactic antibiotic is used, incidence of Urinary Tract Infection **(UTI)** following ureteroscopy is between 4% and 25%. For this reason, use of prophylactic antibiotic is controversial with the lack of strong evidences [7,31]. According to the American Urology Association **(AUA)** Best Practice Policy, 1st generation cephalosporins or fluoroquinolones are generally used preoperatively, and oral antibiotics are given on postoperative 1st day [31]. Administration of prophylactic antibiotic should be considered for the patients who have a Double-J **(DJ)** stent, ureteral catheter or nephrostomy catheter as well as for the patients with risk of bacterial endocarditis or immunosuppression [30,32].

In our daily practice, we use prophylactic 1st generation cephalosporins preoperatively for the patients with a negative urine culture, where appropriate antibiotic is given according to the antibiogram for the patients with a positive urine culture.

ANESTHESIA

General anesthesia is frequently preferred for RIRS. With the regional anesthesia techniques like spinal anesthesia, the patient may feel pain, unwanted traumas may occur due to less relaxation of the ureter or uninhibition of variable breathing movements [33]. Zeng et al. compared the patients performed Combined Spinal and Epidural Anesthesia **(CSEA)** (31 patients) with General Anesthesia **(GA)** (34 patients). They reported that the results in CSEA group were not worse than GA group and no conversion to GA was required in CSEA group. They concluded that the efficiency and safety were similar between two groups, while the cost was lower significantly in CSEA group [34]. Although general anesthesia is the preferred method during RIRS, regional anesthesia can be used due to cost issues or for the patients in whom general anesthesia can be risky.

SURGICAL TECHNIQUE

The surgical technique in RIRS will probably continue to change in the future with the improvements in instruments. The new instruments have the potential to increase the efficiency and cost-benefit ratio, while decreasing the complication rates.

The list of the equipment and instruments used during RIRS is listed below:

- Flexible ureterorenoscope and semi-rigid ureterorenoscope
- Cystoscope
- C-armed fluoroscope
- Guidewires (diameter: 0.025-0.038 inch; length: 80-260 cm)
- Ureteral catheter or dual lumen catheter
- Ureteral dilatator
- Ureteral Access Sheath **(UAS)**
- Holmium: YAG laser with laser fibers (200, 270, 365 μm)
- Stone basket
- Irrigation pump
- Contrast agent

The procedure is performed under general anesthesia in dorsal lithotomy position. The bladder in entered either with a cystoscope or a semi-rigid ureterorenoscope. Guidewires, ureteral stents or dilatators can be used to enter the ureter. In the traditional technique, guidewire is sent to the ureter – preferably under fluoroscopic guidance – when the ureteral orifice is seen. If desired, a second guidewire (security wire) can be passed by the other guidewire via a cystoscope or a dual lumen catheter. A 10 Fr urethral catheter can be placed to the bladder for the drainage of the bladder during the operation.

For the first generation flexible ureteroscopes, the intramural part of the ureter had to be dilated to get access to the ureter in the vast majority of the patients, as the outer diameter of these ureteroscopes was 10 Fr. However, today, as the outer diameter of the distal part of the flexible ureteroscopes is 8 Fr, dilatation of the ureter is seldom needed. In our routine practice, after the guidewire is sent, we go to the renal pelvis through the ureter under direct vision with a semi-rigid ureteroscope. By this way, the ureter can be evaluated for a possible stricture and a co-incidental ureteral stone can be treated as well as the ureter can be dilated mechanically.

After the renal pelvis is reached, the semi-rigid ureteroscope is removed, and the flexible ureteroscope is advanced either via a UAS or through the guidewire directly under fluoroscopic control. Afterwards, a 10 Fr nelaton catheter can be placed into the bladder to prevent over distention of the bladder. All collecting system is observed under direct vision until the stone is found. Sometimes fluoroscopic vision or addition contrast agent can facilitate reaching the stone. Especially repositioning of lower calyx stones with a basket catheter can both facilitate to reach the stone and prolong the lifetime of the flexible device. After the stone is reached, the laser fiber should be advanced when the ureteroscope is not deflected. The stone is fragmented with the laser until clinically unimportant residual fragments are left. If performing a stone analysis is desired, a little stone fragment can be retrieved with a 1.7 Fr or 2.2 Fr basket catheter. There is no need to place a DJ stent if the procedure is completed without any complication and the fragments are too small.

INSTRUMENTATION

Tendency to use RIRS in the treatment of kidney stones has risen with the technological improvements flexible ureteroscope, laser lithotripters, UAS, guidewires, stone baskets and forceps. For a successful result, the surgeon has to know the advantages and disadvantages of the equipments he/she uses.

Ureteroscope

Flexible ureteroscopes are mainly composed of fiberoptic system (that enables the fiber vision and light source), deflection mechanism and working channels [35]. Newly developed digital flexible ureteroscopes have a much higher image quality and durability as no extra light cable and camera head are needed [36,37].

Almost every flexible ureteroscope has a working channel of 3.6 Fr, which enables the irrigation and advancing of the auxiliary instruments at the same time. Dual-lumen flexible ureteroscope has two working channels with a diameter of 3.3 Fr. The limitations in irrigation and vision could have been to overcome with this dual-lumen; but on the other side, this has led an increase to 9.9 Fr in the outer diameter [38]. Available flexible ureteroscopes and their properties are shown in Table 1.

Table 1: Characteristics of Different Flexible Ureterorenoscopes.

Flexible Ureteroscopes									
Company	Product	Imaging system	Ventral deflexion	Dorsal deflexion	Working channel	Diameter (F)			French scale test
						Tip	Shaft	Proximal	
Lumenis	Polyscope	Optical	180	0	3.6	8	8	8	10
Olympus Gyrus ACMI	DUR-8 Elite	Optical	270	270	3.6	8.7	9.4	10.1	10
	DUR-8 Ultra	Optical	270	270	3.6	8.6	9.36	10.1	10
	DUR-D	Digital	250	250	3.6	8.7	9.3	9.3	11
Olympus	URFP6	Optical	275	275	3.6	4.9	7.95	7.95	10
	URFP5	Optical	275	180	3.6	5.3	8.4	8.4	10
	URFV	Digital	275	180	3.6	8.4	10.9	10.9	12
Storz	FLEX-X2	Optical	270	270	3.6	7.5	8.4	8.4	10
	FLEX-XC	Digital	270	270	3.6	8.5	8.5	8.5	10
Stryker	Flex Vision U-500	Optical	275	275	3.6	6.9	7.1	7.2	10
Wolf	Cobra	Optical	270	270	Dual 3.3	6	9.9	10.3	11
	Viper	Optical	270	270	3.6	6	8.8	9	10

Disposable ureteroscope

PolyScope (Lumenis, Yokneam Israel) is a modular ureteroscope that is composed of an isolated optic core and a disposable 3.6 Fr working channel with a one-sided 265° active deflection and an 8 Fr outer sheath. Although the fiberoptic part does not require sterilization between the procedures, sterilization can be needed against unwanted contaminations due to undetected possible injuries in the shaft. In a recent study, no breakdown in optic part has been reported after 100 sterilization cycles [39]. With this disposable flexible ureteroscope, 89.5% success rate after the first procedure has been reported in a series of 86 patients who had upper urinary tract stone disease [40].

