

Role of Suction Ureteral Access Sheath in Controlling Intrarenal Pressure and Enhancing Renal Stone Surgery Safety: A Review of Mechanisms and Clinical Evidence

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Abstract

Renal calculi represent a common urological condition, with retrograde intrarenal surgery (RIRS) emerging as the primary treatment modality due to its minimally invasive nature and high efficacy. Elevated intrarenal pressure during RIRS frequently leads to complications such as infection and renal tissue injury, which significantly compromise surgical safety. The suction ureteral access sheath (SUAS), an innovative device, effectively controls intrarenal pressure through active suction, thereby improving surgical visualization and enhancing lithotripsy efficiency. The SUAS has shown to be very useful in clinical practice, and it has become an important tool for making kidney stone surgery safer and more effective. This paper aims to systematically explore the application value of the SUAS to control intrarenal pressure and perform kidney stone surgery, providing theoretical support for clinical practice. The results of related studies have indicated that the SUAS can effectively reduce the peak intrarenal pressure, improve the surgical field, and increase the efficiency of lithotripsy through the mechanism of “perfusion-absorption balance”, thus significantly reducing the postoperative fever, urogenital septicemia, and re-operation rate, especially in complex stones and high-risk groups. In this paper, it can be concluded that the SUAS is a key tool for controlling intrarenal pressure in RIRS, which can significantly improve the safety and effectiveness of surgery and has a broad clinical application prospect.

Keywords

Suction Ureteral Access Sheath, Intrarenal Pressure, Kidney Stones, Retrograde Pyeloscopy, Surgical Safety

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1. Introduction

1.1. Trends in Minimally Invasive Treatment for Kidney Stones

As a highly prevalent and recurrent urological condition, urinary tract stones have long imposed a significant burden on patients' quality of life and healthcare resources. With continuous advances in medical technology, treatment modalities for kidney stones are undergoing profound transformation, with traditional open surgery gradually being replaced by minimally invasive techniques. Among various minimally invasive approaches, retrograde intrarenal surgery (RIRS) has rapidly emerged as a key treatment option for kidney stones due to its significant advantages: minimal trauma, rapid recovery, and low complication rates. Utilizing flexible ureteroscopes, RIRS enables precise navigation within the kidney's complex anatomy to accurately locate, fragment, and extract stones, thereby enhancing surgical safety and therapeutic efficacy. With continuous improvements in endoscopic equipment performance and increasingly mature surgical techniques, the clinical application of RIRS has significantly expanded globally. It demonstrates exceptional efficacy, particularly in managing small- to medium-sized kidney stones, gradually establishing its dominant position in the field of minimally invasive treatment. The widespread adoption of RIRS has also driven the development of related auxiliary technologies, further optimizing surgical procedures and patient outcomes [1] [2]. RIRS not only represents the technological frontier in kidney stone treatment but also embodies the trend toward precision and minimally invasive approaches in modern urology.

1.2. High Intrarenal Pressure in RIRS and Its Pathological Implications

Under normal circumstances, intrarenal pressure is maintained in a low physiological range to safeguard the normal perfusion and function of renal tissues [3]. Intrarenal pressure is usually maintained at 5 - 10 mmHg under physiological conditions, whereas it can be elevated to 30 - 40 mmHg or even higher during RIRS due to the continuous perfusion and restriction of the outflow tract. Abnormal elevation of intrarenal pressure is a key factor leading to intraoperative and postoperative complications in RIRS. During RIRS procedures, renal pressure frequently increases significantly due to multiple factors, including continuous irrigation fluid infusion, urinary tract strictures, and instrument manipulation. Elevated renal pressure not only induces pyelovenous reflux, allowing bacteria and toxins to enter the bloodstream and increasing systemic infection risk, but may also cause bacterial translocation, triggering severe complications such as postoperative fever and sepsis. Gauhar *et al.* demonstrated through a multicenter study that effective renal pressure control plays a crucial role in reducing intraoperative infection rates and minimizing postoperative complications [4]. Castellani *et al.* emphasized that elevated renal pressure is closely associated with postoperative fever and sepsis. Appropriate regulation of renal pressure can significantly reduce the incidence of these adverse events, thereby enhancing overall surgical safety

