

Research Progress on Flexible Ureteroscopy

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Abstract

The ureteroscopic surgical technique has developed rapidly in recent years and has become an important method of urological surgery. The manufacturing and production of corresponding ureteroscopes are also constantly improving. This article systematically reviews and analyzes existing literature, summarizes the characteristics of various ureteroscopes in recent years, studies the advantages and disadvantages of ureteroscopes with different characteristics, summarizes relevant clinical experience in the use of ureteroscopes, and provides preliminary prospects for the future development of ureteroscopes. The results indicate that disposable electronic ureteroscopes and robotic ureteroscope systems may be an important development direction in the future.

Keywords

Urinary Stones, Disposable Ureteroscope, Repeatable Ureteroscope, Research Progress

1. Introduction

Kidney stones and ureteral stones are common urinary diseases in clinical practice, among which upper ureteral stones are particularly common, and the movement of stones in the ureters will cause a series of clinical manifestations in patients, such as fever, hematuria, waist and abdominal pain, frequent urination, urgency, dysuria, etc. If the obstruction persists, it will eventually cause hydronephrosis, empyema, atrophy and necrosis. Therefore, it is very important for stone patients to receive immediate and effective treatment. In the clinical treatment of stone patients, the choice of drug stone expulsion often has limited effect, and patients are increasingly pursuing efficient, minimally invasive and safe treatment from laparoscopic incision to percutaneous nephrolithotomy to rigid and flexible ureteroscopy. A variety of different surgical methods provide patients with more choices, among which the flexible ureteroscope has a flexible mirror body, which

can play a better role in the upper ureter, renal pelvis and renal calyces, making the non-invasive ureteroscope holmium laser lithotripsy gradually become the first choice for the treatment of upper ureteral stones and kidney stones, and clinical practice has proved that it does have higher safety, better stone removal rate and fewer complications. With the continuous advancement of flexible ureteroscope manufacturing technology, it has gradually become widely recognized around the world. It has become a commonly accepted surgical treatment for stone patients [1].

2. Classification of Flexible Ureteroscopy

So far, there are two types of flexible ureteroscopes: disposable and reusable. Endoscope manufacturers continue to incorporate new technologies, which makes flexible ureteroscopes continuously improved. Durability, vision clarity, and bendability are all improving. These advances have led to a significant improvement in the surgical results of flexible ureteroscopy [2].

2.1. Reusable Flexible Ureteroscopes

Reusable flexible ureteroscopes have certain advantages in terms of cost. However, the service life, cleaning and disinfection and maintenance costs will have some negative effects on the surgical effect, which are unavoidable problems in the use process [3]. The main injuries to reusable flexible ureteroscopes are most commonly located in the imaging system and the bend. At the same time, the operator's proficiency, use scenarios and usage methods will also have an impact on its service life [4].

2.2. Disposable Flexible Ureteroscopes

In order to extend the life of the flexible ureteroscope and strive to reduce the cost of repair or manufacturing, manufacturers have developed disposable flexible ureteroscopes. Disposable flexible ureteroscopes are a valuable alternative to reusable flexible ureteroscopes due to their better clarity and more efficient performance [5]. Studies have shown that disposable flexible ureteroscopes and reusable flexible ureteroscopes have similar performance in terms of operability and bendable angles [6].

3. Problems in the Use of Flexible Ureteroscopy

3.1. Cost Effectiveness

The cost-effectiveness of using disposable and reproducible flexible ureteroscopes remains controversial [7]. The cost analysis of a reusable flexible ureteroscope must consider the purchase price, maintenance and repair costs, and disinfection and sterilization costs. Reusable flexible ureteroscopes have high acquisition and maintenance costs. In the process of research and development by engineers, the diameter of the flexible ureteroscope is constantly decreasing and becoming more refined. Maneuverability continues to improve, but stiffness and flexibility decrease,

so maintenance costs are greatly increased. After the first breakage, the device often needs to be repaired frequently [8]. In contrast, disposable flexible ureteroscopes have obvious advantages in terms of maintenance costs and acquisition costs. Only the purchase price is included in the cost analysis of a flexible disposable ureteroscope. Disposable flexible ureteroscopes may cost less per procedure than reusable flexible ureteroscopes [9].