Ureteral Access Sheath (UAS)

UAS has been developed with the same concept of percutaneous Amplatz sheath. It is being used for decreasing the intrarenal pressure during endourological procedures of the upper urinary tract, and facilitating the fURS. It has some major advantages including facilitating multiple or repeating accesses to the kidney, and decreasing the intrarenal pressure by drainage of the irrigation fluid around the scope; thus it also facilitates removal of small stone fragments by this way [41-44]. Various papers have shown that it decreases the operation time, protects the flexible ureteroscope, and increases the SFR [45-50]. Despite these advantages, its benefit, risk and cost should be kept in mind while it is used [51,52]. In the paper published by Clinical Research Office of the Endourological Society **(CROES)** Ureteroscopy Working Group, it has been observed that with the use of UAS, no difference in SFR existed between the groups and risk of ureteral injury or hemorrhage did not increase; while postoperative complications related to infection were reported to be decreased [51].

Placement of a UAS can cause a decrease in ureteral blood flow causing to ureteral ischemia [52] or a direct ureteral injury during [53]. UAS can cause some peri- and post-operative complications such as mucosal laceration, ureteral perforation, urine extravasation, ureteral avulsion and ureteral stricture. Traxer et al. evaluated the incidence and severity of ureteral injury due to use of UAS during RIRS in a series of 359 patients treated in two different centers [53]. They found a rate of 46.5% for ureteral wall injury, while a rate of 13% was identified for severe injuries including the muscular layer of the ureter. Risk factors for severe injuries were identified as age, male sex and absence of preoperative stent.

UAS should be placed cautiously with keeping the risk of false passage and over distention in mind [46]. The placement should always be performed over a guidewire under fluoroscopic control. The use of a guidewire is generally advised as it stabilizes the ureter while advancing the UAS and facilitates placement of a DJ stent after the procedure [7]. An appropriate UAS should be chosen according to the flexible ureteroscope used. It should be paid attention to have no or minimal friction during the procedure. The inner diameters of the available UASs differ between 9.5 Fr to 14 Fr, while the outer diameter can be between 11.5 Fr and 18 Fr. Characteristics of UAS are shown in Table 2 [54].

Table 2: Ureteral Access Sheath Characteristics.

Company	UAS name	Inner diameter (F)	Outer diameter (F)	Length (cm)
Applied	Forte AxP	10	12–16	20 – 28 – 35– 45 – 55
	Forte HD	12	14–18	
		14	16–18	20 – 28– 35
	Forte deflecting	10	14	35 –55
Bard	Aquaguide	12	14	25 – 35 – 45– 55
		13	15	
Boston Scientific	Navigator	11	13	28 – 36– 46
		13	15	
Coloplast	Retrace	12	14	35–45
		10	12	35–45
Cook	Flexor parallel	12	14	13 – 20 – 35 – 45 – 55
	Flexor	9.5	11.5	13 – 20 – 28 –35– 45 – 55
		12	14	
		14	16	13 – 20 – 28 –35– 45 – 55
	Flexor dual lumen	9.5	14	13 – 20 – 28 –35– 45 – 55
		12	17.5	
Olympus–ACMI	Uropass	12	14	24 – 38– 54
Onset Medical	Pathway	11	14	28 – 36– 46
		12	15	
Rocamed	RocaUS	10 (10.9)	12	35 –45
		12	14	

The working guidewire of a new UAS, 12/14 Fr RE-Trace (Coloplast, Humlebaek, Denmark) returns automatically to a safety guidewire. Doizi et al. experienced a successful placement rate of 82.5% in a prospective study including 137 patients; and concluded that this rate was not related with male sex or existence of a preoperative stent [55]. Another version of this UAS with a 10/12 Fr diameter is also available. In a similar way, Flexor Parallel Rapid Release UAS (Cook, Blooming, USA) has a single wire that can be used as either a working or a safety guidewire. In a study by Breda et al., overall successful placement rate was found to be 94%, while the rates were 98.5% and 82% in patients with or without a preoperative stent respectively [56]. Preoperative stenting was found to be the only single independent risk factor.

Guidewire

Guidewires are essential items for RIRS. An ideal guidewire should be flexible, stiff enough to allow the passage of the instrument at the point of obstruction without making a kinging, and stretched enough to avoid unwanted hydrophilic emplacement. The length of the guidewires differs between 80 and 260 cm, while the diameter ranges from 0.025 inch to 0.038 inch. The outer surfaces are generally covered with hydrophilic or Polytetrafluoroethylene **(PTFE).**

The rigidity in the body and tip of the guidewire plays a crucial role during placement; the flexible tip can maneuver around the stone and the stiff body helps to place the UAS or stent [57]. The rigidity of the body is important for the tip to pass straight through kingings [58]. Additionally, rigidity changing throughout the length, lubricity and rounding of the tip are the other important factors. The combination of all these factors makes the guidewires used effectively and easily in special applications.

A benchtop study evaluated the stiffness, lubricity and potential of the tip to make an injury of 5 different guidewires [59]. Two traditional hydrophilic guidewires were evaluated: NiCore (Bard Medical, Covington, GA) and RadiFocus (Boston Scientific, Natick, MA). RadiFocus was found to be safer with its more flexible tip. Although the hybrid wire U-Nite (Bard Medical, Covington, GA) was more slippery, Sensor (Boston Scientific, Natick, MA) had a more flexible tip and needed more effort when taking out. In theory, this makes Sensor the ideal guidewire as it makes less tissue damage during placement and more resistant to unintended pullouts. The Amplatz Super Stiff (Boston Scientific, Natick, MA) was found to be the stiffest one among all 5 guidewires, and to be in normal flexion among the other Boston Scientific guidewires.

Possibility of ureteral injury exists during use of various guidewires. In a recent study, a significant benefit of safety guidewires was observed during ureteroscope placement and retraction force [60].