and patient outcomes [5]. In-depth exploration of the physiological mechanisms underlying abnormal elevations in intrarenal pressure and their pathological effects holds significant clinical importance for optimizing RIRS surgical procedures, developing effective intrarenal pressure control strategies, and enhancing the safety and efficacy of minimally invasive treatments. Combined with advanced suction technology, precise regulation of intrarenal pressure during surgery is anticipated to further reduce intraoperative risks and ensure patient surgical safety.

1.3. Introduction of the SUAS for Intrarenal Pressure Control and Objectives of This Study

Conventional renal pressure control techniques predominantly depend on passive drainage and pharmacological modulation. However, these approaches exhibit significant limitations in clinical practice, including inefficient drainage, pronounced pressure fluctuations, and inadequate prevention of intraoperative infections. Mao Penglei *et al.* noted that traditional techniques fail to meet the precise IEP control demands of complex nephrolithotomy procedures, significantly increasing postoperative complication risks [6]. To address this challenge, the SUAS was introduced as an innovative auxiliary device. This device creates a low-pressure environment, which helps drain intrarenal fluids quickly and keep pressure stable. This greatly improves visibility during surgery and makes the procedure safer and more effective. Kunwu Yan *et al.* demonstrated that combining suction with flexible endoscopy effectively reduces intrarenal pressure, lowers intraoperative infection rates, and significantly improves surgical success rates [7]. Chen Ning *et al.* further validated the safety and efficacy of SUASs in elderly patients, highlighting their broad application potential in special populations [8]. Against this backdrop, this paper aims to systematically evaluate the pressure control mechanisms, clinical benefits, and future development prospects of SUASs for ureteroscopy. It aims to establish solid theoretical foundations and practical guidance for urology, fostering ongoing enhancements in the safety and effectiveness of minimally invasive treatments for kidney stones.

2. Working Principles and Technological Evolution of SUASs

2.1. Structural Innovation: From Channel Establishment to Pressure Management

Traditional ureteral sheaths primarily serve to establish access and protect the ureter during kidney stone surgery. However, they exhibit significant limitations in controlling intrarenal pressure, often leading to intraoperative increases that heighten risks of infection and tissue injury. To address this challenge, innovative SUASs have emerged recently. These sheaths have a dual-lumen design that combines the creation of passageways with the control of pressure. This design ensures smooth passage of surgical instruments and effectively drains intrarenal fluid through the suction mechanism in both inner and outer lumens. This significantly reduces intrarenal pressure and optimizes the surgical field of view. Advances in

materials science provide a solid foundation for enhancing the performance of sUASs. The application of hydrophilic coatings substantially reduces friction between the sheath and ureteral walls, improving insertion smoothness and patient comfort. The use of compliant materials enhances the sheath's adaptability, minimizes mechanical irritation to the ureter, and lowers the incidence of intraoperative complications. Cacciatore *et al.* noted that structural innovations in suction sheaths markedly enhance surgical safety and efficiency [9]. Gauhar *et al.* further underscored that the integration of flexibility and a hydrophilic coating facilitates a wider and more dependable utilization of suction sheaths in intricate scenarios [10]. Cristallo *et al.* clinically validated this design's positive effects in reducing intrarenal pressure and postoperative infections [11]. Through dual innovations in structure and materials, SUASs overcome the functional limitations of traditional ureteral sheaths. They provide safer, more efficient technical support for minimally invasive kidney stone surgery, advancing the progress and development of urological surgery.

