Urol Res (2012) 40:639–646
DOI 10.1007/s00240-012-0508-9

INVITED REVIEW

Flexible ureterorenoscopic management of upper tract pathologies

Athanasios Papatsoris · Kemal Sarica

Received: 7 July 2012 / Accepted: 4 September 2012 / Published online: 13 September 2012

Abstract The last decade flexible ureteroscopy has progressed from an awkward diagnostic procedure with limited visualization to a precise surgical intervention allowing access to the entire collecting system. In this review, we present the current status and future perspectives of the ureterorenoscopic management of urolithiasis and non-stone-related upper tract pathologies.

Keywords Cancer · Flexible · Kidney · Stone · Ureteroscopy

Introduction

Since 1988, it has been stated that the evolution of flexible ureteroscopic surgery (fURS) should include the improvement of the fiberoptic resolution, angulations capabilities, and working tools [1]. Nowadays, fURS has progressed from an awkward diagnostic procedure with limited visualization to a precise, complex surgical intervention allowing access to the entire collecting system [2]. However, acceptance and widespread use of this new technology has been hampered by the fragility of instruments and high initial and maintenance/repair costs. Despite these set-backs, tertiary and subspecialized stone centers have adopted this new technology, and its use is steadily increasing [3]. Herein, we review the flexible ureterorenoscopic management of upper tract pathologies.

A. Papatsoris (✉)
Department of Urology, University of Athens,
Sismanoglio Hospital, Athens, Greece
e-mail: agpapatsoris@yahoo.gr

K. Sarica
Department of Urology, Yeditepe University Hospital,
Istanbul, Turkey

Digital fURS

The first generations of the flexible ureteroscopes had the major drawback of limited visualization imposed by fiberoptic technology as well as fragility of fiber-based optics. With use, water could leak into the lens and the fibers might burn out or fracture, resulting in a grainy image. Novel digital flexible ureteroscopes have been developed in order to overcome these problems [4].

On the tip of the flexible ureteroscopes, there are digital sensors (“chip on the tip” technology): either a charge-coupled device (CCD) or a complementary metal oxide semiconductor (CMOS) [5]. CCD and CMOS 1-mm image sensors use different technologies for capturing images digitally. Due to these chips that are on the tip of the digital scope, there is no need for a camera head to be adjusted on the scope. The existence of a digital camera at the tip eliminates the need for fragile low-resolution fiberoptics and the image is brighter with no black dots.

Furthermore, the tip of the digital flexible ureteroscope houses dual light-emitting diode (LED)-driven light carriers, which obviates the need for an external light source and, therefore, there is no risk of drape fires or patient burns [3]. LEDs are semiconductors that operate by electroluminescence, a phenomenon in which the emission of photons is caused by electronic excitation of a material charged with an electric current. LED chips are typically 250 × 250 × 250 μm in size and they transform electric charge into visible light. The LED light lasts up to 10,000 h, which is 10–20 times longer than xenon lights [4].

As digital ureteroscopes do not have external cameras or light cables, the flexible ureteroscope is much lighter (up to 50 %) [6]. Furthermore, the digital ureteroscope image is bright with high-resolution technology (1,280 vertical–1,024 horizontal image lines at a format of 5:4) and zooming capability improves up to 150 % in comparison with the fiberoptic ureteroscopes. The high-definition image is visualized on a rectangular monitor without the loss of the peripheral image. However, during laser lithotripsy, it is advisable to minimize the laser localization beam because its interference with digital image capture is more marked than with conventional fiberoptic image capture [3]. Studies have evaluated the applicability of the digital fURS in studying the earliest stages of stone formation [6]. The authors concluded that the ease of use and high-quality images of digital ureterorenoscopy will allow the documentation of the earliest stages of stone formation.

Limited data exist on the occupational hazards posed by complex endourologic procedures. Hand and wrist problems are very common among endourologists [7]. Most colleagues with hand/wrist problems need either medical or surgical intervention. The lighter (up to 50 %) digital flexible scope is reasonable to result in less hand and wrist fatigue in comparison to the flexible scopes of the earlier generations. Future studies are needed to develop more ergonomic platforms and thereby reduce the endourologist's exposure to these occupational hazards.

Working tools in fURS

Instrumentation is one of the most important key issues for success in fURS. The introduction of the laser fiber and other working tools such as the basket and the biopsy forceps influences the deflection angle and the irrigation flow in the flexible ureteroscope. Apparently, the flow rates were dependent on the size of the tool used. Studies have demonstrated that the introduction of the laser fiber or the biopsy forceps resulted in relevant loss of deflection, while the tipless nitinol basket had less influence [8].

A novel nitinol stone basket (Escape^{TM}) prevents stone migration and facilitates simultaneous laser lithotripsy in situ. A prospective study that used this basket in 23 patients demonstrated the safety and efficacy of this device [9]. Furthermore, the development of a dual-channel flexible ureteroscope that can accommodate simultaneously two working tools (basket and laser) seems very promising [10]. Similar to a basket, a novel semi-disposable ureteroscope has been developed. Disposable multi-lumen catheters reduce the risk of scope damage and infection as there is no need for sterilization of the optic cable. The modular design of the semi-disposable PolyScope system (Lumenis, Santa Clara, CA, USA) makes it a cost-effective option [11]. This 8 F scope has a deflection angle of 180° and a working channel of 1.2 mm.