Ureteral Dilatator

Ureteral dilatation is used for cases in which UAS or ureteroscope cannot reach to the targeted localization because of ureteral stricture, spasm or tight ureteral orifice (approximately in 5% of cases) [61].

Different methods can be used for ureteral dilatation. The oldest one is the passive (mechanical) dilatation. In this method, firstly a ureteral stent is placed that stayed for at least 1-2 weeks, which enables passive dilatation, and then ureteroscopy is performed in the second session after the stent is removed. Active dilatation is performed in the same session with ureteroscopy. Co-axial dilatators made of PTFE, teflon or polyethylene with gradual increasing diameters can be used for dilatation. Recently, balloon dilatators are the most commonly used ones. Each balloon dilatator has a safe inflation pressure ranging from 8 atm to 17 atm.

As the diameter of the developed flexible ureteroscopes decreased, the need for ureteral dilatation has been decreased. Sofer et al. found a need for ureteral dilatation in 31% of their patients (185 of 598 patients) [62]. In a recently retrospective study, of 309 fURS cases, 20 patients needed balloon dilatation of which 17 were completed with the primary procedure. After a follow-up of 10 months, no stricture was observed [63].

Irrigation

Enough irrigation is essential for the vision during RIRS. Flexible ureteroscopes can have either a single channel used for working and irrigation at the same time, or two channels of which one is only for irrigation. Irrigation devices are classified as passive (gravity, pressure bag) or active (pump) according to the output soured of the irrigation fluid. An ideal irrigation should provide a clear vision while not causing movement of stone fragments and pyelovenous reflux. In an in vitro evaluation of two different active systems (foot and hand pumps), hand pump was found to cause less migration of the fragments with lower maximum irrigation pulse; but both systems were found to be similar in regards of functionality [64]. In a comparison of active and passive systems, active system achieved better vision and control while was found to be more risky for the migration of stone fragments [65].

Baskets

Nitinol baskets are less rigid compared to stainless steel ones; thus cause less limitation in the deflection of the flexible ureteroscope. Although the working channels of the flexible ureteroscopes are generally larger than 3 Fr, baskets smaller than 2 Fr are commonly used in order to achieve maximal deflection and enough fluid flow [66].

A study evaluated the effects of 3 smallest baskets – namely OptiFlex 1.3 Fr, N-Circle 1.5 Fr and Halo 1.5 Fr – on deflection of ureteroscope and flow rates in Karl Storz Flex X2, ACMI DUR-8 and ACMI DUR-D flexible ureteroscopes [67]. As expected, OptiFlex with the smallest diameter had the least effect on both parameters. Basal channel flow was 70 mL/min, while it decreased to 37.9-38.2 mL/min with OptiFlex and to 29.1-30.3 mL/min with the others. Loss of deflection was 7.1-8° with OptiFlex, and 10.1-11.4° with the others.

It is easier to grab small stones in renal pelvis or calyx base with the tipless baskets.

Lithotripter

Holmium: YAG laser lithotripsy is efficient for all stones with any composition; and provides much smaller fragments than pneumatic and electro hydraulic lithotripters [68,69]. The energy of holmium laser is absorbed by the fluid, so the epithelial injury is less than the electro hydraulic lithotripter [70].

Holmium: YAG laser is the gold standard lithotripter for RIRS [20]. The laser fiber is consisted of the optical elements and plastic sheath, and generates two effects with photo-thermal reaction, namely dusting and fragmentation [71,72]. The fragments can be retrieved with basket or very small fragments can be left to spontaneous clearance with urine like dusts. Fragmentation is more appropriate for the stones >10 mm, as dusts worsen the vision and it may be difficult to find the fragments. In dusting technique, stones not located in middle or upper calyx would be replaced to these locations with a basket; thus, the lifespan of the flexible ureteroscope would be prolonged while the vision would be kept unaffected from the dusts [27].

The power of holmium laser is generally set to be used as 0.5-1.2 Joule and 5-15 Hertz (10 to 15 Watt). Moreover, the settings can be changed according to the desired lithotripsy method [73], and the surgeon can perform the dusting technique by increasing the frequency while maintaining the same energy. The diameters of the laser fibers used for RIRS range between 200 and 365 μm. As the irrigation and deflection would be less affected with smaller diameter (200-270 μm), it has the same fragmentation effect with the wider fibers [74].

POSTOPERATIVE CARE

If a DJ stent has been placed at the end of the operation, it is generally taken 3-10 days postoperatively. In case of a ureteral injury, the patient should be stented for a period of 3-6 weeks. A KUB x-ray can be taken within first 24 hours to evaluate the early results, however, normal evaluation would be performed after 1 to 2 weeks [75]. Small stone fragments (<4 mm) generally fall out after the stent is taken out with the help of the passive dilatation made by DJ stent [76]. A postoperative examination is advised to evaluate residual stone(s) and silent obstruction [75,77]. Secondary silent obstructions can be observed due to ureteral edema, trauma or stricture, and may cause to renal insufficiency if untreated. Nevertheless, some study groups do not advise routine postoperative evaluation if there is no perforation during surgery or no history of known stricture or impacted stone [78]. Evaluation for the success of the operation is generally performed in the 4th to 6th postoperative weeks or 4-6 weeks after the stent is removed.

PREOPERATIVE DOUBLE-J STENT INSERTION

Preoperative ureteral stents are generally used in cases of UTI, aiming to preserve renal functions, ureteral abnormalities that do not permit passing of the ureteroscope or in emergent cases where it helps the surgeon to perform the operation in an elective session while relieving the pain. Other reasons can be facilitating the insertion of UAS and previous unsuccessful RIRS attempts due to ureteral stricture. Common use of preoperative stenting in pediatric population for passive dilatation prior to ureteroscopy has been published [79]. EAU Guidelines state that preoperative stenting is not necessary prior to ureteroscopy [7]. Nonetheless, the positive effects of preoperative stenting in SFR and complication rates have been mentioned by some authors [79,80]. Various centers have reported the use of preoperative stenting for passive dilatation prior to RIRS to facilitate the passing of UAS or flexible ureteroscope [81,82]. However, this stenting has its own morbidities. Irritative urinary symptoms, bacteriuria, fever as well as sexual dysfunction can be seen [83,84]. In the study where Mahajan et al. searched the results of RIRS performed with (double sessions) or without stenting (single session), it was reported that successful results were achieved with single session, and SFR, morbidity and complication rates were not affected with single session procedure [85].

