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REVIEW

Flexible ureteroscopy: Technological advancements, current indications and outcomes in the treatment of urolithiasis



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Abstract The last 3 decades have witnessed great improvements in the technology and clinical applications of many minimally invasive procedures in the urological field. Flexible ureteroscopy (fURS) has advanced considerably to become a widely utilized diagnostic and therapeutic tool for multiple upper urinary tract pathologies. The most common indication for fURS is the treatment of upper urinary tract stones with the aid of Holmium:Yttrium Aluminium Garnet (YAG) laser lithotripsy. Advancements in endoscope technologies and operative techniques have lead to a broader application of fURS in the management of urolithiasis to include larger and more complex stones. fURS has proved to be an effective and safe procedure with few contraindications. Continued progression in fURS may increase its clinical applicability and supplant other procedures as the first line treatment option for urolithiasis. © 2015 Editorial Office of Asian Journal of Urology. Production and hosting by Elsevier (Singapore) Pte Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Flexible ureteroscopy (fURS) has been through significant technological and technical advancements in the previous 3 decades, resulting in the widespread utilization of fURS in

the treatment of a variety of upper urinary tract pathologies, mainly urolithiasis.

Herein, we discuss the major technologic advances in fURS, its current role and outcomes in the treatment of urolithiasis.

2. History and technological advancements of fURS

Since the first report of fURS by Marshall in 1964 [1], major developmental milestones in the technology of flexible

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ureteroscopes have led to the current relative ease of clinical application together with a high success rate and low associated morbidity. In 1980's, fURS was significantly improved after the development of fiberoptic light-bundles together with endoscope tip-deflection mechanisms (passive or active) and the incorporation of an irrigation working-channel that allowed its use as a therapeutic tool [2]. The next substantial technological advancement was in 1994, after the successful therapeutic utilization of a miniaturized flexible ureteroscope, with a tip diameter of 7.5 Fr and an adequate working-channel of 3.6 Fr [3]. The miniaturized flexible ureteroscope enabled active 2-way deflection with secondary passive deflection at the shaft, thus increasing endoscope maneuverability and clinical applicability.

Concurrently, the successful introduction of the Holmium:Yttrium Aluminium Garnet (YAG) laser as a flexible intracorporeal lithotripter with a high safety margin led to an increased interest in the treatment of urolithiasis in a retrograde fashion [4]. In 2001, a flexible ureteroscope with active 2-way exaggerated deflection (up to 270°) was introduced to the market and improved the ability to navigate the entire pelvicaliceal system [5]. The durability of flexible endoscopes subsequently improved and it became possible to perform up to 50 therapeutic procedures before any maintenance was necessary [6]. The revolution of endoscope technology continued with the introduction of digital flexible ureteroscopes in 2006, which improved the image quality and resulted in lighter-weight equipment due to the integration of the light-cable and camera within the endoscope. Unfortunately, digital flexible ureteroscopes had a larger diameter than the conventional fiberoptic flexible counterparts and their use was associated with increased need for placement of a ureteral access sheath (UAS) [7], which is associated with higher risk of ureteral injuries [8]. However, further development led to the introduction of smaller caliber digital flexible ureteroscopes comparable to the previous conventional endoscopes [9].

Advancements and innovations in technology have continued to progress with the goal of designing optimal small diameter endoscopes, improved image quality and maneuvering abilities combined with lasting durability. In 2010, Sun et al. [10] reported the first combined rigid and flexible ureteroscope "the Sun's ureteroscope". The authors treated 175 patients with intrarenal stones using this novel ureteroscope, which has a retractable rigid shaft and flexible tip that enables the operator to treat ureteral and intrarenal stones efficiently without the need to exchange from one endoscope to another. The Sun's ureteroscope resulted in short operative time with an overall stone-free rate (SFR) of 83%. In 2008, Desai et al. [11] reported their feasibility study using a new innovative robotic flexible ureteroscope in an animal model, that was followed by a report on their encouraging clinical experience in treating urolithiasis using the same robotic flexible device [12]. In 2014 the initial experience with a new robotic platform for fURS was reported [13]. Seven experienced surgeons examined the new robotic platform in treating 81 patients with urolithiasis. The initial experience was successful and was associated with improved ergonomics in comparison to conventional counterparts.