The ureteral access sheath is commonly used to facilitate the insertion and straight alignment of the flexible ureteroscope in the upper urinary tract [3]. Its use has been demonstrated to facilitate ureteral re-entry and efflux of irrigation fluid, decrease operative time and cost, as well as minimize morbidity. A pre-existing stent is associated with a more successful deployment of the access sheath. Traditional access sheaths rely on tapered dilators and the principle of axial force in order to gain access into the ureter. Harper et al. [12] compared the performance of a novel balloon expandable ureteral access sheath using radial dilatation with that of a conventional one. The novel ureteral access sheath was inserted with less maximum and average force and was associated with a lower subjective trauma scale rating.

Laser damage is thought to be the main factor for the short lifespan of the ureterorenoscopes. The endoscopic protection system (EPS) uses optical feedback from a digital sensor to terminate laser energy on retraction of the laser fiber toward the tip of the scope [13]. The laser shut down occurs before the actively firing laser fiber enters into the endoscope, usually at 0–2 mm distance. EPS could help prevent the endoscope damage and extend the life of the endoscope, thus preventing costly repairs.

The use of the laser systems

Ho:YAG laser system

As stated in the European Association of Urology Guidelines, the most efficient laser system for the treatment of stones in all locations and of all mineral composition is the holmium:yttrium-aluminium-garnet (Ho:YAG) laser [5]. Studies demonstrated that shorter pulse durations produced more stone retropulsion than longer pulses at any given pulse energy [14]. Regardless of pulse duration, higher pulse energy and larger fibers resulted in larger ablation volume and retropulsion. Therefore, less retropulsion and equivalent fragmentation occurred when Ho:YAG laser pulse duration increased. Except for stone treatment, the holmium laser has been successfully used during fURS for other endourological procedures such as endoureterotomy [15].

Non-Ho:YAG laser systems

The frequency doubled double-pulse Nd:YAG (FREDDY) laser functions through the generation of a plasma bubble [16]. The FREDDY laser presents an affordable and safe option for intracorporeal lithotripsy, but it does not fragment all stone compositions, and does not have soft tissue applications. Studies demonstrated that in vitro stone fragmentation was significantly greater with the FREDDY laser than with the Ho:YAG laser. However, stone retropulsion was significantly greater with the FREDDY laser compared with the Ho:YAG laser.

Initial experiments with the Erbium:YAG laser showed that it has improved efficiency of lithotripsy and more precise ablative and incisional properties compared to Ho:YAG, but the lack of adequate optical fibers limits its current use [17]. The high-temperature water absorption coefficient at the erbium laser wavelength of 2.94 μm is about 30 times higher than that of the holmium laser wavelength at 2.12 μm, which has translated to a 2- to 3-fold increase in efficiency for fragmenting stones.

The thulium fiber laser wavelength is tunable, and, when operated in the pulsed mode, it is capable of fragmenting urinary calculi [15]. Furthermore, the thulium fiber laser-beam diameter is only 18 μm, allowing easy coupling of the laser radiation into small-core optical fibers. Such diminutive fibers have a great potential when used with flexible ureteroscopes, especially in challenging cases such as lower pole lithiasis. The results of clinical studies with the thulium as well with the other lasers are warranted.

Stone treatment with fURS

Renal stones

Flexible URS is indicated in treating renal stones less than 15 mm that do not respond to SWL and is an attractive option for treating renal and ureteral stones in the same patient in a single session [18]. Stone size larger than 15 mm is associated with single-session treatment failure for stone-free status [5, 18]. In the vast majority, cases of flexible URS for unilateral renal stones can be performed as outpatient procedures. In a study of 51 patients with 161 renal stones (mean stone size of 6.6 mm), the overall stone-free rate after one and two procedures was 64.7 and 92.2 %, respectively [19]. In 97.6 % of the cases, the operation was performed on an outpatient basis. The authors use a 7.2 F flexible ureteroscope (Stortz Flex-X or Gyrus ACMI DUR-8 Elite). Using the same scopes, Perlmutter et al. [20] studied whether stone location affects the stone-free rates of flexible URS. A total of 86 renal stones were treated and the stone-free rates were 100 % for upper pole stones, 95.8 % for middle pole and 90.9 % for lower pole stones ($p = 0.338$). Lower pole stones may not be easily accessed and fragmented because of acute infundibular angles and reduced deflection of ureteroscopes. This can be overcome by relocating lower pole stones into a more favorable location before fragmentation. Nevertheless, a small prospective randomized trial comparing SWL (32 patients) and URS (35 patients) for lower pole calyceal stones of 1 cm or less did not demonstrate a statistically significant difference in stone-free rates in favor of URS [21].