Some other authors have also published that preoperative stenting increased SFR, and decreased the duration of operation and also the cost for big stones [86-88]. However, the use and effects of preoperative stenting have still controversies as the patient has to undergo a separate procedure and may experience inconveniences due to the DJ stent [89]. In the CROES-URS study, it was stated that the duration of the operation was longer, the SFR was higher, and the rate of intraoperative complication was lower in the group with preoperative stenting [90]. For the patients with preoperative stenting, RIRS is performed at least a few weeks after the procedure.

POSTPERATIVE DOUBLE-J STENT INSERTION

The purpose of postoperative stenting is to prevent hydronephrosis, pain and ureteral stricture, and to facilitate the healing process and the passage of the stone fragments. Postoperative stenting is necessary in cases of mucosal edema and hemorrhage, epithelium injury, ureter perforation and solitary kidney [91,92]

Besides its disadvantages such as elongation in the operation duration, need of an extra procedure to take out, increased symptoms (dysuria, pollacuria, frequency, urgency, suprapubic or flank pain, fever) and decreased quality of life, minimal benefit was reported in regards of SFR and prevention of stricture formation [93].

In a study where the complications were assessed in patients undergoing RIRS with UAS insertion, no difference was found between postoperatively stented group and non-stented group, while postoperative pain was found to be lower in the stented group [94]. In a series of 319 uncomplicated patients undergoing RIRS without previous stenting, 11.9% of the patients needed urgent stenting; and male sex and stone located in proximal ureter were found to be risk factors [95]. Ozyuvali et al. reported that no stenting was needed after RIRS as it increased the cost, morbidity and operation time in their study including 162 renal units [96]. On the other hand, they found higher postoperative pain scores in patients with stones larger than 15 mm or located in renal pelvis. There is no consensus for optimal duration of stenting. In one study, an increased risk for fever and flank pain has been identified for stenting more than 15 days [97].

IS A SAFETY GUIDEWIRE NECESSARY?

A safety guidewire is kept in the ureter and collecting system during ureteroscopy so that it prevents loss of access during stone manipulation, and enables to place a DJ stent in case of a perforation or after the procedure completed. Some question marks have been appeared whether a safety guidewire should be used or not as the experience in fURS has increased. Although some centers report routine use of a safety guidewire, nowadays it is not generally routinely used except in some specific cases.

Dickstein et al. have performed 305 RIRS in 246 patients (59 bilateral procedures), and divided cases according to their characteristics into two as complicated and non-complicated [98]. A safety guidewire was used in 35 complicated cases, where these cases were defined as those having concomitant obstructing ureteral stones requiring treatment, an associated encrusted ureteral stent, or difficult access secondary to a large stone burden (steinstrasse or staghorn) or aberrant anatomy (pelvic kidney, urethral/ureteral stricture, ileal loop, suprapubic tube, limb contractures). No intraoperative complications, including lost of access, ureteral perforation/ avulsion and need for percutaneous nephrostomy tube were observed due to lack of a safety guidewire. As a result, in this relatively big cohort, the authors concluded that there was no need to use a safety guidewire in routine cases.

CONTRAINDICATIONS AND COMPLICATIONS

Except an untreated UTI and other anesthesia contraindications, no specific contraindication exists for fURS [7]. RIRS can be performed to all patients including especially the ones in whom SWL or PCNL is contraindicated or not suitable. With the improving technology and increasing use and experience, more procedures are being performed with less morbidity. Its complications can be listed as hemorrhage, intrapelvic hematoma, mucosal injury, ureteral perforation and avulsion, UTI and sepsis. Overall complication rates remain low with most complications being minor and easily managed.

In the prospective URS study of CROES, of 11.885 total patients, 1.781 (15%) underwent only fURS where 10.7% had a combined treatment of flexible and semi-rigid URS [99]. Rate of general postoperative complication was found to be 3.5%, which were mostly (2.8%) grade 1 and 2 according to Clavien-Dindo classification. Only 0.2% of the patients needed blood transfusion, and 5 mortalities were reported in postoperative first 30 days due to sepsis, pulmonary embolism, multiorgan dysfunction and cardiac reasons. 8.4% of the patients re-admitted to hospital in postoperative first 3 months with flank pain and discomfort due to ureteral stent being the main reasons. No difference was found in regards of postoperative complications and readmission rates between semi-rigid and flexible URS groups [100].

Oguz et al. reported rate of intraoperative complications as 30.4% according to modified Satava classification system [101]. Grade 1, 2a and 2b complications were documented in 15.9%, 5.6% and 8.9% of the patients respectively, where no grade 3 complication was observed.

EFFECT OF STONE COMPOSITION ON RIRS

Only laser lithotripters are used for stone fragmentation during RIRS. Although holmium laser can be used for every type of stone, the fragmentation time is variable [102]. Xue et al. evaluated retrospectively the results of RIRS performed in 74 patients with stones ranging from 1 cm to 3 cm [103]. Calcium oxalate monohydrate and calcium phosphate stones were found to be fragmented slower than calcium oxalate dehydrate, magnesium ammonium phosphate and uric acid stones, where this finding was especially significant in stones larger than 2 cm.

PREOPERATIVE ASSESSMENT OF THE SFR FOR RIRS

Three important studies have been published for predicting the surgical success after RIRS. Resorlu et al. searched for the prognostic factors related to success of RIRS, and then developed a scoring system – named Resorlu-Unsal stone scoring – to predict SFR after RIRS [104]. With the assessment of 207 patients, stone dimension, localization and number, renal malformations and lower pole IPA were found to be the affecting factors for RIRS result. Stone composition was not added into the scoring, as it cannot be identified prior to surgery. In this scoring system, total score is between 0 and 4, and SFRs are 97.1%, 85.4%, 70% and 27.2% for the scores 0, 1, 2 and ≥3, respectively (Table 3).

Table 3: Resorlu-Unsal Sone Score.

Weight	Clinical Condition
1	Stone size >20 (one wt per 10mm)
1	Lower pole stone location and IPA<45^0
1	Stone number in different calyces >1
1	Abnormal renal anatomy (horseshoe kidney or pelvic kidney)

Similarly, Jung et al. developed another scoring system for RIRS called the Modified Seul National University Renal Stone Complexity (S-ReSC) scoring system [105]. This scoring system is based on the number of sites of renal stones involved. The anatomical sites were classified into 9 subgroups, such as the renal pelvis (#1), superior and inferior major calyceal groups (#2-3), and anterior and posterior minor calyceal groups of the superior (#4-5), middle (#6-7), and inferior calyx (#8-9). If the stone is located in the inferior calyceal area (#3, #8-9), one additional point per site is added to the original score. The modified S-ReSC score, which differs between 1-12, is classified into either a low (1-2 points), intermediate (3-4) or high (>4) group, where SFRs are 94.2%, 84% and 45.5% for these groups respectively. The advantage of this scoring system is that it was externally validated for the first time and its predictive accuracy was shown to be better than that of the Resorlu-Unsal Stone Score [106]. Park et al. performed its external validation, and found SFRs 86.7%, 70.2% and 48.6% for low (1-2), intermediate (3-4) and high (5-12) score groups respectively [106]. Both scoring systems have been helpful for separating patients into outcome groups and for determining plans of treatment.