3. The current role of fURS in the treatment of urolithiasis

3.1. Treatment of intrarenal stones less than 2 cm

With the continued advancements of technology and increasing experience gained by urologists in ureteroscopic skills, fURS has become an integral aspect of the armamentarium in treating intrarenal stones less than 2 cm in diameter. In the previous iteration of the European guidelines on the management of urolithiasis, fURS was recommended as a second-line treatment for stones less than 2 cm after shock wave lithotripsy (SWL), however in the recent revision of the guidelines, both fURS and SWL were recommended as first-line management options especially for stones measuring between 11 and 20 mm [14], reflecting the increasing success in treating intrarenal stones in a retrograde fashion.

In 1990's, the initial reports on successful management of urolithiasis with fURS came from high-volume experienced centers [15,16]. Grasso and Ficazzola [16] achieved an SFR of 94% and 95% for intrarenal stones measuring less than or equal to 10 mm and 11–20 mm, respectively with fURS and laser lithotripsy. Sofer et al. [15] reported their experience with a large cohort of patients including 598 patients who were treated with ureteroscopy (URS) and laser lithotripsy from 1993 till 1999. The average stone size was 11.3 mm and 56 of the included patients had intrarenal stones treated with fURS. The authors achieved an SFR of 84% for intrarenal stones with a low overall complication rate of 4%.

Comparative studies of fURS, SWL and/or percutaneous nephrolithotripsy (PCNL) showed an advantage in the success rate of fURS over SWL [17], while fURS had a comparable success-rate to PCNL (or Miniperc) with lower associated morbidity in the treatment of intrarenal stones [18–20].

It is anticipated that fURS will play a more important role in the management of symptomatic intrarenal stones in the near future and fURS may significantly supplant SWL as the modality of choice for treating intrarenal stones less than 2 cm.

3.2. Treatment of intrarenal stones greater than 2 cm

PCNL is the gold standard for large renal stones measuring 2 cm or greater as defined by American Urological Association (AUA) and European Urological Association (EUA) guidelines [14,21]. PCNL however can be associated with significant complications, longer hospital stay and convalescence. Therefore, a less morbid option to treat large renal stones would be especially advantageous to high-risk patients.

Early reports on the use of fURS in the treatment of large renal stones appeared in the 1990's, when Aso et al. [22] described their experience in treating 34 patients with staghorn renal stones. At that time, the only available flexible intracorporeal lithotripter was electrohydraulic based, which resulted in a high complication rate rendering fURS an unacceptable management option for large renal

stones. Efforts to find a safe alternative to PCNL continued and a trial to combine fURS with SWL to treat staghorn stones was successful in fragmenting 21 out of 27 stones [23], patients however required up to 26 SWL sessions (mean of 8.4 procedures), leading to concerns about shock wave bioeffects on the renal parenchyma and costs. With further advancement of endoscope and Holmium:YAG laser lithotripter technology, fURS has re-emerged as a therapeutic option for large renal stones. Grasso et al. [24] treated 45 large intrarenal stones using fURS and Holmium:YAG laser lithotripsy. They included patients with stones greater than 2 cm in a population with medical comorbidities that precluded treatment with PCNL. The SFR, defined as fragments less than 2 mm, was encouraging at 76% after the first treatment and re-treatment with fURS increased the final SFR to 91%. The high success rate reported by Grasso et al. [24] was accompanied by a low postoperative complication rate of 6.2%. Recently, a meta-analysis by Aboumarzouk et al. [25] included nine primary studies reporting on 445 patients (460 renal units) diagnosed with large intrarenal stones and treated with fURS and laser lithotripsy. The average SFR was 93.7% (range 77.0%–96.7%) after an average of 1.6 procedures per patient for treatment stones with of a mean size of 2.5 cm. That high success rate, comparable to PCNL results, was associated with a complication rate of 10.1%. Major complications including steinstrasse, subcapsular hematoma, obstructive pyelonephritis, cerebrovascular accident, acute prostatitis and hematuria leading to clot retention were noted in 5.3% patients, while 4.8% of patients experienced minor complications mostly self limiting hematuria and postoperative fever. However, a subgroup analysis revealed no major complications in the group of patients with a 2–3 cm stone. Further reports on fURS for the treatment of large renal stones achieved similar high SFR after multiple procedures [26,27]. Concurrent use of UAS, which facilitated multiple re-entries of the endoscope and improved visibility, was noted as a factor contributing to improved outcomes.