Lower pole stones

The retrograde endoscopic approach to lower calyceal calculi represents the latest result of technological advancement in the field of endourology. Small caliber, flexible instruments with the use of holmium:YAG laser fibers and nitinol end baskets, as well as advanced access sheaths have improved access to the pelvicalyceal system and stone management. Reported stone-free rates range from 53 to 87 % in various studies [2]. fURS is a reasonable approach for lower pole lithiasis, especially in obese individuals, patients on anticoagulation, concomitant ureteral calculi, and bilateral occurrence. Based on the available literature, flexible URS seems to have comparable efficacy as ESWL for stones <15 mm [5]. It is also reported that, in difficult cases, repositioning of the calculi to more accessible upper and/or middle calyces, especially for stones 1–2 cm, is safe and advisable [22].

Lower pole anatomy influences the performance and success of flexible URS [23]. The first anatomic parameter studied was the infundibular length, followed by the infundibular diameter and the pelvicalyceal height. Other anatomic parameters included the lower pole infundibulopelvic and infundibuloureteric angles. Geavlete et al. [24] evaluated the correlation between anatomy and the success of flexible URS in 47 patients with lower calyx stones. The success rate was 88 % in patients with an infundibulopelvic angle wider than 90°, 74 % when this angle ranged between 30° and 90°, and 0 % in patients with an angle smaller than 30°. In patients with an infundibulopelvic angle between 30° and 90°, the success rate was 88 % when the length of the inferior calyceal infundibulum was shorter than 30 mm and 61 % when it was longer.

Another study compared fURS with PCNL for stones 1.5–2 cm [25]. The authors reported similar stone-free rates, both at initial treatment (89.3 vs. 92.8 %, URS vs. PCNL) and also for additional intervention (94.6 vs. 97.6 %, respectively). Complications did not differ statistically, except for the need for transfusion in the PCNL group. It was concluded that URS has acceptable efficacy for medium-sized lower pole stones. To support these findings, Wendt-Nordahl et al. [26] in another study, investigated the novel digital flexible scopes in the improvement of lower pole clearance rates. Novel digital scopes have improved deflexion, as well as a stiffer sheath, which allows for quick and multiple passes and working at lower collecting system pressures. When compared to standard flexible ureterorenoscopes, lower calyx access was better, with a double stone-free rate (31 vs. 69 %).

Large stones

Although PCNL has been recommended as the first-line treatment for renal stones larger than 2 cm, its major complication rate is not negligible and less invasive approaches such as fURS are under evaluation [5]. Recently, Takazawa et al. [27] treated 20 patients with renal stones ≥2 cm with fURS (Olympus URF-P5). Mean stone size was 3.1 cm (range 2.0–5.0), while the average number of procedures was 1.4. One, two and three procedures were required in 13, 6 and 1 patients, respectively. The mean operative time per procedure was 114 min and, per patient, it was 159 min. The stone-free rate for preoperative stone size of 2 to ≤4 cm and >4 cm was 100 and 67 %, respectively. No major intraoperative complications were identified. The authors concluded that fURS is a favorable option for selected patients with renal stones 2–4 cm. However, as the mean operative time per procedure is nearly 2 h, fURS lasts longer than the standard PCNL.

Even for patients with renal stones >2 cm, fURS and Ho:YAG laser lithotripsy represent a favorable option for selected patients. Such cases include patients who do not consent to PCNL, patients on anticoagulation treatment that should not be discontinued, patients with morbid obesity, solitary kidney, or chronic renal insufficiency.

Large proximal ureteral stones are challenging in terms of treatment options. A randomized study on 150 patients with large (>15 mm) upper ureteral stones compared the safety and efficacy between semirigid URS, PCNL, and transperitoneal laparoscopic ureterolithotomy [28]. Although the success rate of ureteroscopy was not significantly lower than the other two options (76 vs. 86 and 90 %, respectively), the complications recorded with URS were negligible.

fURS combined with other procedures

In the modified-Valdivia position, it is possible to perform retrograde and anterograde procedures simultaneously, such as fURS and PCNL for concomitant pathologies (i.e., ureteric and renal stones, ureteric stricture and renal stone) [29]. Recently, Kawahara et al. [30] as well as other researchers [31] have described a technique for ureteroscopy assisted PCNL. A Lawson retrograde nephrostomy puncture wire was placed in the ureteroscope, and after the needle has exited through the skin, no further steps were required in preparation for dilatation. Continuous visualization was possible from puncture to inserting the nephron-access sheath. The procedure provided less radiation exposure, less bleeding, and a shorter procedure than the classic PCNL techniques. This procedure represented another option PCNL in patients with a non-dilated collecting system. This technique is a natural extension of modern retrograde intrarenal surgical techniques and a modernization of the original Lawson technique for retrograde nephrostomy creation.

fURS in special stone cases

Nowadays, in many challenging cases, such as kidney stones in prepubertal children, in pregnancy, urinary diversions (antegrade approach), morbidly obese patients, pelvic kidneys, polycystic kidney disease, horseshoe kidneys, calyceal diverticula and lower pole stones, fURS is now considered by many endourologists as the first-line treatment [3]. For instance, fURS is a safe and efficient modality for treating obese patients with renal stones, especially for stones <2 cm. Recently, Aboumarzouk et al. [32] performed a meta-analysis of 7 studies upon 131 obese patients (mean BMI 42.2) treated with fURS for urinary calculi. The stone-free rate was 87.5 % after completion of treatment with a follow-up ranged between 3 months and 3.5 years. The mean operative time was 97.1 min. There was an overall 11.4 % complication rate, however, none of the patients needed further monitoring and were treated conservatively.

