Flexible Ureterorenoscopy: Practical considerations and a glimpse to the future - A narrative review

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ABSTRACT

Flexible ureterorenoscopy (fURS) has emerged as a cornerstone in the minimally invasive treatment of urolithiasis and various other urological disorders. This narrative review synthesizes current practices, technological advancements, and the evolving role of fURS in urology, highlighting its application in managing kidney stones, ureteral strictures, calyceal diverticula, and upper tract urothelial carcinomas. The technique's versatility and efficacy have expanded its indications, making it an invaluable tool in scenarios where percutaneous nephrolithotomy (PCNL) and extracorporeal shock wave lithotripsy (ESWL) might be contraindicated or less effective. Key to fURS's success is the utilization of state-of-the-art disposables and equipment, including guide wires and ureteral access sheaths, which facilitate safe and efficient navigation of the urinary tract. Advances in laser lithotripsy, particularly the Holmium: YAG laser, have enhanced fURS's capability to fragment stones and ablate tumors with precision, minimizing tissue damage. The review also underscores the procedure's adaptability in treating special patient populations, such as those with anatomical variations, pregnant women, and pediatric patients, thereby broadening its clinical utility. Despite its widespread application and benefits, fURS maintain a favorable safety profile. Large-scale studies, such as the CROES URS study, report low complication rates and high success rates, validating its efficacy and minimal morbidity. Complications, when present, are generally minor and manageable, emphasizing the procedure's safety. In summary, fURS stands as a testament to the advancements in endourological techniques, offering a versatile, effective, and patient-friendly option for managing a broad spectrum of urological conditions. As technology continues to evolve and procedural expertise deepens, fURS is expected to further cement its role in improving patient outcomes, reducing hospital stays, and enhancing the quality of life for those suffering from urological diseases.

Key-words: flexible ureterorenoscopy (fURS), urolithiasis, kidney stones, upper tract urothelial carcinoma, ureteral strictures, calyceal diverticula, percutaneous nephrolithotomy (PCNL) and extracorporeal shock wave lithotripsy (ESWL).

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INTRODUCTION

Urolithiasis stands as a significant medical challenge, with a growing prevalence in developed countries, highlighting its commonality and the evolving landscape of its management [1]. Currently, among the diverse array of treatments available, percutaneous nephrolithotomy (PCNL) is established as the gold-standard for managing kidney stones larger than 20 mm, in alignment with the latest guidelines. For smaller stones, options include extracorporeal shock wave lithotripsy (ESWL) and flexible ureterorenoscopy (fURS), though the efficacy for stones between 15 and 20 mm may be less than ideal [1,2].

Adding to this landscape is the recent development of mini-percutaneous nephrolithotomy (mini-PCNL), a variant of the traditional PCNL, tailored for reducing renal parenchymal damage and bleeding by employing a smaller access sheath, e.g. 22 Ch diameter or less. This innovation aims to better clinical outcomes through enhanced aspiration and fragment removal capabilities compared to fURS, albeit with a lingering debate over its superiority in overall stone free rates (SFRs), due to precisely the reduced size of the access sheath and the lack of standardization in the diameter of access sheaths and instruments used, prohibiting accurate comparisons. Achieving optimal SFRs is indeed a primary goal; however, the occurrence of residual fragments poses a significant concern, potentially necessitating additional interventions. The concept of clinically insignificant residual fragments has been introduced, yet a definitive strategy for the management, clearance, or prevention of residual fragments is still lacking [3,4].

The introduction of flexible ureteroscopy by Bagley in 1987, following Marshall's first description of ureteroscopy (URS) in 1964, marked a significant advancement in endourology [5,6]. This technology has since expanded the scope of ureteroscopic stone surgery beyond small ureter stones in initial patients, to include large renal stones, stones in special populations such as pregnant women, morbidly obese individuals, those with urinary diversions, pediatric patients, and patients with calyceal diverticula [7]. Furthermore, (f)URS is now utilized as a primary diagnostic tool for upper tract urothelial carcinoma and as a treatment modality in selected cases [8]. Moreover, nowadays, we are witnessing a transition, with fURS being advocated as either the first or second line of treatment for kidney stones of any size, including those larger than 2 cm [2,3]. Despite technological advancements, such as the introduction of newer generation flexible ureterorenoscopes and laser lithotripsy techniques (Holmium: yttrium-aluminum-garnet – Ho: YAG and Thulium fiber laser), achieving high success rates in the removal of stones larger than 2 cm remains a challenge, with reported SFRs varying from 56.7% after a single session, to 89.3% following 1.6 sessions [3].