Ito et al. have developed a new nomogram by using 5 preoperative parameters, namely stone volume and number, presence of stone in lower calyx and hydronephrosis, and experience of the surgeon (>50 fURS) [107]. The maximum score can be 25, and the authors have stated that the success of the fURS would be higher as the patient's score gets toward the maximum.

COST OF RIRS

Although RIRS is an effective treatment modality with lower complication rates, it can be an expensive procedure. Flexible ureteroscope, laser lithotripter, guidewire, and UAS and stone basket (on the discretion of the surgeon) are be used. Gurbuz et al. evaluated the cost analysis of RIRS in 302 patients [108]. In this analysis, the cost of flexible ureteroscope was found $118, laser lithotripter $156, guidewire $38 and UAS $231, where the overall cost was calculated $543 per a case. They reported the cost of a stone basket as $611, which increased the overall cost significantly when used. It should be kept in mind that this analysis was performed in a high volume center, which probably had an effect to be calculated lower. It should also be remembered that flexible ureteroscopes are very delicate devices and can be broken even after 1 or 2 cases if not used properly, where the cost reaches to very high values at that time.

RIRS AND EDUCATION – HOW TO IMPROVE SURGICAL TECHNIQUES

There is only one study that shows the learning curve for RIRS. Choe et al. evaluated retrospectively 100 patients with middle sized stone and undergone RIRS for single session [109]. They identified the learning curve by using cumulative sum analysis for monitoring change in fragmentation efficacy. The study revealed that 56 cases were required for reaching a plateau in the learning curve, and the acceptable level of fragmentation was 25 mL/min. Stone multiplicity and localization were found to be significant predictors for SFR in RIRS.

RIRS AND FLUOROSCOPY

Fluoroscopic imaging plays an important role in endourology. Fluoroscopy is generally used for insertion of guidewire, UAS and DJ stent, determination of stone localization, identification of renal anatomy, and ureteral balloon dilatation during ureteroscopy (either semi-rigid or flexible). With the increase in the endourological interventions, radiation exposure of surgeons, patients and operating room staff has also increased. Although the exposed dosage is low during ureteroscopy, the cumulative radiation dosage has theoretically a potential to increase the risk of cancers. For this reason, in order to decrease the exposed dosage, decreased use of fluoroscopy or fluoroscopy-free techniques has been reported.

Peng et al. evaluated the fluoroscopy-free RIRS in 144 patients with a mean stone dimension of 1.4±0.4 cm [110]. They experienced a requirement of fluoroscopy use in only 1 patient who had a duplicated collecting system. Stone-free status was achieved in 134 patients (95.7%), where no major complication was observed besides a minor complication rate of 3.6%.

Kırac et al. performed RIRS with a reduced fluoroscopy dosage in 76 patients with a stone dimension of 14.1±4.1 mm, in which single-shoot fluoroscopy was used for only insertion of guidewire [111]. Additional fluoroscopy use was required in only 4 patients (5.2%) for localization of stone in 2 patients and identification of collecting system anatomy in 2 patients with a history of prior operation. They reported a SFR of 82.9% and a complication rate of 6.6% without any major complications.

As a result, for protection against the harmful effects of radiation, RIRS with reduced fluoroscopy or without any fluoroscopy can be performed easily and efficiently by experienced surgeons.

THE CURRENT ROLE OF RIRS IN THE TREATMENT OF UROLITHIASIS

In various studies, it has been emphasized that RIRS is an effective and reliable method in the treatment of kidney stones. The success rates of RIRS range between 65% and 92% in the literature [112].

Treatment of Intrarenal Stones Less Than 2 cm

With the technological improvements, RIRS has become a routine option in the treatment of stones <2 cm. In the past, flexible ureteroscopy was classified as a secondary treatment after SWL for the stones <2 cm; however, in the new revised version of EAU Guidelines, with the increased success of RIRS, fURS and SWL are regarded as first line treatment options, especially for the stones with a diameter of 11-20 mm [7].

In 1990s, successful results have been published for fURS in the treatment of urolithiasis from centers with high caseloads. Grasso and Ficazzola reported a SFR of 94% and 95% for stones ≤10 mm and 11-20 mm, respectively [113]. In their large series between 1993-1999, Sofer et al. also reported a SFR of 84% and a low complication rate as 4% in their patients with a mean stone dimension of 11.3 mm [114].

In the studies comparing fURS with SWL and/or PCNL, it has been reported that fURS had a higher success rate than SWL, and a comparable success rate with lower morbidity when compared to PCNL (or MicroPerc) [115-118]. As the time passes, fURS will probably take the place of SWL in symptomatic stones <2 cm.

Treatment of Intrarenal Stones Larger Than 2 cm

Recent guidelines recommend PCNL as the first-line treatment for stones >2 cm. Although the success rates in PCNL can be as high as 95%, it has some main complications and disadvantages such as urinary extravasation (7.2%), hemorrhage requiring blood transfusion (11.2%-17.5%), postoperative fever (21%-32.1%), septicemia (0.3%-4.7%), colon injury (0.2%-0.8%), pleural injury (0%-3.1%), and prolonged hospitalization and convalescence [119,120]. For this reason, alternative options with less morbidity are more advantageous especially for patients with high risk.

First published reports regarding the use of fURS go back to 1990s. Aso et al. reported their first experience in 34 patients with staghorn calculi [121]. As electrohydraulic lithotripter was the only one available at that time, fURS were not an acceptable treatment option for large stones because of its high complication rates. Mugia et al. reported a success in 21 of 27 patients [122]. However, 26 SWL sessions (mean 8.4 session for a patient) were required, which caused major concerns about the overall cost and renal parenchymal injury doe to shock waves. Grasso et al. published the results of fURS with holmium: YAG laser in 45 patients in whom PCNL was contraindicated due to their comorbidities [123]. They reported SFR after first session as 76%, while it rose up to 91% after re-treatment with fURS with an overall postoperative complication rate of 2%, where they defined success as residual stone fragments smaller than 2 mm. These results have been encouraging for the use of fURS in the end of 1990s.