2.2. "Irrigation-Suction Balance" Mechanism: A Breakthrough in Fluid Dynamics

The "irrigation-suction balance" mechanism is the main new idea behind ureteral SUAS technology. It uses the principles of fluid dynamics. By synchronizing irrigation and suction, it effectively establishes and maintains dynamic equilibrium of renal pelvic pressure. In conventional retrograde pyeloscopy procedures, continuous irrigation fluid infusion often elevates intrarenal pressure, increasing risks of intraoperative infection and renal tissue injury—potentially leading to severe postoperative complications. The suction sheath prevents abnormal pressure surges by setting an optimal suction value to promptly drain excess irrigation fluid, thereby avoiding accumulation within the renal pelvis and safeguarding renal environment stability. Zhu *et al.* noted that this mechanism not only significantly improves surgical visualization clarity and reduces peak intrarenal pressure but also enhances lithotripsy efficiency and overall procedural safety [12]. Zeng *et al.* further validated the significant advantages of SUASs in renal pressure control through a multicenter randomized controlled trial, emphasizing their clinical value and potential for widespread adoption in complex kidney stone treatment [13]. The mechanism relies on a precise suction regulation system and an efficient fluid drainage pathway. Their synergistic action ensures a dynamic equilibrium between irrigation and suction fluid flow rates, preventing excessive fluctuations in renal pelvic pressure. The "irrigation-suction equilibrium" mechanism not only provides a robust theoretical foundation for effective renal pressure control but also establishes a crucial practical safeguard for enhancing the safety and efficacy of minimally invasive kidney stone surgery.

2.3. Technological Iteration and Model Selection

The first-generation ureteral suction sheath was the start of a new era in technology

for controlling renal pressure. Giulioni *et al.* demonstrated through multicenter registry data that the first-generation sheath significantly reduced intraoperative renal pressure and infection complications. However, its rigid structure imposed operational limitations in complex anatomical settings, restricting its applicability [14]. To overcome this limitation, subsequent development led to the creation of flexible SUASs. SUASs have unique advantages over other intrarenal pressure control strategies. Traditional methods, such as manual low-pressure perfusion, depend on the operator's experience and result in unstable pressure control. While vacuum-assisted lithotripsy sheaths can provide some drainage, they lack an active, adjustable suction system, making their efficiency and stability inferior to that of specialized SUASs. Additionally, intelligent pressure control systems can dynamically adjust the perfusion pressure; however, they are expensive and complicated to operate. The SUAS achieves "irrigation and suction balance" through active drainage, providing not only more accurate pressure control but also synchronized removal of stone fragments; thus, its dual function of pressure control and stone removal represents one of the most comprehensive advantages of this technology. GAUHAR *et al.* reported in a global multicenter prospective study that this model, with its flexible design, better conforms to the natural curvature of the renal pelvis and ureter. This significantly enhances surgical adaptability and lithotripsy efficiency, demonstrating superior clinical outcomes, particularly in complex cases [15]. Personalized selection of suction sheaths with varying inner and outer diameters based on patient-specific factors—stone size, location, and ureteral anatomy—emerged as a key strategy to enhance surgical safety and success rates. GAUHAR *et al.* further emphasized that rational model selection not only optimizes active suction efficacy and effectively reduces the risk of intraoperative mechanical injury but also provides a robust theoretical foundation and practical guidance for clinical implementation [16]. The continuous iteration and model diversification of ureteral suction sheath technology have significantly advanced its widespread application in minimally invasive kidney stone treatment, markedly enhancing surgical safety and efficacy while demonstrating broad clinical prospects.

3. Core Clinical Evidence and Multidimensional Benefits

3.1. Direct Evidence for Intrarenal Pressure Control and Infection Prevention

Research on ureteral SUASs in renal pressure control has deepened progressively. Gauhar *et al.* systematically assessed the regulatory impacts of SUASs on renal pressure utilizing animal models and clinical intraoperative pressure monitoring. The SUAS significantly lowered peak intraoperative renal pressure, reduced fluid retention in the renal pelvis, and thus lowered the risk of infection after surgery. By maintaining dynamic equilibrium within the renal environment, this technology suppresses the potential for bacterial retrograde infection, demonstrating its crucial role in protecting renal tissue and preventing infection [17]. Similarly, Castellani *et al.* conducted a clinical study involving 540 patients, comparing SUASs