3.2. Equipment Wear and Tear

Disposable flexible ureteroscopes do not incur maintenance or repair costs and can provide consistent performance from procedure to procedure. Due to the angle of ureteral flexion and visibility, it can also be challenging to quickly and safely manipulate the flexible ureteroscope to the target area. Improper operation often leads to urinary system damage, resulting in intraoperative bleeding, affecting the surgical vision, reducing surgical efficiency, and increasing the loss of flexible ureteroscope [10]. Therefore, for hypohalite calculi and cast stones, disposable flexible ureteroscopes should be used instead of reusable flexible ureteroscopes, so as to reduce the loss of instruments, reduce the cost of consumables, and improve the utilization rate of flexible ureteroscopes. The length of the flexible ureteroscope will also affect the intraoperative operation and service life. Studies have shown that the water flow rate of a 45 cm flexible ureteroscope is higher than that of a standard-length flexible ureteroscope. But there is no significant advantage in terms of bending angle [11]. In order to reduce maintenance costs and extend the service life of flexible ureteroscopes, it is necessary to improve the material and function of the mirror body. For example, damage to the deflection site of a reusable Olympus flexible ureteroscope is less common. However, the distal externally curved rubber deflection tip is the most common site of injury to Olympus flexible ureteroscopes [12]. Compared with reusable flexible ureteroscopes, disposable flexible ureteroscopes have a clearer field of view and are more operational. However, there are no definitive data to show that the use of disposable flexible ureteroscopes improves stone clearance or reduces complications [13]. Disposable digital flexible ureteroscopes can be routinely used for the examination and treatment of urological diseases, especially in healthcare facilities where sterilization facilities are inadequate. Therefore, each medical institution must first analyze the local medical resources and medical costs, and then decide on the purchase of the corresponding flexible ureteroscopy equipment.

4. Direction of Development of Flexible Ureteroscopy

Flexible ureteroscopy is also one of the indispensable means in the diagnosis and treatment of diseases in urology today, flexible ureteroscopy can be used for early detection and diagnosis of various urinary tumors, stones, polyps and other diseases, in recent years, the introduction and popularization of robotic systems, digital and disposable flexible ureteroscopy have expanded the role of flexible ureteroscopy in the treatment of urological diseases.

4.1. Surgical Robotic Systems

For example, surgical robotic systems, due to their excellent ergonomics, have revolutionized the way urology is surgical. Robotics has been maturely applied to many urological procedures, such as nephrectomy, prostatectomy, and many more. However, the use of robotic systems for flexible ureteroscopes remains a huge challenge [14].

The Avicenna Robflex surgical robot was developed to provide all the necessary functions for flexible ureteroscopes. It consists of a small console with an integrated flat screen and two joysticks for moving the endoscope, which is fixed by a robotic arm and controlled by a console, and two fluoroscopes and a laser lithotripsy that are activated by a console pedal. Geavlete *et al.* [15] conducted a study of the Avicenna Roboflex surgical robot and compared the surgical effects of the robot with a conventional flexible ureteroscope in 132 patients. The processing time (51 min and 50 min) and fragmentation time (37 min vs. 39 min) were similar. However, the rate of stone removal was higher when surgery was performed with robotic systems (92.4% vs. 89.4%). However, in the process of stone removal operated by their robotic system, the doctor still does it manually, as a fully automated system has not yet been achieved.

4.2. Disposable Flexible Electronic Ureteroscope

Boylu *et al.* [16] combine six commonly used ureteroscopes, including the Olympus URF-P3, Storz(R) 11278AU and 11274AAU, ACMI DUR-8 Elite and DUR-8, and Wolf 7331.001 (Richard Wolf Medical Instruments, Vernon Hills, Illinois), with the recently introduced SemiFlex Scope disposable flexible ureteroscope was compared. The disposable ureteroscope consists of an eyepiece and a semi-flexible shaft with a 3.3Fr working channel. The results show that compared to other flexible ureteroscopes on the market, the deflection angle, visual clarity and water flow rate of the disposable flexible ureteroscope are better. This also provides more references for expanding the use scenarios of disposable flexible ureteroscopes. The Karl Storz FLEX-XC1 is a new disposable flexible ureteroscope with the same imaging system as a reusable ureteroscope. In its studies, the FLEX-XC1 was found to be comparable in image quality and operability compared to reusable flexible ureteroscopes. However, the FLEX-XC1 may have significant advantages in long-term surgical operations that require high visual clarity [17]. In recent years, endoscopy designers have placed electrically coupled device chips at the tip of endoscopes. This allows images to be instantly digitized and converted into electrical signals for transmission. Digital technology was first introduced into flexible cystoscopy, followed by ureteroscope and flexible ureteroscopy. The development of digital flexible ureteroscopes represents a major technological advancement in urology. Compared with the traditional flexible optical ureteroscope, the image of the new generation of digital flexible ureteroscope has obvious advantages, and the resolution and color contrast are significantly improved, so the disposable flexible electronic ureteroscope technology will inevitably become a hot research direction

in the future of urology [18].