Aboumarzouk et al. published a meta-analysis of 9 studies performed between 1990-2011, which included 445 patients (460 renal units) with big kidney stones; and they found mean stone diameter as 2.5 cm, mean SFR as 93.7% after a mean of 1.6 procedures, and general complication rate as 10.1% (major 5.3%, minor 4.8%) [124]. Major complications were defined as steinstrasse, subcapsular hematoma, obstructive pyelonephritis, cerebrovascular accident, acute prostatitis and hematuria causing cloth retention; where minor complications were hematuria recovering spontaneously and postoperative fever. In subgroup analysis, SFR was 95.7% and minor complication rate was 14.3% without any major complication for stones with a dimension of 2-3 cm; where SFR was found 84.6%, and minor and major complication rates were 15.4% and 11.5% respectively for stones larger than 3 cm. The authors concluded that fURS for stones larger than 2 cm could be performed with lower complication rate and high SFR in experienced hands. Later on, other studies also reported similar high SFR with multiple procedures [125,126]. UAS has enabled multiple accesses and increased the image quality; which have contributed to achieve successful results.

In a matched-pair analysis, Akman et al. evaluated fURS and PCNL groups, each including 34 patients [127]. After first procedure, SFR was found 91.2% for PCNL and 73.5% for fURS with a significant difference in PCNL. However, this significant difference disappeared after the second fURS where SFR rose to 88.2% in fURS group. While PCNL was superior for operation time, fURS were superior in regards of hospitalization time. Two patients in PCNL group needed blood transfusion, but no significant difference was found for complication rates. In another matched-pair analysis by Zeng et al. for stones larger than 2 cm, fURS was found to have a lower SFR compared to mini-PCNL (43.4% *vs*. 71.7%) [128].

In most series, requirement of more than one session to achieve successful results for big kidney stones with fURS is the main concern; but this issue can be tolerated with lower complication rates and by this way, fURS can be a good and valuable alternative to PCNL especially for patients with high risk [129].

RIRS for Lower Pole Stones

The limited spontaneous drainage of stone fragments after SWL due to the position of lower pole causes a dilemma in the treatment of lower pole stones [130]. Additionally, due to the anatomy, lower pole stones can be reached more difficultly with fURS compared to middle and upper pole stones. In 1999, Grasso and Ficazzola reported a failure rate of 7% to access lower pole with the first generation devices that had limited deflection [113]. They reported a success rate of 95%, 94% and 45% for stones <1 cm, >1 cm and ≥2 cm, respectively. After a second session, the overall success was 91% and 82% for stones ≥2 cm.

Anatomical factors that affect the failure to access lower pole in fURS were evaluated [131]. Although acute IPA <30° and length of infundibulum >3 cm were found to be lower SFR, while width of infundibulum had no effect. Increase in deflection with technological developments and improvements in surgical technique have led flexible ureteroscopes to reach lower pole more easily [134]. Repositioning of lower pole stones with tipless nitinol baskets to other calyxes that are accessed easily has increased the treatment success of fURS in the management of lower pole stones [135]. Schuster et al. published that SFR has increased for lower pole stones after repositioning when compared to in situ lithotripsy, in which the difference was more pronounced for stones >1 cm (100% for repositioning *vs*. 29% for in situ) [136]. With improvements in surgical technique, some authors published similar SFR both for repositioned and non-repositioned stones [137,138].

In their randomized study, Lower Pole Study Group published that fURS was not superior to SWL for stones <1 cm; however, more recent studies reported the superiority of fURS [139]. In a matched-pair analysis for lower pole stones ranged between 11-20 mm by Nahis et al., fURS was found to have significantly a higher SFR (86.5% *vs*. 67.7%) and a lower re-treatment rate (8% *vs*. 60%) than SWL [140]. In another prospective randomized study which evaluated fURS and SWL in 195 patients, mean stone dimension and SFR were found to be similar, while re-treatment rate was higher in SWL group (61.1% *vs*. 11.1%) [141]. Success and complication rates of fURS were found to be similar to that of PCNL or mini-PCNL for lower pole stones ≤20 mm in retrospective studies [142,143]. Operation time was shorter in PCNL and mini-PCNL groups, while fluoroscopy and hospitalization times were longer than fURS. These results show us that fURS have a potential to be important in the treatment of stones smaller than 2 cm.

RIRS FOR KIDNEY STONES IN SPECIAL CONDITIONS

RIRS in Anticoagulated Patients

Bleeding diathesis and use of anticoagulant therapy are contraindications for PCNL and SWL due to risk of severe hemorrhage. In various studies, the efficiency and reliability of fURS with holmium: YAG laser have been showed in these patients [144-147]. In a matched-cohort study that compared 37 patients using anticoagulant treatment with normal patients, no difference was found for SFR, and intraoperative and postoperative complication rates [146].

RIRS in Obese Patients

Obesity has negative effects on stone formation and treatment in upper urinary tract stone disease. Risk of uric acid and calcium oxalate stone formation has been raised in obese patients [148,149]. Success of SWL is lower in obese patients and longer tract (stone-to-skin distance) and prone position in PCNL creates higher anesthesia risk in obese patients. The efficiency of fURS for obese and morbid obese patients has been evaluated in various studies, and SFR and complication rates were found to be not affected by body-mass index [150-156].

RIRS in Pediatric Patients

Urinary stone disease is seen in a rate of 1%-2% in pediatric population (<18 years) [157]. The treatment of stone disease in pediatric age group has a significant importance, as recurrence rate is higher in this group.

After the first description of pediatric ureteroscopy by Richard et al. in 1998, use of RIRS in pediatric age group has been postponed because of large size of instruments and complications such as ischemia, injury, perforation, stricture and vesicoureteral reflux [158]. However, it has been used commonly after technological developments.

The first high-volumed series was published by Cannon et al. in 2007 [159]. The SFR was reported as 76% in 21 children (with an upper age limit of 20), where no intra- and postoperative complications were seen. Passive dilatation with preoperative stenting was performed for 38% of patients, while UAS was used in 43%. Smaldone et al. reported that they performed passive and active dilatation in 54% and 70% of patients respectively, and used UAS in 24% of patients. In this series of 100 patients, SFR was noted as 91%, and 5 perforations were encountered, in which 1 of them needed a reimplantation [160].

In their series of 50 kidney stones in children with an age range of 1.2-13.6 years, Tanaka et al. achieved SFR with single session in 58% and needed an additional procedure in 36% of patients [161]. They found that success was correlated with stone dimension, where need for additional procedure was correlated with both stone dimension and patient age. In a series of 167 patients with a mean age of 62.4 months, Kim et al. reported a SFR of 100% and 97% in stones smaller and bigger than 10 mm, respectively, without any intraoperative and postoperative complications [162]. Insertion of a stent was required in 57% of patients in whom an access was not achieved.