with traditional surgical methods regarding postoperative fever rates, bacteremia, and urinary-related sepsis incidence. Patients using the SUAS exhibited significantly lower postoperative fever rates and markedly reduced incidence of severe infectious complications, further validating the clinical value of this technology in infection control [18]. The multicenter clinical study by Castellani *et al.* (n = 540), which used a control group design, provided moderately strong evidence that SUASs are effective in reducing postoperative febrile and infectious complications; however, it lacked the support of a large-scale randomized controlled trial (RCT), and the strength of the evidence was only moderate. These findings provide robust theoretical and practical support for enhancing the safety of minimally invasive kidney stone surgery, driving the widespread clinical adoption and promotion of this technology.

3.2. Enhanced Stone Clearance Efficiency and Prevention of Stone Retention

Stable intraoperative visualization and timely removal of fragmented stones are critical factors in improving stone clearance efficiency. Quandong Zhang *et al.* noted that employing passive bendable SUASs in patients with intricate renal stones markedly improved intraoperative visualization clarity, thereby minimizing interference during stone fragmentation. This led to a marked increase in one-stage stone clearance rates and a decrease in postoperative residual stone incidence [19]. Haichao Chen *et al.* further indicated that the SUAS, through continuous suction and drainage, promotes the timely expulsion of lithotripsy fragments. This procedure effectively prevents accumulation of fragments within the ureter, significantly reducing the risk of stone street formation. Consequently, it decreases the reintervention rate for patients, ensuring surgical safety and efficacy [20]. Lingchao Meng *et al.* utilized SUASs in the management of unilateral duplicated kidney-ureteral anomalies complicated by upper urinary tract calculi. They confirmed that this approach not only enhances lithotripsy efficiency but also effectively reduces postoperative residual fragments and complications caused by stone bridges, demonstrating the technology's broad applicability and clinical value in complex cases [21]. The SUAS greatly increases the primary stone clearance rate in nephrolithotomy by improving intraoperative fluid dynamics, stabilizing the surgical field, and making it easier to quickly remove lithotripsy fragments. It also effectively prevents stone retention, reduces the need for postoperative reintervention, and provides robust technical assurance and clinical support for minimally invasive kidney stone treatment. Gonçalves *et al.* showed by meta-analysis that the use of SUASs significantly improved stone clearance rates and reduced complications and length of hospital stay [22]. The studies by Zhang *et al.* and Chen *et al.* were observational case series with small samples and no control group and had low strength of evidence, whereas the meta-analysis by Gonçalves *et al.*, which integrated a number of studies, had a high quality of design, and the strength of the evidence was elevated to moderate to high.

3.3. Expansion of Surgical Indications

With continuous innovation and refinement of the SUAS, its feasibility, safety, and efficacy in treating >2 cm kidney stones have gained widespread clinical recognition. CHEN Y, *et al.* found in a randomized controlled study that flexible ureteroscopy combined with SUAS surgery would be a viable alternative to mPCNL for the treatment of 10-30 mm simple lower calyceal kidney stones [23]. Feng Zheng *et al.* systematically demonstrated that the SUAS effectively regulates intrarenal pressure, significantly reduces intraoperative infection risks, and enhances clearance efficiency for large stones, exhibiting superior safety and therapeutic outcomes compared to traditional surgical methods [24]. Yonglin Li *et al.* further highlighted the technique's unique protective role in patients with infected stones, demonstrating its ability to mitigate postoperative inflammatory responses, reduce complication rates, and thereby accelerate patient recovery [25] [26]. Based on this clinical evidence, relevant expert consensus has scientifically revised the indications for kidney stone surgery, explicitly recommending the SUAS as a crucial adjunctive tool for treating complex and large stones. This advancement promotes the rational expansion and optimization of surgical indications [26]. In terms of research design, it is easy to see that, the randomized controlled trial (RCT) by Chen Y *et al.* was rigorously designed and directly compared SUASs with minimally invasive percutaneous nephrolithotomy, with a high strength of evidence; however, other supportive studies (e.g., Zheng *et al.*) were observational in design, had limited samples, and had weaker evidence.