Flexible URS is indicated for upper and middle (anterior or posterior) diverticulum symptomatic stones [2]. Lastly, matrix renal stones present a management challenge. Although PCNL is the gold standard of therapy for large renal matrix stones, fURS and laser lithotripsy could also be used. Laser lithotripsy was performed in conjunction with the use of a ureteral access sheath to facilitate irrigation of the mucous matrix stone material [33].

Traditionally, it is contraindicated to perform PCNL or ESWL on patients who are on anticoagulation medication, unless it has been discontinued before the procedure. Turna et al. [34] compared 37 patients who underwent flexible URS without discontinuing their anticoagulation medication with 37 patients not on anticoagulant but also underwent fURS with Ho:YAG laser lithotripsy. No operation had to be terminated in the anticoagulation group due to poor visibility because of bleeding. Stone-free rate and complication rate including hemorrhagic or thromboembolic adverse events were comparable in the two groups. The authors concluded that fURS could be performed safely and efficaciously in patients on anticoagulation therapy without altering their medication.

Urothelial cancer diagnosis and treatment

The traditional pitfalls of the upper urinary tract-urothelial cell carcinoma (UUT-UCC) diagnosis, namely poor visualization and difficulty in obtaining representative histological samples, are being circumvented by the introduction of modern digital fURS [3]. This can be combined with photodynamic diagnosis (PDD) and molecular analysis to improve tumor classification and the ability to select which patients would benefit from conservative treatment as opposed to radical surgery [35]. The accuracy of the diagnostic work up of UUT-UCC is improving due to advances in technology, pharmaceutical agents and incorporation of molecular markers, all factors allowing us to classify tumors of the UUT more definitively.

Endoscopic management of UUT-UCCs offers the advantage of preserving the renal function in selected patients. The most significant prognostic factors are the tumor location (pyelocalyceal system vs. ureter), multiplicity and size (below or above 1.5 cm), tumor stage and grade [36]. A ureteral stent is placed at the end of the procedure, and left until a 'second-look' repeat procedure is performed, usually at 6–12 weeks [36]. The patients' compliance is very important for detecting recurrences.

The imperative indications for the use of fURS in the treatment of UUT-UCC are the presence of solitary kidney, bilateral tumors, chronic renal failure and significant comorbidities impeding the open surgery. This approach has optimal results in small tumors (<1.5 cm) located in the upper ureter or the pyelocalyceal system. For the larger ones or for those in patients with characteristics predicting a difficult retrograde approach (i.e., complex anatomy, lower pole location), another approach (i.e., percutaneous procedure) must be taken into consideration [37].

Studies showed that the tumor-free rate in patients with low and high grade tumors conservatively treated was 76 and 40 %, respectively (mean follow-up 60 months) [36, 37]. Tumor size influences both the immediate and long-term success. Tumors smaller than 1.5 cm are more often completely resected (91 vs. 36 %) and less often present recurrences (25 vs. 50 %) when compared with the larger ones [38]. Regarding multifocality, Keeley et al. [39] reported that 50 % of the patients with multiple lesions had residual tumoral tissue while this occurred only in 19 % of the cases with solitary malignancies. Tumor location does not seem to influence the oncological outcome, the recurrence rate being similar for lesions located in the ureter or in the renal pelvis (31.2 vs. 33 %) [40]. Nevertheless, diagnostic work up of UUT-UCC still needs improvement as demonstrated in a comparative study between five different biopsy forcipes [41].

Narrow band imaging (NBI)

fURS with laser vaporization has appeared to be a promising solution for local nephron-sparing treatment of low-grade smaller TCC of the upper urinary tract, and newer technical developments such as NBI have shown considerable improvements in tumor visibility and detection rate [3]. NBI uses two discrete light bands: a blue at 415 nm and a green at 540 nm, resulting in a high-contrast image. The shorter wavelength penetrates only the superficial layers of the bladder wall and the longer wavelength penetrates deeper. Both are avidly absorbed by the hemoglobin circulating in the capillaries. NBI blue light shows superficial capillary networks, while green light shows subepithelial vessels, and when combined, they offer an extremely high-contrast image of the tissue surface. With the usage of the CCD digital technology, there is improved visibility of the superficial capillaries and the subepithelial vessels.

Clinical studies demonstrated better visualization of UUT-UCC with the use of NBI versus white-light digital fURS [3]. Traxer et al. [42] reported that NBI significantly improved the endoscopic visualization of tumors, providing a detailed description of their limits and vascular architecture. In other words, more tumors and extended tumor limits were demonstrated. They performed NBI and white-light fURS in 27 patients and concluded that NBI technology is a valuable diagnostic method, because it considerably improves tumor detection rate by 23 % compared with white light. Further studies are warranted to clarify the effects of this technology on the diagnosis, recurrence rate, tumor-free survival period, and overall management of these patients.