5. Clinical Experience in the Use of Flexible Ureteroscopy

5.1. Common Causes of Damage to Ureteroscopes

At present, there are still many problems in the application of flexible ureteroscope, and the loss of many instruments is caused by improper use. Sung *et al.* analyzed the types of flexible ureteroscope injuries, causes of injury, and repair costs from four major ureteroscope manufacturers (ACMI, Olympus America, Karl Storz, and Richard Wolf). It has been found that for flexible ureteroscopy, the frequency of repair increases as the diameter of the flexible ureteroscope decreases and the length of the instrument increases. Small-diameter flexible ureteroscopes are much more mobile and passable, but they are also more fragile. Common causes of flexible ureteroscope injuries include burns to the lens and lens body during laser use. There is also damage to the working passage caused by the passage of instruments, such as guidewires, stones, nets, baskets, etc., as well as deflection injuries at extreme angles after indwelling instruments. It is also caused by excessive distortion and improper handling during aseptic processing in the operating room [19].

5.2. Experience Sharing on Reducing Instrument Wear and Tear

In the process of surgery, doctors can actually take corresponding precautions to avoid these injuries, such as mastering the length of the laser extending out of the lens and controlling the distance of the gravel to avoid high-energy thermal injury. In the renal calyces, it can be combined with a stone removal basket to avoid excessive deflection, and the operation can be gentle during the insertion of instruments and stone removal, so as to remove the stone residue immediately, and avoid friction and damage to the lens body in the ureteroscope sheath, at the same time, in the process of moving, storage, cleaning and disinfection, pay attention to protecting the lens body to avoid artificial damage. All of these methods can help us minimize the cost of flexible ureteroscope repairs. Therefore, it is important that doctors and staff are aware of these issues and take appropriate measures to maximize the life of flexible ureteroscopes.

6. Summary

Literature Research Methods

In this paper, we retrospectively analyzed the relevant literature on flexible ureteroscopy, and obtained more comprehensive and accurate information about flexible ureteroscopy. In the course of the study, we first asked the search question of “development of flexible ureteroscope”, and then selected databases for searching, browsed the preface of the abstract and excluded irrelevant literature, intensively read the literature to identify the core literature, clarify new discoveries and new progress in the literature, and make excerpts and summaries, and finally summarized and discussed the relevant literature. This paper comprehensively analyzes and

summarizes the research status, achievements, problems and development trends of flexible ureteroscopy, and comprehensively understands the research trends and progress in this field.

Recently, there have been more improvements in the use of flexible ureteroscope, such as disposable digital endoscopes with better visibility and flexibility, high-power lasers, thulium fiber lasers, smaller laser fibers and accessories, all of which have made the use of flexible ureteroscopes more effective and safer. Thulium fiber lasers are gaining acceptance in combination with a variety of suction devices and can significantly improve the stone removal rate while reducing the loss of flexible ureteroscopy [20]. With the development of science and technology, flexible ureteroscopes can be distinguished based on several core functions. The imaging principle, deflection angle and water flow irrigation characteristics of flexible ureteroscopes are slightly different from each manufacturer, and in the future, new technologies will be gradually integrated into the R&D and manufacturing of flexible ureteroscopes, including sensors for monitoring intrarenal pressure and temperature, immediate suction of stones and negative pressure devices to maintain low pressure in the renal pelvis, and computer imaging for artificial intelligence. These techniques will bring different benefits to the development of flexible ureteroscopes [21]. In summary, ureteroscopy has evolved from optical ureteroscopy to electronic ureteroscopy, from single-function ureteroscopy to multifunctional composite ureteroscopy, and even developed robotic ureteroscopy systems. These advances indicate that ureteroscopy is becoming an increasingly important surgical method in urology. The advancement of science and technology has brought better results to clinical treatment, and the extensive clinical experience has also pointed out the direction for the future development of ureteroscopy.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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