Akman et al. [28] pair-matched and analyzed 34 patients with 2–4 cm renal stones treated with fURS with patients treated with PCNL. Patients were matched on demographics (age, gender and body mass index), renal anomalies (solitary kidney and degree of hydronephrosis), stone characteristics (size, number and location) and history of previous interventions (SWL and open surgery). The initial stone-free status was significantly higher in favor of PCNL (73.5% and 91.2% for fURS and PCNL, respectively), but the difference lost its significance after the second fURS procedures with a final SFR of 88.2%. PCNL was found to be statistically better in terms of shorter mean operative time, but with a longer hospital stay than fURS. There was no statistical difference in the associated complications after both procedures, although two patients required blood transfusions after PCNL. However, fURS was found to be significantly inferior in treating intrarenal stones greater than 2 cm compared to miniperc (18 Fr tract) in another matched-pair analysis [29]. The success rate was only 43.4% after the first fURS procedure.

In most series, the number of procedures required to achieve a successful outcome is the main concern in using fURS to treat large intrarenal stones [30]. This is offset by

the low associated complication rate, making fURS a valid alternative to PCNL especially in high-risk patients.

fURS has also been described as a successful adjunct to PCNL in treating complex renal stones in order to reduce the number of tracts and associated complications [31–34]. fURS was performed either simultaneously with or in a staged fashion from PCNL resulting in results equal to conventional PCNL.

3.3. Treatment of lower pole stones

Treatment of lower pole renal stones is an ongoing dilemma due to the dependent position of the lower calyces limiting spontaneous passage of stone fragments after SWL [35]. Additionally, the anatomy of the lower pole calyces makes them less accessible by flexible ureteroscopes than mid or upper calyces. In 1999, Grasso and Ficazzola [16] failed to access the lower pole by fURS in 7% of their patients using an early generation ureteroscope with limited active deflection ability, yet they achieved a high success rate in treating 93% of the cohort with an SFR of 94% and 95% for stones greater than 1 cm and less than 1 cm, respectively. Researchers have tried to determine the anatomical factors associated with failure to access the lower pole in a retrograde fashion by fURS [36–38]. An acute infundibulo-pelvic angle (<30°) and a long infundibular length (>3 cm) were found to be associated with lower SFR in treating lower calyceal stones, while there was no effect exerted by the infundibular width [36–38]. However, after the development of modern endoscopes with extended active deflection abilities and advancement of operative techniques [39], accessibility of lower pole stones to fURS has improved. Stone repositioning to a more accessible calyx using tipless Nitinol baskets before laser lithotripsy is a technique that has improved the success rate of fURS in treating lower pole stones. Baskets result in minimal loss of endoscope active deflection and irrigation flow in comparison to the smallest laser fiber facilitating successful access to the lower pole with better visibility [40]. Schuster et al. [41] found an improved SFR after stone repositioning in comparison to *in situ* lithotripsy of lower pole stones. The difference was significant especially for stones greater than 1 cm, with SFR of 100% and 29% for stone repositioning and *in situ* lithotripsy, respectively. As a result of technological and technical advancements, some authors have demonstrated equivalent SFR achieved after treating lower pole stones compared to stones residing in other calyces with fURS [42,43].