Evaluation of benign hematuria

Patients suffering from relapsing and/or persisting hematuria are thoroughly evaluated by the urologist. Despite all efforts, no source of malignancy can be found in a certain percent of the cases through standard diagnostic measures. Although such patients were often closely followed up on a regular basis in the past, fURS has nowadays become the diagnostic and therapeutic method of choice.

A discrete vascular lesion that can be fulgurated during evaluation phase could be detected in about 50 % of the patients undergoing fURS for benign hematuria. These vascular lesions, including hemangioma or arterio-venous malformations, have been reported to be equally distributed throughout the collecting system of the kidney. On the other hand, as a result of this approach, a renal calculus or small, upper tract transitional cell carcinoma can be detected in approximately 5–10 % of patients. The fURS of the entire renal collecting system can most often be performed in a successful manner in the majority of these cases. Several centers revealed different types and percentages of discrete pathologies such as malignancy, vascular lesions, hemangiomas, sickle cell disease related bleeding sites and inflammatory lesions could be counted [43–49].

Management of ureteropelvic junction (UPJ) stenosis

Ureteropelvic junction stenosis has been managed by a variety of techniques such as open or laparoscopic/robotic pyeloplasty, antegrade endopyelotomy, retrograde Acucise endopyelotomy, and retrograde ureteroscopic endopyelotomy. Urologist's experience as well as the available equipment is the most crucial factor affecting the final decision on the technique used.

Antegrade endopyelotomy requires expertise in percutaneous renal surgery and is the minimal invasive technique of choice in cases of concomitant renal calculi. Long-term success rates with Acucise retrograde endopyelotomy have ranged from 66 to 84 % [50]. Nevertheless, the surgeon should be very careful when using this technique in the presence of aberrant crossing vessels. A preoperative CT scan with angiographic phase and three-dimensional reconstruction provides reliable information regarding periureteral vasculature at the level of the UPJ [51]. The relevant literature so far has not shown that retrograde ureteroscopic endopyelotomy provides a first-line treatment of UPJ stenosis, in comparison with open or laparoscopic pyeloplasty [51–57].

With the advent of smaller ureteroscopes and ancillary devices, fURS can nowadays be performed in children with UPJ stenosis. Adherence to strict endourologic principles and direct visualization make retrograde ureteroscopic endopyelotomy a safe and effective treatment modality.

Treatment of calyceal diverticulum

Another established indication for fURS is the management of relatively small sized (<1.5 cm) symptomatic calyceal diverticulum with or without lithiasis [58]. Diverticula located in the anterior calyx are difficult to be approached percutaneously and constitute the most appropriate indication for fURS. Nevertheless, the definition of success after this approach has not been clearly defined (i.e., the absence of symptoms, stone-free status, disappearance of the diverticular cavity).

The location of the diverticulum in the kidney largely affects the final outcome of the procedure where the upper and mid-calyceal ones are more successfully treated in comparison to the inferior calyceal ones: 84 versus 29 % [59, 60]. During the procedure, recalibration of the diverticulum neck is performed with balloon dilation or with electric/laser incision. In case of stones inside the diverticulum, they can be removed in 83–100 % of the cases [57, 61]. Following the removal of the stone; the ablation of the intradiverticular cavity with the laser is recommended. However, the results of some studies showed that the persistence of the diverticular cavity may be acceptable if there is a large communication with the pyelocalyceal system and there are no symptoms and stones [59].

Robotic and virtual reality fURS

A novel robotic catheter system has been developed for performing fURS. Desai et al. [62] performed remote fURS with a 14F robotic catheter system, which manipulated a passive optical fiberscope mounted on a remote catheter manipulator. The robotic flexible ureteroscope could be successfully manipulated into 83 of the 85 (98 %) calices. The time required to inspect all calices decreased from 15 min in the first kidney to 49 s in the last. On a visual analog scale, the reproducibility of calyceal access was rated at 8, and instrument tip stability was rated at 10. The potential advantages of robotic flexible URS compared with conventional manual URS include an increased range of motion, instrument stability, and improved ergonomics. The results of the initial clinical experience from the same group of researchers were encouraging [63].

Regarding virtual reality training, Mishra et al. [64] performed a comparative study of high-fidelity training models for fURS. They tried to determine whether high-fidelity non-virtual reality (VR) models (Uro-scopic Trainer™; Endo-Urologie-Modell™) were as effective as the VR model (URO Mentor™) in teaching fURS skills. Performance of the trainees was evaluated with the pass rating and global rating score (GRS).