In endourology, the use of suction techniques, often in conjunction with ultrasound and ballistic devices, has been a staple for over 25 years, to assist in the removal of renal stones and stone fragments, during PCNL [9]. Suction during fURS has the added benefit of potentially reducing the internal temperature and pressure within the kidney being operated on, which might thus, in turn, decrease the risk of infections, and potentially enhance surgical outcomes [10]. The selection of lithotripsy techniques (fragmentation or dusting) during fURS, as well as the use of emerging surgical tools, such as a stone vacuum or a steerable multi-lumen irrigation/aspiration device, varies based on factors like the specific laser technology used and the surgeon's preference.

In fact, the last two decades have seen remarkable enhancements in fURS technology, characterized by reduced outer diameters, enlarged working channels, improved active deflection capabilities, and advanced fiber optics [11,12]. The integration of digital imaging and high-definition television has significantly elevated image quality, with digital chips now embedded at the tips of modern fURS devices. Furthermore, advancements in supportive equipment, including graspers, baskets, and laser technologies, have facilitated the execution of more intricate surgical interventions. These technological strides have propelled a substantial increase in the performance of ureterorenoscopic procedures [13].

Today, fURS is employed in a wide array of treatments, from calculus disease management and diagnostic explorations to the endoscopic treatment of upper tract tumors and procedures like endoureterotomy or endopyelotomy. This

paper aims to provide an overview of flexible ureterorenoscopic techniques, offering practical "tips and tricks" for achieving success across various procedural applications, in an effort to improve surgical outcomes and minimize complications.

2. PRACTICAL PREOPERATIVE CONSIDERATIONS

2.1. Disposables Used in Flexible Ureterorenoscopy

Guide wires are indispensable tools in urologic endoscopy, providing critical access to the renal collecting system and facilitating the insertion of various endourological devices such as stents and catheters. These wires are engineered to exhibit three essential characteristics: a flexible tip for precise navigation, a low-friction coating to minimize tissue damage and ease insertion, and a rigid shaft that provides the necessary support for the passage of devices. The standard practice involves the use of two guide wires, each extending to 150 cm in length, with diameters of either 0.035 or 0.038 inches. These wires include a 'safety' wire and a 'working' wire, each designed with a distal tip that ranges from 3 to 15 cm in flexibility to accommodate varying ureteral anatomies and procedural needs. To reduce the friction encountered during insertion, guide wires are coated with materials such as polytetrafluoroethylene (PTFE) or hydrophilic polymers. Hydrophilic-coated wires, in particular, are prized for their ability to navigate challenging ureteric pathways, though it's crucial they remain moist to maintain their slick properties. The working wire is typically hydrophilic to safeguard the integrity of the scope's working channel during instrumentation. For difficult ureteral access scenarios, several strategies can be employed: advancing the guide wire through a ureteral catheter, using a hydrophilic guide wire, or directly navigating it under visual guidance via ureteroscopy to address obstacles like stones or strictures that impede passage [7,8].

The ureteral catheter, usually ranging from 5 to 6 French in diameter with an open tip, serves multiple purposes: facilitating retrograde pyelograms, guiding the placement of the guide wire, and sampling urine from the pelvicalyceal system for diagnostic tests. The increasing adoption of fURS for complex renal conditions has heralded the widespread use of ureteral access sheaths (UASs). These sheaths, characterized by their hydrophilic nature, streamline ureterorenoscopy by enabling repeated scope insertions, thereby reducing intra-renal pressures and improving both the irrigation flow and visibility within the urinary tract [14,15]. This enhancement not only diminishes the overall operative time but also curtails procedural costs. The sheath, accompanied by an internal dilator, is inserted over the working wire with fluoroscopic guidance to ensure precise placement, avoiding forceful application to prevent ureteral trauma [16].