Unsal et al. used passive dilatation in 37.5%, active dilatation in 29.4% and UAS in 17.6% of 16 preschool children who had a mean stone dimension of 11.5 mm [163]. They reported a SFR of 100% and 81% for stones smaller and larger than 10 mm respectively, and concluded that RIRS could be performed efficiently in infants. The largest series in preschool children was published by Erkurt et al. including 72 renal units in 65 children [164]. For the stones ranging between 7-30 mm, they reported a SFR of 83% after first session, and 92.3% after the second session. Complications, including hematuria, UTI with fever and ureteral wall injury, were seen in 18 patients (27.7%), and they concluded that RIRS was an efficient and reliable treatment modality in the treatment of kidney stones in preschool children.

In a multi-centered comparative study by Resorlu et al., patients who had a kidney stone ranging between 10-30 mm underwent either RIRS (95 patients) or mini-PCNL (106 patients), and SFR after single session was found as 84.2% and 85.8%, respectively [165]. With the additional treatments, these ratios rose to 92.6% and 94.3%. While no major complications were observed, minor complications were noted in 8.4% and 17% of patients in RIRS and mini-PCNL groups, respectively. Hospitalization, fluoroscopy and operation times were found to be higher in mini-PCNL group. When the stones were classified according to their sizes, the success rates were calculated as 87% and 100% in 1-2 cm group, and 50% and 84% in 2-3 cm group for RIRS and mini-PCNL, respectively. The authors concluded that RIRS was more advantageous for stones <2 cm; but it could also be an alternative for stones >2 cm.

As a conclusion, it should be kept in mind that access to collecting system in the first session can be difficult in pediatric age group due to relatively narrower ureteral calibration, but this problem can be overcome by stenting preoperatively. RIRS is a successful treatment option in pediatric age group, but stone dimension should be taken into consideration for indication.

RIRS in Solitary Kidney

After a good preoperative planning, complete stone removal with a minimal morbidity is crucial in patients with solitary kidney. PCNL and SWL were first-line treatment options for stones larger and smaller than 2 cm, respectively. Although PCNL has a high rate of stone clearance and treatment efficiency, it has a high morbidity rate, especially hemorrhage [166]. SWL has a lower SFR compared to PCNL and RIRS, thus re-treatment is required more often [167]. Indications of RIRS in solitary kidneys include previous unsuccessful SWL, patients for whom PCNL is contraindicated, and patience preference. Contraindications are severe hydronephrosis and big staghorn stones [168].

Gao et al. performed 68 procedures in 45 patients with a mean stone dimension of 18.4±1.9 mm, and noted a SFR of 64.44% and 93.33% after the first and last procedure respectively [168]. No difference was found between stones larger and smaller than 2 cm in regards of procedure count per patient. Complications were seen in 26.6% of patients, of which 20% was grade 1, 4.4% was grade 2, and 2.2% was grade 3 (urgent intervention for anuria due to steinstrasse) according to Clavien-Dindo classification.

Giusti et al. reported their series of 29 patients with a stone dimension up to 2 cm [169]. Primary SFR was 72.4%, while secondary SFR was 93.1% with 1.24 procedures per patient. No difference was observed in serum creatinine levels between preoperative and postoperative 1st day evaluation as well as in long-term follow-up that was available in 18 patients with an average follow-up of 35.7±19.3 months. They concluded that RIRS is an efficient and reliable method without any impairment in kidney functions for the treatment of kidney stones in patients with solitary kidney.

Atis et al. published a SFR of 83.3% and 95.8% after first and second procedures in their series of 24 patients with an average stone dimension of 19.83±5.9 mm [170]. They did not find any difference in creatinine levels measured preoperatively and 2 weeks after the stent was removed. Minor complications were observed in 16.6% of the patients, while no major complication was noted.

RIRS in Patients with Spinal Deformities

In the series of 8 patients with stones ranging between 9-20 mm, Resorlu et al. reported a SFR of 75% [171]. No severe complications regarding anesthesia or surgery were observed, and the authors concluded that RIRS was a reliable and efficient procedure in patients with spinal deformities.

RIRS in Patients with Isolated Renal Rotation Anomalies

Rotation anomalies occur during the branching of the budding ureteral tree. Increase in fibrotic tissue in upper ureter and ureteropelvic junction causes urinary obstruction and stasis [172]. Clearance of fragments after SWL can be unsuccessful in kidneys with isolated renal rotation anomaly because of the obstruction. Tunc et al. evaluated SWL in 150 kidneys with anomalies, where SFR was found to be 56.7% that was lower than in normal kidneys [173]. When PCNL results are evaluated in this kind of kidneys, SFR ranging from 77.3% to 81% was published [174,175].

Ural et al. published a SFR of 75% after first session and a final SFR of 83.3% after additional procedures without any major complications in 24 patients with malrotated kidneys [176]. No difference was found in patients' characteristics when the patients with and without a successful result were compared. As a result, RIRS is an efficient treatment method without any major complications in patients with isolated renal rotation anomalies.

RIRS in Pelvic Kidneys

SWL has a lower success rates in pelvic kidneys due to both difficult clearance of fragments and inhibition of shock waves to reach the stone. PCNL also has a difficulty in gaining access because of pelvic bones and neighboring organs. For this reason, US- or laparoscopy-assisted access can be used. A retrograde pyelography prior to fURS would help to evaluate the anatomy, and a safety guidewire can be used. Due to ureter's abnormal route, and tortuous and short ureter, it is much safer not to use a UAS. High ureteral insertion and lower pole localization complicates the operation [177]. Weizer et al. succeeded in 3 of 4 pelvic kidneys, while Binbay et al. had a SFR of 70.8% after first procedure without any major complications [178,179]. Bozkurt et al. reported a success rate of 84.7% after single session with a minor complication rate of 19.2% [177]. As a result, it can be concluded that fURS is an efficient and reliable treatment option for small and medium sized stones in pelvic ectopic kidneys.

RIRS in Horseshoe Kidneys

Kidney stones are seen in 20% of horseshoe kidneys, and impaired urinary drainage, recurrent UTIs and metabolic abnormalities are the major risk factors for stone formation [180,181]. Weizer et al. had a SFR of 75% in patients with horseshoe kidney with a kidney stone smaller than 2 cm, while Molimard et al. reported that SFR was 53% after first session and added that this ratio rose to 88% after an average of 1.5 procedures in 17 patients [182,183]. Atis et al. found a SFR of 70% at postoperative 1st month in 20 horseshoe kidneys, while 2 of the 6 patients with residual stone became stone-free after SWL [184]. As a result, it can be concluded that RIRS is a treatment option with minimal morbidities and high success rates for patients with horseshoe kidney.