Complications

The only true contraindication of fURS is the presence of untreated urinary tract infection because of the risk of urosepsis [65]. As the depth of tissue penetration of the Ho:YAG laser is 0.4 mm, in the vast majorities, injuries can be managed conservatively, although a ureteral stricture may be a long-term event. The rate of development of subcapsular renal hematoma after fURS is low. In a prospective study of 2,848 consecutive patients who underwent laser URS, 11 (0.4 %) developed such a complication [66]. All these cases were diagnosed due to clinical signs and symptoms and were successfully treated conservatively. Follow-up computerized tomography at 6 months was normal in all cases. Chang et al. [67] described a case of a fatal gas embolism that occurred during fURS under spinal anesthesia. Another extremely rare complication after fURS and Ho:YAG lithotripsy was the development of an intra-renal arteriovenous bleeding fistula which was embolized [68].

In case of accidental laser fiber breakage, the detection of the radiolucent fiber remainders may become troublesome. A recent study evaluated a prototype of a radiopaque laser fiber that was designed for lithotripsy with a Ho:YAG laser [69]. An optical core gold-clad fiber prototype offered comparable performance to the commercially available fiber of the same optical core diameter. Radiopaque property was proven in vitro as well as intracorporeally, thereby adding an additional safety feature to laser treatment.

Epilogue

Nowadays, fURS is emerging as one of the mainstays of treatment of upper urinary tract pathologies, rather than as a technique for exclusive use of the enthusiast. Independent, non-corporate sponsored research will help urologists performing fURS in instrumentation selection and reduce reliance on uncontrolled clinical evaluations of new products. Therefore, fURS seems to have been established as the diagnostic and treatment option with the most fascinating and promising evolution.

The success of fURS largely depends on the type of the endoscope, the energy source, and the ancillary instruments utilized. All these crucial factors should be taken into account before planning a diagnostic and/or therapeutic intervention in order to achieve a successful outcome with limited complications. The research into new flexible scopes, fibers, economic and long-lasting tools will be the future challenge.

References

1. Aso Y, Takayasu H, Ohta N, Tajima A (1988) Flexible ureterorenoscopy. Urol Clin North Am 15:329
2. Skolarikos AA, Papatsoris AG, Mitsogiannis IC, Chatzidarellis L, Liakouras C, Deliveliotis C (2009) Current status of ureteroscopic treatment for urolithiasis. Int J Urol 16:713
3. Papatsoris AG, Kachrilas S, El Howairis M, Masood J, Buchholz N (2011) Novel technologies in flexible ureteroscopy. Arab J Urol 9:41
4. Andonian S, Okeke Z, Smith AD (2008) Digital ureteroscopy: the next step. J Endourol 22:603
5. Turk C, Knoll T, Petrik A, Sarica K, Straub M, Seitz C, members of the European Association of Urology (EAU) Guidelines Office (2012). Guidelines on Urolithiasis. In: EAU Guidelines, edition presented at the 27th EAU Annual Congress, Paris 2012. ISBN 978-90-79754-83-0
6. Humphreys MR, Miller NL, Williams JC Jr, Evan AP, Munch LC, Lingeman JE (2008) A new world revealed: early experience with digital ureteroscopy. J Urol 179:970
7. Healy KA, Pak RW, Cleary RC, Colon-Herdman A, Bagley DH (2011) Hand problems among endourologists. J Endourol 25:1915
8. Bach T, Geavlete B, Herrmann TR, Gross AJ (2008) Working tools in flexible ureterorenoscopy—influence on flow and deflection: what does matter? J Endourol 22:1639