3.4. Value in Special Populations and Complex Scenarios

In the treatment of kidney stones in patients with solitary kidneys, preserving residual renal function is particularly critical. Shrestha *et al.* demonstrated through a multicenter prospective study that the SUAS effectively regulates intrarenal pressure, reduces mechanical injury to renal tissue and ischemic time during surgery, and thereby significantly lowers the risk of postoperative renal function deterioration. This highlights its crucial protective role in solitary kidney patients [27]. This finding has a significant impact on clinical practice, especially for patients with limited renal reserve, where the proper use of SUASs can enhance renal safety. Candela *et al.* conducted research that further validated the efficacy of SUASs in minimizing intraoperative blood loss and procedure duration for patients with bleeding tendencies or advanced age by sustaining stable intrarenal pressure and enhancing surgical visualization. This approach significantly enhances overall surgical safety and lowers the incidence of postoperative complications [16]. This advantage demonstrates the unique clinical value of SUASs in high-risk patient populations, providing robust assurance for minimally invasive treatment of complex cases. The multicenter prospective studies by Shrestha *et al.* and Candela *et al.* had large samples but lacked randomization and had a moderate strength of evidence; more RCTs are still needed to validate their value in patients with isolated kidneys and advanced age. By precisely controlling intrarenal

pressure and optimizing the surgical environment, SUASs significantly enhance surgical safety and efficacy, providing robust support for developing individualized treatment strategies and advancing minimally invasive kidney stone treatment to higher levels.

4. Technical Challenges, Limitations, and Cost-Effectiveness Analysis

4.1. Learning Curve and Intraoperative Operational Difficulties

Although the ureteral suction sheath offers significant benefits in nephrolithotomy, its implementation presents a challenging learning curve. Huang *et al.* noted that the depth and positioning of sheath placement critically impact surgical outcomes. Shallow placement compromises suction efficacy, while excessive depth risks renal pelvic tissue injury and elevated intraoperative hazards. Precise control of sheath positioning thus emerges as a key intraoperative challenge [28]. Kwok *et al.* further emphasized that suction settings must balance effectively reducing intrarenal pressure with preventing renal pelvic collapse. While excessively high suction enhances fluid drainage and lowers intrarenal pressure, it simultaneously increases the risk of renal pelvic collapse. This compromises surgical visibility and working space, thereby elevating surgical complexity and difficulty [16] [29]. Lua *et al.* conducted an in vitro simulation study to systematically analyze the effects of varying suction parameters on renal pelvis morphology. They proposed technical strategies for optimizing suction adjustment, stressing that surgeons should flexibly modify settings based on individual patient anatomy and surgical progression to ensure procedural safety and efficiency [30]. The effective utilization of SUASs depends not only on the surgeon's comprehensive anatomical understanding and substantial surgical experience but also on proficiency in suction adjustment techniques. This enables effective overcoming of the learning curve challenges during operation, thereby enhancing surgical safety and therapeutic outcomes.

4.2. Current Limitations in Clinical Application

Multiple limitations constrain the widespread adoption of SUASs for ureters, despite their significant clinical advantages in minimally invasive kidney stone surgery. For instance, ischemia of the ureteral wall may result from prolonged compression of the sheath or excessive suction, particularly in patients with ureteral stenosis or anatomical anomalies. The proximity of tissue to the sheath under suction may increase the risk of thermal injury during laser lithotripsy. Therefore, surgeons should carefully control the intensity of suction and the duration of the procedure intraoperatively, and they should avoid continuous high suction to reduce the probability of tissue injury. In addition, adding related equipment will always raise the cost of surgery. Against the backdrop of China's healthcare system, which has yet to fully cover such emerging technologies, the financial burden on patients has become a key factor limiting their broad application. Xiaojiang Wu *et al.* noted that while SUASs effectively reduce intrarenal pressure and en-