RIRS in Infundinular Stenosis and Stones in Calyx Diverticulum

The incidence of calyx diverticulum is 0.6% in the population, while the incidence of stone formation in a calyx diverticulum is 10%-50% [185,186]. It is important to check the collecting system with contrast agent after the kidney is reached. Koopman et al. dilated the calyx neck with either balloon dilatator or laser incision, and succeeded to reach the stone in calyx diverticulum in 94% of 108 patients [187]. General SFR was 90%, while they reported a SFR of 75% for 2-3 cm stones with addition of SWL. Chen et al. opened the calyx neck with only laser incision in 43 patients, and had success in 35 patients (81.4%) after the first session [188]. Five of the remaining 8 patients were stone-free after the second session, and they reported an overall SFR of 93% without any major complication. The success rate after first session in lower pole calyx group was found to be significantly lower compared to other localizations. With these results, RIRS seems to be a highly efficient treatment modality with low morbidity for stones in calyx diverticulum.

RIRS in Patients with a History of Open Renal Stone Surgery

Endoscopic stone treatment is more difficult in patients with a history of open surgery due to anatomic distortion. Osman et al. reported SFRs of 79.2% and 92.4% after first and second procedures in 53 patients with an average stone dimension of 14.3 mm [189]. They noted 2 (3.7%) intraoperative complications, including a ureteral perforation and extravasation, and a hemorrhage not requiring blood transfusion; while 9 postoperative complications (18%) were noted.

Alkan et al. compared 32 and 38 patients with and without a history of open renal stone surgery, respectively [190]. SFRs were 100% and 95% after second procedure, and clinically insignificant residual fragment (≤4 mm) rates were 29% and 20% for patients with and without history of surgery, respectively. Seven minor complications were observed in each group, while no major complication was reported. These results show us that RIRS is a reliable option with high success rate in patients with a history of open renal stone surgery.

RIRS in Multiple Unilateral Stones

Multiple unilateral stones are seen 20%-25% of the urolithiasis patients [191-193]. Alkan et al. published their results for 173 stones in 48 patients with multiple unilateral stones [194]. RIRS was performed as a primary procedure in 81.2%, after SWL in 14.6% and after PCNL in 4.2% of the patients. SFRs in patients with a stone ≤2 cm (23 patients) and >2 cm (25 patients) were 100% and 84%, respectively. Residual stones ≥4 mm were seen in 4 patients of whom all had a stone >2 cm.

Similar results were reported by other researchers ranging between 92%-100% for stones <2 cm, and 85%-100% for stones ≥2 cm (195,196). RIRS can be concluded as an efficient treatment for multiple unilateral stones, especially for that ≤2 cm.

RIRS as Second-line Therapy

Stav et al. reported a SFR of 67% in 81 patients with a history of unsuccessful SWL [197]. Holland et al. compared 93 patients, whom were divided into two groups of 42 patients with primary treatment and 51 patients with secondary treatment (92% after SWL, 8% after PCNL) [198]. Success rates were 80% and 67% for primary and second-line treatment groups, respectively. As a result, RIRS had a lower SFR when performed after an unsuccessful SWL, as the negative factors affecting the success of SWL also affect the SFR after RIRS.

Yuruk et al. found no difference in SFR for patients with primary RIRS and after SWL treatment (82.5% *vs*. 86.9%) [199]. In a similar way, Pillippou et al. found no difference for SFR, complication rate, and operation and hospitalization times for the patients with or without a prior SWL [200]. It seems that prior SWL does not affect the success and complication rates of RIRS.

RIRS for Simultaneous Bilateral Stones

Bilateral kidney stones are detected in 20%-25% of urolithiasis patients [192,193]. Alkan et al. treated simultaneously 201 bilateral stones in 44 patients, and found an overall SFR of 88.6% [201]. When the patients grouped according to stone burden, SFR was 100% and 80% for stones smaller and larger than 25 mm, respectively. They concluded that a simultaneous bilateral approach had advantages of decrease in total procedure time, anesthesia count and recovery time, while risk of bilateral ureteral injury was the disadvantage. Similar results were published by Atis et al. in 42 patients, with SFR rates of 92.8% and 97.6% after the first and second session, respectively.

In a matched-pair analysis of 59 patients with simultaneous bilateral RIRS and 59 patients with unilateral RIRS, no significant difference was observed in SFRs (84.7% *vs*. 91.5%, respectively) and overall complication rates [203]. The authors concluded that bilateral RIRS was as efficient and reliable as unilateral RIRS.

Simultaneous bilateral RIRS is an efficient and reliable treatment option in selected patients.

Stone burden should be taken into consideration when estimating the SFR, and at least one side should be stented after the operation.

COMBINED TREATMENT METHODS

Use of RIRS with PCNL or SWL at the same session has been a new treatment modality recently. This combination has been developed to reduce access tract numbers and complications in the management of complex renal stones.

Harnomoto et al. compared the results of combined RIRS and mini-PCNL with those of only mini-PCNL and standard PCNL in the treatment of patients with high stone burden [204]. All procedures were performed in prone position; and decreased operation time, increased SFR, and lower hemoglobin decrease were observed in the combined therapy group.

In another study comparing standard PCNL in supine position with combination of supine PCNL and RIRS, no difference was observed for complication rate and hospitalization duration, while success rate was higher in combination group [205].

Traxer et al. reported their first experience of RIRS combined with SWL as a very new treatment modality [206]. Stone fragmentation was achieved in 100% of 6 patients, while SFR was 50%. Remaining 50% required a second intervention. They did not observe any injury in digital ureteroscope as well as in laser probe. Although this new modality can be a promising option for the patients who have the risk of failure after RIRS alone, the complexity and cost of the procedure should be kept in mind.

CONCLUSION

RIRS has gained an increasing popularity recently, and in parallel to this, our knowledge and experience have increased. This treatment modality is an efficient and reliable method with lower complication rates and higher success rates. Accessing to the kidney via a natural route without penetrating to the parenchyma is its major feature. The length of this route as well as the delicacy and cost of the equipment are the major issues that should be overcome.

In the light of recent data, RIRS seems to be an ideal treatment modality in the management of patients with stone smaller than 2 cm, serious comorbidities, renal anomalies and bleeding disorders. High success rates can be achieved by only repeating sessions or combined treatments in patients with high stone volume.

If the problematic issues can be overcome with the ongoing technological developments, RIRS has a potential to be the first-line treatment option in the management of kidney stones.

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