9. Kesler SS, Pierre SA, Brison DI, Preminger GM, Munver R (2008) Use of the Escape nitinol stone retrieval basket facilitates fragmentation and extraction of ureteral and renal calculi: a pilot study. J Endourol 22:1213
10. Haberman K, Ortiz-Alvarado O, Chotikawanich E, Monga M (2011) A dual-channel flexible ureteroscope: evaluation of deflection, flow, illumination, and optics. J Endourol 25:1411
11. Bader MJ, Gratzke C, Walther S, Schlenker B, Tilki D, Hocaoglu Y, Sroka R, Stief CG, Reich O (2010) The PolyScope: a modular design, semidisposable flexible ureterorenoscope system. J Endourol 24:1061
12. Harper JD, Ebrahimi KY, Auge BK, Lamberton GR, Pham AK, Zuppan C, Albala DM, Preminger GM, Baldwin DD (2008) Comparison of a novel radially dilating balloon ureteral access sheath to a conventional sheath in the porcine model. J Urol 179:2042
13. Xavier K, Hruby GW, Kelly CR, Landman J, Gupta M (2009) Clinical evaluation of efficacy of novel optically activated digital endoscope protection system against laser energy damage. Urology 73:37
14. Kang HW, Lee H, Teichman JM, Oh J, Kim J, Welch AJ (2006) Dependence of calculus retropulsion on pulse duration during Ho:YAG laser lithotripsy. Lasers Surg Med 38:762
15. Papatsoris AG, Skolarikos A, Buchholz N (2012) Intracorporeal laser lithotripsy. Arab J Urol 10:301
16. Marks AJ, Teichman JM (2007) Lasers in clinical urology: state of the art and new horizons. World J Urol 25:227
17. Amón Sesmero JH (2008) New perspectives for laser therapy. Arch Esp Urol 61:1163
18. Wong MY (2008) Flexible ureteroscopy is the ideal choice to manage a 1.5 cm diameter lower-pole stone. J Endourol 22:1845
19. Breda A, Ogunyemi O, Leppert JT, Schulam PG (2009) Flexible ureteroscopy and laser lithotripsy for multiple unilateral intrarenal stones. Eur Urol 55:1190
20. Perlmutter AE, Talug C, Tarry WF, Zaslau S, Mohseni H, Kandzari SJ (2008) Impact of stone location on success rates of endoscopic lithotripsy for nephrolithiasis. Urology 71:214
21. Pearle MS, Lingeman JE, Leveillee R et al (2008) Prospective randomized trial comparing shock wave lithotripsy and ureteroscopy for lower pole caliceal calculi 1 cm or less. J Urol 179(5 Suppl):69
22. Schuster TG, Hollenbeck BK, Faerber GJ, Wolf JS Jr (2002) Ureteroscopic treatment of lower pole calculi: comparison of lithotripsy in situ and after displacement. J Urol 168:43
23. Zomorrodi A, Buhluli A, Fathi S (2010) Anatomy of the collecting system of lower pole of the kidney in patients with a single renal stone: a comparative study with individuals with normal kidneys. Saudi J Kidney Dis Transpl 21:666
24. Geavlete P, Multescu R, Geavlete B (2008) Influence of pyelocaliceal anatomy on the success of flexible ureteroscopic approach. J Endourol 22:2235
25. Geavlete P, Multescu R, Geavlete B (2011) Retrograde flexible ureteroscopy: reshaping the upper urinary tract endourology. Arch Esp Urol 64:3
26. Wendt-Nordahl G, Mut T, Krombach P et al (2001) Do new generation flexible ureterorenoscopes offer a higher treatment success than their predecessors? Urol Res 39:185
27. Takazawa R, Kitayama S, Tsujii T (2012) Successful outcome of flexible ureteroscopy with holmium laser lithotripsy for renal stones 2 cm or greater. Int J Urol 19:264
28. Basiri A, Simforoosh N, Ziaee A, Shayaninasab H, Moghaddam SM, Zare S (2008) Retrograde, antegrade, and laparoscopic approaches for the management of large, proximal ureteral stones: a randomized clinical trial. J Endourol 22:2677
29. Papatsoris AG, Zaman F, Panah A, Masood J, El-Husseiny T, Buchholz N (2008) Simultaneous anterograde and retrograde endourologic access: "the Barts technique". J Endourol 22:2665