Although fURS had no advantage over SWL in treating lower pole stones ≤1 cm in a randomized control trial conducted by the Lower Pole Study Group [44]. More recent studies have demonstrated advantages in favor of fURS [45,46]. In 2012, El-Nahas and colleagues [45] analyzed a matched-pair group of patients with 10–20 mm lower pole stones treated with fURS or SWL. fURS had a statistically significant higher SFR (86.5% vs. 67.7% for SWL) and lower retreatment rate (8% vs. 60% for SWL group). A recent prospective randomized trial by Kumar et al. [46] included 195 patients with radio-opaque lower pole stones treated by fURS or SWL. The mean stone size was comparable in the two groups (12 mm). Both treatment groups had comparable SFR at 3 months, but the retreatment rate was

significantly higher for the SWL patients (61.1% vs. 11.1% for fURS). The additional retreatment rate would impact the associated costs of both procedures.

fURS was also retrospectively compared to PCNL (and miniperc) in the treatment of lower pole stones less than 20 mm [47,48]. The success rate was similar in both groups with no difference in associated complications. PCNL and miniperc were associated with shorter operative time, higher fluoroscopy time and longer hospital stay in comparison to fURS.

fURS seems poised to play an important role in the management of lower pole renal stones less than 2 cm.

3.4. Proximal ureteral stones

SWL and fURS account for the vast majority of interventions for proximal ureteral stones worldwide. Both procedures are accepted as first line treatment option for proximal ureteral stones according to the latest EAU guidelines [14]. Although a less invasive procedure than fURS, SWL has been associated with a lower success rate and higher retreatment rate in comparison to fURS for ureteral stones [49]. Additionally, Pace et al. [50] demonstrated a significant decrease in the SFR with retreatment of ureteral stones by SWL after a failed initial treatment. On the other hand, early reports on fURS and laser lithotripsy for the treatment of proximal ureteral stones demonstrated a high SFR of more than 95% [15,24]. The high success rate of fURS in treatment of proximal ureteral stones was recently redemonstrated in a prospective, multi-institutional study that included 71 patients with solitary proximal ureteral stones [51], with an overall SFR of 95% and SFR of 100% for stones less than 1 cm. In a systematic review by Kijvika et al. [52] to examine the outcomes of SWL and URS in the management of proximal ureteral stones less than or equal to 2 cm, a significantly better outcome was found after URS for stones over 10 mm. However, the review included heterogeneous data from studies of both semi-rigid URS and fURS.

Therefore, fURS may be considered a competitive option to treat proximal ureteral stones when compared to SWL, especially in treating larger stone burdens or SWL-refractory stones.

4. Stones in special situations

4.1. Treatment of urolithiasis during pregnancy

Despite the low incidence of urolithiasis during pregnancy, it is the most common non-obstetric cause for hospital admission [53]. In a population-based retrospective cohort study, Swartz et al. [54] found that pregnant women admitted to hospital with urolithiasis have an increased risk of preterm delivery in comparison to pregnant women admitted due to other non-obstetric causes. There was no significant difference in obstetric complications between pregnant patients who underwent intervention for nephrolithiasis compared to patients who did not [54].

Up to 20% of pregnant women with nephrolithiasis may require procedural intervention [53]. Temporizing measures with deferred definitive treatment have a limited role

in the management of urolithiasis during pregnancy, especially during the first two trimesters, due to the associated increased encrustation of ureteric stents and blockage of nephrostomy tubes with subsequent need for frequent exchanges [55]. Additionally, SWL is contraindicated during pregnancy due to potential harmful effects on the developing fetus [14]. Thus, URS poised to be an attractive definitive option to treat urolithiasis during pregnancy [56].

In 1988, Rittenberg and Bagley [57] were the first to report performing fURS in two pregnant women. Watterson et al. [58] treated eight pregnant women with urolithiasis by URS (semi-rigid and flexible) using the Holmium:YAG laser under general anesthesia and achieved an 89% SFR with no postoperative urologic or obstetric complications. Ureteral dilatation was not required in their series, however six patients had pre-stented ureters [58]. While Lifshitz and Lingeman [59] had to dilate the ureteric orifices in four patients to facilitate URS, they performed fURS in the majority of patients under spinal anesthesia with no major postoperative complications.