Stone extraction devices, notably those constructed from Nitinol, represent a significant advancement in urologic endoscopy. These devices, which include stone graspers, baskets, and forceps, are designed to facilitate the retrieval of calculi with minimal impact on the scope's maneuverability and the ureteral mucosa. The selection of an extraction device is a critical decision, influenced by the stone's size, location, and the procedural context, emphasizing the importance of continuous visual monitoring and the strategic use of a safety wire to mitigate the risk of complications [7,8].

In the context of ureteral stenting and drainage, a wide variety of stent designs and materials are available, reflecting advancements in polymer science aimed at reducing the incidence of stent-related complications such as encrustation and infection. Modern stents incorporate coatings and materials designed to minimize bacterial adherence and biofilm formation, thereby enhancing patient comfort and stent longevity [7].

This detailed exposition underscores the intricate balance between technology and technique in the realm of fURS, illustrating the nuanced considerations that underpin the successful management of renal stones, calyceal diverticula, and upper tract urothelial tumors. Through the judicious selection and application of guide wires, catheters, sheaths, and laser technology, urologists can navigate the complex anatomy of the urinary tract with precision, optimizing patient outcomes in the process.

2.2. Surgical and Technical Considerations

The intricate process of setting up and executing a

fURS procedure demands meticulous attention to detail, from preoperative preparations to postoperative management, ensuring patient safety and optimizing procedural outcomes. This comprehensive approach encompasses anesthesia selection, prophylactic measures, patient positioning, equipment setup, and the nuanced handling of endosurgical instruments and technologies.

Before undertaking fURS, a thorough assessment including urinalysis is essential to exclude urinary tract infections, a potential source of postoperative complications. Based on these findings, prophylactic perioperative antibiotics are administered according to the latest clinical guidelines and the specific antibiogram patterns of the healthcare facility, ensuring broad-spectrum coverage against common uropathogens [2,7].

The patient is placed under spinal or general anesthesia, chosen based on the patient's medical history, the expected duration of the procedure, and the specific anesthetic considerations of fURS. Following anesthesia, the patient is positioned in the dorsal lithotomy position, a setup that facilitates access to the urethra and aligns the urinary tract for optimal instrument navigation. Special attention is paid to protecting pressure points with appropriate padding to prevent neuropathies or pressure ulcers, ensuring patient comfort and safety throughout the procedure [2,8].

Fluoroscopy plays a vital role in fURS, enabling real-time imaging to guide the precise placement of instruments. The fluoroscopy equipment is arranged with the X-ray source positioned underneath the operating table and the image receptor situated above but close to the patient. This configuration minimizes radiation exposure to the surgical team while reducing the zoom effect for optimal imaging quality. The surgeon should stand in such a way as to not be directly in front of the patient, parallel, but rather, it is recommended that the operator take a lateral stance, at a 90-degree angle, perpendicular to the patient. This positioning facilitates effective control and manipulation of the flexible ureterorenoscope. A safety wire is then carefully secured within the plastic sheath, positioned at the same level and as close as possible to the urethral opening to prevent any displacement [8,17].

To ensure a low intra-renal pressure during the procedure, a gravity-fed irrigation system using saline is employed, maintaining a pressure not exceeding 40 cm of water (30 mmHg). The use of a UAS can further optimize outflow. Given the laser fiber's length, typically between 2 and 2.5 meters, it should be placed on the working table and covered with saline-moistened gauze, to maintain asepsis and ensure stable handling, due to the weight of the wet compresses. The arrangement of the OR equipment should position the radiology C-arm and the endoscopic tower on opposite sides to facilitate ease of use and accessibility [7,8].

The initial step involves performing cystoscopy to evaluate the ureteric orifices—assessing their position and size—to facilitate the precise placement of a guide wire into the renal pelvis under fluoroscopic guidance. This is followed by a retrograde pyelogram (RPG) through a ureteric access catheter, allowing for detailed visualization of the ureteric and intra-renal anatomy or pathology. A critical component of ureteroscopic procedures is the placement of a 'safety wire,' which ensures consistent access to the renal pelvis and serves as a safeguard throughout the procedure.