30. Kawahara T, Ito H, Terao H, Yoshida M, Ogawa T, Uemura H, Kubota Y, Matsuzaki J (2012) Ureteroscopy assisted retrograde nephrostomy: a new technique for percutaneous nephrolithotomy (PCNL). BJU Int 110:588
31. Wynberg JB, Borin JF, Vicena JZ, Hannosh VN, Salmon SA (2012) Flexible ureteroscopy-directed retrograde nephrostomy for percutaneous nephrolithotomy—description of a technique. J Endourol (Epub ahead of print)
32. Aboumarzouk OM, Somani B, Monga M (2012) Safety and efficacy of ureteroscopic lithotripsy for stone disease in obese patients: a systematic review of the literature. BJU Int (Epub ahead of print)
33. Chan CH, El-Hakim A, Andonian S (2010) Renal matrix stone managed by ureteroscopic holmium laser lithotripsy. Can J Urol 17:5127
34. Turna B, Stein RJ, Smaldone MC et al (2008) Safety and efficacy of flexible ureterorenoscopy and holmium:YAG lithotripsy for intrarenal stones in anticoagulated cases. J Urol 179:1415
35. Audenet F, Traxer O, Yates DR, Cussenot O, Rouprêt M (2012) Potential role of photodynamic techniques combined with new generation flexible ureterorenoscopes and molecular markers for the management of urothelial carcinoma of the upper urinary tract. BJU Int 109:608
36. Niţă G, Georgescu D, Mulţescu R, Draguţescu M, Mihai B, Geavlete B, Persu C, Geavlete P (2012) Prognostic factors in laser treatment of upper urinary tract urothelial tumours. J Med Life 5:33
37. Zigeuner R, Pummer K (2008) Urothelial carcinoma of the upper urinary tract: surgical approach and prognostic factors. Eur Urol 53:720
38. Keeley FX, Kulp DA, Bibbo M, McCue PA, Bagley DH (1997) Diagnostic accuracy of ureteroscopic biopsy in upper tract transitional cell carcinoma. J Urol 157:33
39. Keeley FX Jr, Bibbo M, Bagley DH (1997) Ureteroscopic treatment and surveillance of upper urinary tract transitional cell carcinoma. J Urol 157:1560
40. Tawfiek ER, Bagley D (1997) Upper-tract transitional cell carcinoma. Urology 50:321
41. Ritter M, Bolenz C, Bach T, Ströbel P, Häcker A (2012) Standardized ex vivo comparison of different upper urinary tract biopsy devices: impact on ureterorenoscopes and tissue quality. World J Urol (Epub ahead of print)
42. Traxer O, Geavlete B, de Medina SG, Sibony M, Al-Qahtani SM (2011) Narrow-band imaging digital flexible ureteroscopy in detection of upper urinary tract transitional-cell carcinoma: initial experience. J Endourol 25:19
43. Patterson DE, Segura JW, Benson RC Jr, Leroy AJ, Wagoner R (1984) Endoscopic evaluation and treatment of patients with idiopathic gross hematuria. J Urol 132:1199
44. Kumon H, Tsugawa M, Matsumura Y, Ohmori H (1989) Endoscopic diagnosis and treatment of unilateral hematuria of uncertain etiology. J Urol 143:554
45. Bagley DH, Allen J (1990) Flexible ureteropyeloscopy in the diagnosis of benign essential hematuria. J Urol 143:549
46. Nakada SY, Elashry OM, Picus D, Clayman RV (1997) Long-term outcome of flexible ureterorenoscopy in the diagnosis and treatment of lateralizing essential hematuria. J Urol 157:776
47. Yazaki T, Kamiyama Y, Tomomasa H, Shimuzi H, Okano Y, Iiyama T et al (1999) Ureteropyeloscopy in the diagnosis of patients with upper tract hematuria: an initial clinical study. Int J Urol 6:219
48. Tawfiek ER, Bagley DH (1998) Ureteroscopic evaluation and treatment of chronic unilateral hematuria. J Urol 160:700
49. Kavoussi LR, Clayman RV, Basler J (1989) Flexible, actively deflectable fiberoptic ureteronephroscopy. J Urol 142:949
50. Nakada SY, Pearle MS, Clayman RV (1996) Acucise endopyelotomy: evolution of a less invasive technology. J Endourol 10:133
51. Quillin SP, Brink JA, Heiken JP (1996) Helical CT angiography for identification of crossing vessels at the ureteropelvic junction. AJR Am J Roentgenol 166:1125
52. Van Cangh PJ, Nesa S, Tombal B (2001) The role of endourology in ureteropelvic junction obstruction. Curr Urol Rep 2:149
53. Thomas R (1994) Endopyelotomy for ureteropelvic junction obstruction and ureteral stricture disease: a comparison of antegrade and retrograde techniques. Curr Opin Urol 4:174
54. Conlin MJ, Bagley DH (1998) Ureteroscopic endopyelotomy at a single setting. J Urol 159:727
55. Meretyk I, Meretyk S, Clayman RV (1992) Endopyelotomy: comparison of ureteroscopic retrograde and antegrade percutaneous techniques. J Urol 148:775
56. Gerber GS, Kim JC (2000) Ureteroscopic endopyelotomy in the treatment of patients with uretero-pelvic junction obstruction. J Urol 55:198
57. Hibi H, Yamada Y, Mizumoto H, Okada M, Mitsui K, Taki T et al (2002) Retrograde ureteroscopic endopyelotomy using the holmium:YAG laser. Int J Urol 9:77
58. Monga M, Beeman WW (2004) Advanced intrarenal ureteroscopic procedures. Urol Clin North Am 31:129
59. Geavlete P, Multescu R, Georgescu D (2006) Flexible ureteroscopic approach in upper urinary tract pathology. Chirurgia 101:497
60. Batter SJ, Dretler SP (1997) Ureterorenoscopic approach to the symptomatic caliceal diverticulum. J Urol 158:709
61. Bellman GC, Silverstein JI, Blickensderfer S, Smith AD (1993) Technique and follow-up of percutaneous management of caliceal diverticula. Urology 42:21
62. Desai MM, Aron M, Gill IS (2008) Flexible robotic retrograde renoscopy: description of novel robotic device and preliminary laboratory experience. Urology 72:42
63. Desai MM, Grover R, Aron M, Ganpule A, Joshi SS, Desai MR, Gill IS (2011) Robotic flexible ureteroscopy for renal calculi: initial clinical experience. J Urol 186:563
64. Mishra S, Sharma R, Kumar A, Ganatra P, Sabnis RB, Desai MR (2011) Comparative performance of high-fidelity training models for flexible ureteroscopy: are all models effective? Indian J Urol 27:451
65. Matlaga BR, Lingeman JE (2009) Surgical management of stones: new technology. Adv Chronic Kidney Dis 16:60
66. Bai J, Li C, Wang S, Liu J, Ye Z, Yu X et al (2012) Subcapsular renal haematoma after holmium:yttrium-aluminum-garnet laser ureterolithotripsy. BJU Int 109:1230
67. Chang CP, Liou CC, Yang YL, Sun MS (2008) Fatal gas embolism during ureteroscopic holmium: yttrium-aluminium-garnet laser lithotripsy under spinal anesthesia—a case report. Minim Invasive Ther Allied Technol 17:259
68. Tiplitsky SI, Milhoua PM, Patel MB, Minsky L, Hoenig DM (2007) Case report: intrarenal arteriovenous fistula after ureteroscopic stone extraction with holmium laser lithotripsy. J Endourol 21:530
69. Bach T, Herrmann TR, Gross AJ (2012) Radiopaque laser fibre for holmium: yttrium-aluminum-garnet laser lithotripsy: critical evaluation. J Endourol 26:722