Semins et al. [60] performed a systematic review examining the safety of URS during pregnancy. The authors found a low rate of postoperative complications in 108 patients. Most of the reported complications were Clavien level 1 and 2, and there was no significant difference in ureteral injury or urinary tract infection rates in comparison to a multinational meta-analysis of URS in non-pregnant women.

Although large cohort studies are not available in the literature, fURS seems to be a safe definitive method for treatment of urolithiasis during pregnancy with a low rate of major complications.

4.2. Treatment of urolithiasis in children

In the recent years, the vast majority of pediatric urolithiasis are managed by minimally invasive endourologic procedures such as SWL, URS and PCNL [61]. Similar to the adult population, the shift from open surgery to endourologic management was possible due to advancement of technology and miniaturization of endourologic instruments. Previously, concerns over instrument associated intraoperative complications such as ureteral perforation and vesicoureteral reflux lead to the late adoption of URS in the treatment of pediatric stone disease. While currently, URS (both semi-rigid and flexible) is playing an important role in the management of upper urinary tract stones in children and is now feasible even in preschool age children [62].

Tan et al. [63] published one of the first reports on the management of pediatric urolithiasis by URS that included six children who were treated by fURS successfully. In 2008, Kim et al. [64] had the largest cohort of pediatric patients treated by fURS and Holmium:YAG laser lithotripsy. The authors performed 170 procedures to treat 167 children suffering from intrarenal and ureteral stones, with 100% and 97% stone clearance for stones less than 10 mm and greater than 10 mm, respectively. The mean age of their patients was 62.4 months with a mean stone size of 6.12 mm (range 3–24 mm). Active ureteral dilation was avoided, but initial retrograde access was not possible in 57% of the children who were subsequently stented for 1–2 weeks followed by successful fURS. The authors

stated that no major intraoperative or postoperative complications were encountered with a mean follow-up of 19.7 months. Likewise, fURS with laser lithotripsy was found to be a safe and effective procedure in treating pediatric intrarenal stones by a systematic review that included 282 children from six studies [65]. With a total reported complication rate of 12.4%, the vast majority of the complications were within Clavien grade 1 or 2. Only six patients had Clavien grade 3 complications; five ureteral perforations and one extravasation, which were related to UAS insertion or active balloon dilatation of the ureter [62,66]. The mean SFR reported in the systematic review was 85.5% (range 58%–93%) after one fURS procedure, demonstrating the effectiveness of fURS in children.

Despite the apparent need for pre-stenting in a significant percentage of children prior to achieving safe retrograde ureteroscopic access, Mokhless et al. [67] were able to proceed with initial URS in almost all of the included children by starting with the semi-rigid ureteroscope to hydro-dilate the ureter before inserting the flexible ureteroscope. They prospectively compared the outcomes of retrograde intrarenal surgery (RIRS) to SWL in the treatment of pediatric renal stones after randomly allocating 60 children (mean age of 2.4 years) with 10–20 mm stones into one of the two treatment arms. RIRS was found to have a better initial SFR of 86.6% in comparison to 70% after SWL, however at 3 months the SFR was comparable at 96.6% and 93.3% post RIRS and SWL, respectively. Furthermore, in a multi-center comparative analysis of the outcomes of pediatric patients with renal stones 10–30 mm in size treated with miniperc ($n = 106$) or RIRS ($n = 95$) [68], stone-free status was comparable at 84% and 86% for RIRS and miniperc, respectively. However, minor complication rates were 8.4% for RIRS and 17% for miniperc, with 6% transfusion rate after miniperc in comparison to no blood transfusion post RIRS. Moreover, the analysis showed favorable results to RIRS in terms of shorter fluoroscopy exposure, operative time and hospital stay, compared to miniperc.