In males, the penis should be held straight to align the urethra, optimizing the pathway for the ureteroscope or access sheath. The flexible ureterorenoscope or UAS is then carefully advanced over a 'working' guide wire under fluoroscopic observation. The handling of the ureterorenoscope demands precision and skill; the dominant hand holds the scope's handle with the thumb manipulating the deflection control, while the non-dominant hand manages the scope's advancement or withdrawal. Initially, the scope should be inserted without any distal tip deflection over the working wire, which is then retracted to connect the cold-light cable, camera, and irrigation system [8].

Ureteral dilatation, though not always necessary, can be facilitated by a ureteral balloon catheter inserted over the working guide wire. This process involves the inflation of the balloon with a contrast agent under fluoroscopic guidance to dilate the ureter. The subsequent insertion of a UAS over the working guide wire, also under fluoroscopic control, allows for the selection of the sheath based on its diameter and length, tailored to the specific procedural requirements and the unique

anatomical features of the ureter [7]. Guide wires serve as essential tools for gaining access to the renal collecting system and facilitating the passage of scopes and stents. These wires typically feature a flexible tip for easy navigation, a low-friction coating to minimize tissue irritation, and a rigid shaft for stable manipulation. The use of a UAS is particularly advantageous in the management of large renal stones due to its ability to allow for multiple passages of the ureterorenoscope, reducing intra-renal pressure, and thereby enhancing irrigation flow and improving endoscopic visibility. Studies have highlighted that UAS use can significantly decrease the risk of infectious complications, underscoring its role in safer endourologic procedures [14-16].

The choice of UAS is determined by several factors, including clinical needs, patient-specific anatomical considerations, the type and size of the ureterorenoscope, and the surgeon's personal preference. The balance of inflow and outflow, critical for maintaining optimal intra-renal pressure during procedures, is influenced by the diameter of the working channel (typically 3.6 Ch) and the residual space between the ureterorenoscope and the inner wall of the UAS. It is advised to select the smallest feasible UAS size for the intended procedure and to avoid using excessive force during its insertion. While UAS facilitates fURS, it is crucial to ensure its safe deployment and to prevent ureteral injury. Although concerns have been raised regarding the long-term use of UAS and the potential risk of ureteric stricture, recent studies, including pediatric research, have not conclusively proven this risk. Ideally, the tip of the UAS should be positioned just below the pelvi-ureteric junction (PUJ) or within the upper ureter. If resistance is encountered during UAS placement, alternative strategies include advancing the scope over a guide wire or inserting a temporary ureteral stent to facilitate a later secondary fURS procedure [14-16].

Gaining access to the ureteral orifice is a crucial initial step in endourology. It is recommended to first place a safety wire through a cystoscope, ensuring its correct positioning. Following this, a semi-rigid URS is performed over a working wire, typically using the surgeon's dominant hand. In cases where the ureteric orifice is tight or challenging to access, rotating the scope by 90°–180° at the orifice may facilitate entry. Semi-rigid URS naturally dilates the ureteric orifice and ureter, allowing for the identification and management of ureteric stones while also enabling an assessment of the potential for UAS insertion. For fURS, the scope may be inserted either through a UAS or directly over a guide wire, with an angled guidewire being particularly useful for the latter approach. The manipulation of the flexible scope involves a combination of rotational movements, deflection, and in/out movements, employing both the dominant and non-dominant hands for macro and micro adjustments, respectively. The exploration sequence typically starts with the upper calices, followed by the middle and lower calices. Digital flexible ureterorenoscopes offer superior visualization capabilities, with screen indicators, such as a black triangle, denoting the 12 o'clock position, and bubbles indicating anterior calyces, aiding in navigation within the renal cavities [7,8].

Vision enhancement during URS is critical for successful outcomes. Pre-procedure adjustments such as focusing the scope, calibrating brightness, and setting white balance are foundational steps. The use of UAS can significantly improve irrigation efficiency and visualization. Additionally, employing pressure irrigation devices cautiously can further enhance visibility, although careful use is warranted to mitigate risks associated with increased intra-renal pressure, such as hemorrhage and infection. In certain situations, the application of contrast media can aid in clearing debris, blood, or stone dust, although patience is sometimes required for natural improvement in visibility. Advances in digital endoscope technology have markedly improved visual clarity compared to older fiber optic systems [18].

Laser technology, particularly the Ho: YAG laser, has become a cornerstone in modern endourology, due to its proven safety and versatility over the past two decades, offering unparalleled precision in stone fragmentation, tumor ablation, and stricture management. The laser's pulse duration, energy, and frequency settings must be tailored to the specific treatment objectives, whether it be stone fragmentation, dusting, or pop-corning, with the laser fiber's positioning critically influencing the efficacy of the procedure. Emerging recent techniques like pop-dusting offering efficient

management of large stones in a single session. The treatment approach varies depending on the location of the stone, with ureteral stones typically addressed from the center outward, and renal stones treated from the outer surface inward. A laser fiber, typically 200 or 365 µm in diameter, is threaded through the working channel, extending slightly beyond the scope's end. The laser is primed with an aiming beam, setting the stage for lithotripsy. Initial laser settings typically range between a frequency of 5-10 Hz and power of 1-1.5 J. The fiber's direct contact with the stone initiates fragmentation, followed by the retrieval of stone fragments using graspers for removal. Post-fragmentation, the renal system is thoroughly inspected for residual fragments. Depending on the need for ureteral drainage, a ureteric catheter or an internal stent is placed, providing post-operative urinary passage [8,19].

The management of stone clearance post-laser treatment acknowledges that stone volume is not directly proportional to its diameter, emphasizing the need for patient counseling regarding treatment expectations for larger stones. Techniques such as stone repositioning to more accessible calyces or the strategic introduction of laser fibers can optimize treatment outcomes and minimize the risk of endoscopic damage. The post-procedural application of the glue-clot technique allows for effective removal of dust and small fragments by trapping them within a clot formed by autologous blood, further enhancing stone clearance efficiency [20].

3. THE EVOLVING ROLE OF FLEXIBLE URETERORENOSCOPY IN UROLITHIASIS MANAGEMENT

3.1. Management of Intra-Renal Stones Under 2 cm

Technological advancements and the accumulated expertise of urologists in ureteroscopic techniques have solidified fURS as a critical tool for managing intra-renal stones measuring less than 2 cm. Initially recommended as a secondary option, after ESWL, in European urolithiasis guidelines, recent updates now position fURS on equal footing, alongside ESWL, as primary treatments, particularly for stones sized between 11 and 20 mm [2]. This change underscores the growing efficacy of fURS in treating these stones retrogradely.

The 1990s saw the first successful fURS applications for urolithiasis, in specialized centers. Grasso and Ficazzola reported SFRs of 94% and 95% for stones ≤10 mm and 11-20 mm, respectively, using fURS and laser lithotripsy [21]. Sofer et al. detailed their experience with 598 patients treated with fURS and laser lithotripsy between 1993 and 1999, achieving an 84% SFR for intrarenal stones and maintaining a low complication rate of 4% [22].

Studies comparing fURS to ESWL and/or PCNL indicate fURS's superior success rates over ESWL [23], and competitive success rates versus PCNL (or mini-PCNL) [24-26], with fURS showing lower associated morbidity for treating intra-renal stones than the latter. Thus, fURS is expected to increasingly become the preferred method for managing symptomatic intra-renal stones smaller than 2 cm.

3.2. Management of Intra-Renal Stones Over 2 cm

For renal stones ≥2 cm, PCNL remains the recommended standard according to the American Urological Association (AUA) and European Association of Urology (EAU) [2,27]. Despite its effectiveness, PCNL's association with significant complications and extended recovery periods prompts the need for less invasive alternatives, especially beneficial for high-risk patients. fURS, offering a less morbid alternative, gained early attention in the 1990s for large renal stones, though initial methods like electrohydraulic lithotripsy had high complication rates. Combining fURS with ESWL for staghorn stones has shown promise, yet usually requires numerous sessions. The refinement of endoscope and Holmium: YAG laser lithotripter technologies has re-established fURS as a viable option for large stones, especially in patients with comorbidities making PCNL risky. Studies report encouraging SFRs with relatively low complication rates, positioning fURS as a valid alternative, particularly for high-risk patients, and, more importantly, as an adjuvant technique to PCNL in complex stones, reducing the need for multiple PCNL tracts [28].