4.3. Treatment of urolithiasis with renal anomalies

The management of urolithiasis in patients with anomalous kidneys imparts a special challenge to the treating urologist [69], due to the associated abnormal vascular supply, pelvicaliceal anatomic abnormalities such as ureteropelvic obstruction, and the unusual relation to surrounding structures.

SWL has a high failure rate in patients with renal anomalies due to either the impaired urinary drainage associated with the anomaly or difficulty targeting the stone due to overlying bones [69]. More invasive procedures such as PCNL and laparoscopy can be associated with increased risk of iatrogenic injury to adjacent organs and vascular structures [69]. Thus, fURS offers a minimally invasive therapeutic option for urolithiasis in patients with renal anomalies that can be performed as a day-procedure with low rate of complications.

Horseshoe kidney (HSK) is one of the common renal anomalies with an incidence up to 1/400 live births and is associated with urolithiasis in 20% of the cases [70]. Weizer et al. [71] were the first to report the successful treatment

of renal stones in patients with HSK with fURS. They achieved a 75% SFR after performing fURS with Holmium:YAG laser lithotripsy and nitinol baskets in four patients with HSK and four patients with pelvic ectopic kidneys (PEK). In 2010, Molimard and colleagues [72] published their retrospective experience in treating 17 HSK patients with fURS and laser lithotripsy. Of the 17 included patients, eight had SWL refractory stones and four patients failed previous PCNL. Stone repositioning was required in nine patients with lower pole stones before laser lithotripsy. Their reported success rate, defined as stone-free status or residual stone less than 3 mm, was 88.2% after 1.5 procedures for the treatment of stones measuring 7–35 mm (average of 16 mm), with no major complications encountered. More recently, the Turkish experience was reported in treating 20 patients with a mean stone size of 17.8 mm in HSK by fURS [70]. Treatment was successful in 70% of patients who were rendered either completely stone free or with insignificant residual fragments less than 4 mm. Postoperative complication rate of 25% consisted of only minor Clavien grade 1 and 2 complications that included fever and self-limiting hematuria.

While Weizer et al. [71] had a 75% success rate in treating intrarenal stones within 4 PEK patients by fURS, Bozkurt et al. [73] experienced 84.6% successful fURS procedures in their retrospective multi-center report of 26 patients with stone bearing PEK. The mean stone size was 17 mm (range of 10–28 mm) with nine SWL refractory stones. Stone lithotripsy was accomplished by Holmium:YAG laser lithotripsy while stone repositioning was performed only if needed. The authors reported 19.2% postoperative complication rate with two patients requiring insertion of ureteral stents due to persistent renal colic.

The role of fURS and laser lithotripsy in the treatment of stone bearing calyceal diverticula was perhaps more studied than other pelvicaliceal system anomalies. In 2010, Sejny et al. [74] reported the largest retrospective cohort at that time describing their experience in treating symptomatic stone bearing calyceal diverticula with fURS and laser lithotripsy. They treated 36 symptomatic patients with an average stone size of 11.4 mm (5–22 mm), with 30 stones that had failed previous SWL. In that report, the authors described “The blue-test”, a novel technique to identify the diverticular neck in difficult cases using retrograde Methylene blue injection. After identification of the diverticular neck, careful incision of the neck was carried out to allow the passage of the flexible ureteroscope into the diverticulum. Neck incision was performed in 30 patients using high frequency and low energy laser settings (10 Hz and 0.8 J). The authors achieved 55.3% SFR with an additional 26.3% of patients having insignificant residual fragments less than 4 mm. Ninety percent of patients were rendered symptom-free making the results comparable to those after PCNL in treating calyceal diverticula stones, yet with lower morbidity, as there were no major complications observed after the fURS. Koopman and Fuchs [75] successfully identified the neck or the stenotic infundibular segment in 95% of 108 symptomatic patients due to intrarenal stones residing in caliceal diverticula or beyond an infundibular stenosis. They were able to dilate or incise the stenotic segment in 94% of the patients after successfully coiling a guide-wire into the diverticulum or

dilated calyx. fURS with laser lithotripsy and nitinol baskets were used in patients with less than 2 cm stones, while patients with stones 2 cm and larger were treated using a combined approach of fURS, laser lithotripsy with nitinol baskets and SWL. The SFR was 90% and 75% for stones less than 2 cm and 2 cm and greater, respectively. Both Sejjny et al. [74] and Koopman and Fuchs [75] noticed greater difficulty and less satisfactory results associated with lower pole stones in comparison to other calyces.