3.3. Management of Lower Pole Stones

Lower pole stones present a challenge due to anatomical constraints that hinder spontaneous fragment passage after ESWL and limit fURS access. Initial attempts had limited success, but modern endoscopes with enhanced deflection and stone repositioning techniques have improved fURS outcomes for lower pole stones. Recent studies highlight fURS's efficacy, offering significant advantages over ESWL, particularly for stones between 10 and 20 mm, achieving superior success rates, with lower need for reinterventions, thus potentially reducing overall treatment costs [28]. Comparisons with PCNL for smaller lower pole stones (< 2 cm) reveal similar success rates with fewer complications, underscoring fURS's role in managing these challenging cases [29, 30].

Strategic repositioning approaches involve utilizing a Nitinol basket (1.5-2.4F), the lower pole calculus is ensnared and repositioned to a more accessible location, such as the upper pole calyx or renal pelvis, facilitating easier fragmentation. If repositioning proves impractical, in-situ fragmentation is undertaken using a smaller laser fiber (150-200 µm), ensuring the scope remains straight during fiber introduction to prevent damage. The scope is only deflected post-fiber positioning at the tip. After fURS, to counter the risk of small fragments migrating back to the lower pole calices, the lower pole calices are flushed with saline through the endoscope, pushing fragments towards the renal pelvis. Subsequently, 5-10 ml of autologous blood, drawn from a peripheral venous line, are injected through the scope into the lower calices. Fluoroscopy confirms the scope's position as the injected blood obscure endoscopic view. After allowing time for the clot to form, its presence and efficacy in sealing the lower calices are confirmed via RPG, ensuring no visualization of the lower calyx and thus preventing fragment re-accumulation [28].

The intricate fURS procedure for kidney stones beyond the lower pole underscores the advancements in urological care, offering patients a less invasive, yet highly effective treatment option. The detailed procedural steps, from preparation through to post-operative care, illustrate the comprehensive approach taken to optimize patient outcomes, reduce complications, and enhance recovery.

3.4. Management of Proximal Ureteral Stones

For proximal ureteral stones, both ESWL and fURS are recognized as first-line treatments, with fURS often achieving higher SFRs and lower retreatment rates than ESWL. Both initial and more recent studies support fURS's high efficiency in this context, particularly for stones smaller than 1 cm [28]. A systematic review found URS, including fURS, to be particularly effective for stones larger than 10 mm [31]. Thus, fURS stands out as a strong candidate for treating proximal ureteral stones, especially those resistant to ESWL or of larger size.

3.5. Management of Urinary Stones in Special Situations

3.5.1. During Pregnancy

Although urolithiasis is uncommon during pregnancy, it stands as the leading non-obstetric reason for hospital admissions. Studies, such as one by Swartz et al., have shown that pregnant women hospitalized for urolithiasis face a higher risk of preterm delivery compared to those admitted for other non-obstetric reasons [32]. However, undergoing nephrolithiasis interventions does not significantly alter obstetric complication rates. Up to 20% of pregnant patients with nephrolithiasis might need procedural interventions. Deferred treatment is less favored during pregnancy, especially in the early trimesters, due to the complications like increased encrustation and blockage of ureteric stents and nephrostomy tubes, necessitating frequent replacements [33]. Moreover, ESWL is contraindicated during pregnancy due to the potential fetal risks. Consequently, fURS becomes a preferred treatment option during pregnancy, proven safe and effective through initial applications by Rittenberg and Bagley [34] and subsequent successful treatments by Watterson et al., achieving an 89% SFR without postoperative complications [35].

3.5.2. Pediatric Urolithiasis

Recent advancements in minimally invasive techniques have shifted pediatric urolithiasis management towards endourologic procedures such as ESWL, URS, and PCNL. This transition has been facilitated by technological progress and miniaturization of instruments. Despite initial reservations due to potential instrument-related complications, fURS is now a significant method for treating upper urinary tract stones in children, applicable even in preschoolers. Reports from Tan et al. [36] and larger cohort studies, like Kim et al.'s [37], demonstrate the efficacy and safety of fURS in pediatric patients, highlighting the minimal intraoperative and postoperative complications and high SFRs.

3.5.3. Patients with Renal Anomalies

Treating urolithiasis in patients with renal anomalies presents unique challenges due to abnormal vascular and anatomical considerations. ESWL often fails in these cases due to impaired drainage or targeting difficulties, while more invasive methods pose a risk of damage to abnormal vasculature or adjacent organs. fURS, however, offers a less invasive alternative with a lower complication rate, proving effective in patients with conditions such as horseshoe kidney and pelvic ectopic kidneys, as demonstrated in studies by Weizer et al. and others, showing significant success rates and minor complications [38].

3.5.4. Anticoagulated Patients

For patients on anticoagulation therapy or with bleeding disorders, traditional treatments like PCNL or ESWL pose significant bleeding risks. fURS, combined with Holmium: YAG laser lithotripsy, has been shown to be a safe and effective alternative, with studies like Watterson et al.'s [39] and Turna et al.'s [40] pair-matched analysis confirming its safety and comparable SFRs without increasing the risk of complications.

3.5.5. Obese Patients

Obesity, which is linked to a higher incidence of urolithiasis, complicates treatment due to factors like decreased ESWL success rates and the increased complexity of PCNL in obese patients. However, the effectiveness of fURS in treating upper tract stones in obese individuals has been well documented, with studies indicating that the procedure's success and complication rates are not influenced by the patient's body mass index, making it a viable option for this patient group [41].

4.FLEXIBLE URETERORENOSCOPY BEYOND UROLITHIASIS

The clinical applications of fURS extend beyond the realm of stone management, playing a pivotal role in treating various specialized urological conditions such as para-pelvic cysts, calyceal diverticula, and PUJ strictures [42-44].

The intricate management of calyceal diverticula with fURS exemplifies the nuanced decision-making process in urology, particularly when choosing between fURS and PCNL. This choice hinges on several anatomical considerations, including the diverticulum's location, size, and the infundibulum's length. fURS offers a minimally invasive route to address these diverticula, prioritizing patient comfort and recovery [45].

The procedural approach involves navigating the fURS to the renal pelvis, followed by the identification and subsequent laser incision of renal cyst walls or diverticula for effective drainage. The procedure commences with the fURS's navigation into the intra-renal collecting system, followed by the injection of a contrast agent mixed with methylene blue or indigo carmine through the scope's working channel. This step is pivotal for opacifying the diverticulum under fluoroscopic guidance, revealing the patency of the diverticulum's neck. A subsequent saline flush of the intra-renal system aids in observing any dye leakage from the diverticulum, with delayed emptying suggesting a narrow neck—a critical factor in planning the treatment approach [46].

A key moment in the procedure involves the introduction of a laser fiber, typically ranging from

350 to 400 µm, through the scope's working channel to incise the neck of the diverticulum, enabling access to the diverticulum for stone management. The choice between fragmenting the stone in situ or extracting it intact with a nitinol grasper is made based on the stone's characteristics and the diverticulum's anatomy. The final step involves a generous laser incision to marsupialize the diverticulum into the collecting system, ensuring effective drainage and preventing recurrence. The procedure concludes with a thorough inspection for any residual fragments and the placement of a ureteral stent, facilitating healing and ureteral patency. The strategic placement of a ureteric stent post-incision facilitates optimal healing, with its removal typically occurring after four weeks, signifying a minimally invasive yet effective intervention strategy [45,46].

Beyond calyceal diverticula, fURS's versatility extends to the management of PUJ obstructions and ureteral strictures through retrograde endopyelotomy and endoureterotomy, respectively. In addressing ureteral strictures, the procedure's success hinges on accurately locating the stricture, for a full-thickness incision, tailored according to the stricture's position, to mitigate vascular injury risk. These procedures underscore fURS's capability in addressing obstructions with precision, employing laser technology for incisions and utilizing balloon catheters for dilation, followed by stenting to ensure the urinary tract's integrity. This delineates the nuanced and precise application of fURS in managing complex renal and ureteral pathologies, underscoring its versatility and efficacy [7,43,44].