4.4. Treatment of urolithiasis in anticoagulated patients

Patients with bleeding diathesis or on anticoagulation medications cannot be treated with PCNL or SWL due to the associated risk of significant bleeding. While fURS has been proven to be safe and efficient when used together with the Holmium:YAG laser lithotripsy in the treatment of urolithiasis in patients with different types of bleeding diatheses or anticoagulants [76–79]. Watterson et al. [76] reviewed the charts of 25 patients with bleeding diathesis who were managed by ureteroscopic procedures for the treatment of urolithiasis. The bleeding diathesis consisted of warfarin administration in 17 patients, thrombocytopenia in four, liver end-stage disease in three and von Willebrand's disease in one. Nineteen procedures were performed mainly using fURS and the Holmium:YAG laser lithotripsy, while electrohydraulic lithotripsy was used earlier in the study in two patients. The authors found only one major complication, retroperitoneal bleeding, in a patient who was concomitantly treated by electrohydraulic lithotripsy while there was no complications in the rest of the patients treated with the aid of the Holmium:YAG laser lithotripsy. More recently, a pair-matched analysis was performed by Turna et al. [78] to examine the safety of fURS and Holmium:YAG laser lithotripsy in treating intrarenal stones in anticoagulated patients. Although the anticoagulation group was significantly older and had a greater American Society of Anesthesiologists Score, there was no difference in the intraoperative and postoperative complications with comparable SFR rates.

4.5. Treatment of urolithiasis in obese patients

Obesity is a common prevalent disease of the Western world that is associated with higher risk of urolithiasis. Yet obesity can negatively affect the treatment options for upper tract urinary stones. The success rate of SWL is decreased with obesity and greater skin-stone distance, while PCNL becomes more complicated in obese patients due to the longer tracts and increased risk of anesthetic complications associated with prone positioning. The efficacy of fURS in the treatment of upper tract stones in obese and morbidly obese patients has been well studied [80–86], and the SFR and associated complications of fURS were not affected by the patient's body mass index [84–86].

5. Contraindications and complications of fURS

Apart from general considerations, such as anesthetic contraindications and untreated urinary tract infection,

fURS has no specific contraindication [14]. fURS can be performed in virtually every patient and it is especially suitable in situations when PCNL and SWL are either contraindicated or unsuitable.

The continually developing endoscope technology and the associated widespread utilization of fURS [87] have led to increased experience and improved skills in performing the procedure with low associated morbidity [88]. In the prospective CROES study, which included 11,885 patients from 114 centers in 32 different countries, 15% of the included patients ($n = 1781$) underwent fURS alone, while another 10.7% had combined semirigid and fURS for the treatment of their stones [89]. The overall postoperative complication rate was as low as 3.5% and the majority of the complications were Clavien grade 1 or 2 (2.8%). Only 0.2% of patients required blood transfusion, and there were five mortalities in the 30-day postoperative period due to sepsis, lung embolism, multi-organ dysfunction and cardiac causes. The readmission rate in the CROES URS study was 8.4% at 3 months postoperatively mainly due to flank pain and ureteral stent discomfort. In a subgroup analysis reported separately, there was no significant difference observed for postoperative complications or readmission rates between semirigid and fURS [90].

6. Conclusion

The role of fURS in the management of urolithiasis has expanded greatly during the last 3 decades thanks to the advancing equipment technology and surgical techniques. Increased ureteroscopic skills and experience together with miniaturization of flexible ureteroscopes has led to an associated high safety margin for fURS. fURS is expected to play a more important role in the management of urolithiasis in the near future.

Conflicts of interest

The authors declare no conflict of interest.

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