Antegrade fURS represents a specialized approach for cases where retrograde access is challenging, such as in urinary diversions. This method places additional mechanical stress on the scope but allows for direct intervention from the renal collecting system, illustrating fURS's adaptability in complex urological scenarios [47].

Lastly, in the evolving landscape of urology, the last two decades have underscored the significance of ureteroscopic biopsy in the diagnosis and selection of patients for the endoscopic treatment of upper tract urothelial carcinomas. The management of urothelial tumors has seen significant advancements with fURS, especially in preserving renal function in patients with solitary kidneys, chronic renal insufficiency, or bilateral disease. This technique's refinement is paramount for ensuring accurate histological characterization, which is foundational for tailoring patient-specific management strategies. The introduction of Nitinol baskets has been a notable advancement, facilitating effective histological sampling of papillary lesions and enhancing the diagnostic precision for tumors exceeding 1 cm in size and of those presenting as multifocal. This has opened avenues for the conservative management of these tumors through laser photo-ablation, highlighting the minimally invasive potential for treating upper tract urothelial carcinoma [7,48,49].

5. CONTRAINDICATIONS AND COMPLICATIONS

The landscape of endourology has greatly evolved with the advancement of endoscope technology, making fURS a highly versatile and minimally invasive procedure for the management of various urological conditions, especially urolithiasis. Despite its wide applicability and suitability even in situations where PCNL and ESWL may not be the preferred options, due to specific contraindications or unsuitability, fURS has remarkably few contraindications. Other than general considerations like anesthetic contraindications and untreated urinary tract infections, fURS is notably devoid of specific contraindications, showcasing its potential as a universally applicable procedure within the scope of endourology.

The utilization of fURS has expanded, driven by technological advancements in endoscope design and an increase in the procedural expertise among urologists. This expansion has been accompanied by a significant decrease in associated morbidity, making fURS a relatively safe procedure with a low complication rate. Data from the large-scale, prospective Clinical Research Office of the Endourological Society (CROES) study, which included 11,885 patients across 114 centers in 32 countries, sheds light on the safety profile of fURS. Within this cohort, 15% of patients underwent fURS exclusively for stone treatment, while an additional 10.7% received a combination of semirigid and fURS. The study reported an overall postoperative

complication rate of merely 3.5%, with the vast majority of complications being minor (Clavien grade 1 or 2), amounting to 2.8% [50].

Significant complications were rare, with only 0.2% of the patients requiring a blood transfusion postoperatively. The study also reported five mortalities within the 30-day postoperative period, attributed to severe complications such as sepsis, lung embolism, multi-organ dysfunction, and cardiac issues. Notably, the readmission rate post-fURS was reported at 8.4% three months postoperatively, predominantly due to flank pain and discomfort related to the ureteral stent. A separate subgroup analysis within the study found no significant difference in postoperative complications or readmission rates between semi-rigid URS and fURS, further emphasizing the procedure's safety across its different modalities [50].

These findings underscore the safety and efficacy of fURS in the management of urological conditions, particularly urolithiasis. While acknowledging the potential for complications, the procedure's low complication rate, coupled with its broad applicability, makes it a valuable tool in the armamentarium of modern endourology. The continual advancements in endoscopic technology, alongside the growing expertise among urologists, are likely to further enhance the safety profile of fURS, cementing its role as a preferred minimally invasive treatment option for a wide array of urological conditions.

6. CONCLUSIONS

The evolution of fURS marks a significant advancement in the management of urolithiasis and other complex urological conditions. This review has highlighted the procedure's versatility, efficacy, and the technological progress that has expanded its applications beyond stone management to include treatment of urothelial tumors, calyceal diverticula, and more, even in challenging scenarios like pregnancy or pediatric cases. With a focus on surgical techniques, preoperative considerations, and the use of innovative disposables, fURS has demonstrated low complication rates and high success rates, establishing itself as a minimally invasive yet highly effective option in endourology. The future of fURS looks promising, with ongoing advancements expected to further enhance patient outcomes and solidify its role in modern urological practice.

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