hance surgical safety, high equipment costs and inadequate medical insurance reimbursement policies limit their adoption in primary healthcare facilities [31]. Significant variations in structural design and suction regulation capabilities exist among different brands and models of SUAS, leading to prominent compatibility issues during clinical use. Baihua Shen and Yiwei Lin emphasized that inconsistent device performance not only disrupts the fluidity of surgical procedures but may also negatively impact surgical outcomes, increasing learning difficulties and operational risks for physicians [32]. Quan Yuan and Wei Tang further noted that the complexity of intelligent pressure control systems requires operators to possess advanced technical skills; otherwise, the equipment's advantages cannot be fully realized, limiting its adoption in certain medical institutions [33]. Liren Hu *et al.* also highlighted that compatibility issues become particularly pronounced when multiple brands of equipment are used concurrently, potentially causing surgical interruptions or device malfunctions that compromise surgical safety [34]. Increased costs, lagging medical insurance policies, device performance disparities, and compatibility issues constitute critical bottlenecks demanding urgent breakthroughs in the clinical application of SUASs. Future efforts should prioritize policy support and technical standardization to facilitate broader, safer implementation of this technology in clinical practice.

4.3. Preliminary Health Economic Evaluation

As an innovative auxiliary device, the ureteral SUAS requires higher initial procurement and maintenance expenses. However, its demonstrated clinical advantages lay the foundation for achieving economic benefits. Related studies indicate that by effectively controlling intrarenal pressure, this technology significantly reduces the incidence of intraoperative and postoperative complications such as infections. This, in turn, shortens patient hospital stays and reduces the need for follow-up treatments, leading to savings and optimization of medical resources [35]. The application of SUASs not only enhances surgical success rates and lithotripsy efficiency but also effectively shortens procedure duration. This alleviates operational burdens on healthcare institutions while reducing labor and equipment utilization costs [16]. From a medium-to-long-term perspective, despite substantial initial equipment investment, SUASs hold promise for optimizing overall healthcare expenditures by reducing complications and associated medical costs, thereby improving the cost-effectiveness of medical services. Therefore, health economic evaluations should comprehensively weigh the relationship between device costs and savings from reduced complications. By integrating large-scale, multicenter clinical data, these evaluations should thoroughly analyze the potential impacts on healthcare resource allocation and patient financial burdens. Only by carefully weighing both the economic benefits and the clinical value can strong theoretical support and practical advice be given for the widespread use of ureteral SUASs. This will propel minimally invasive kidney stone treatment toward safer, more efficient, and cost-effective directions.

5. Future Outlook

5.1. Technological Development Directions

As ureteral suction sheaths become more common in minimally invasive kidney stone surgery, related technologies are quickly moving toward smart and personalized solutions. HUANG *et al.* first reported a digitally integrated suction sheath system capable of real-time intrarenal pressure monitoring and dynamic suction adjustment, effectively reducing intraoperative complication risks while significantly enhancing surgical safety and efficacy [28]. At the same time, KWOK *et al.* stressed how important sheath size and biocompatible design are. They noted that employing thinner-diameter, softer-material sheaths not only reduces mechanical irritation to the urethra and ureter but also significantly improves postoperative patient comfort and recovery speed, thereby promoting postoperative rehabilitation [29]. LUA *et al.* explored the application prospects of novel highly biocompatible materials in SUASs from a materials science perspective. They propose that future sheaths will combine high strength with superior flexibility, further optimizing surgical experience and enhancing clinical efficacy [30]. The two main areas of focus for the advancement of ureteral SUAS technology are the creation of intelligent pressure sensing and feedback systems and the design of finer-diameter, higher-biocompatibility sheaths. The result not only heralds the arrival of more precise, safe, and user-friendly surgical assistance tools in this field but also provides a solid technical foundation for the safety and efficacy of minimally invasive kidney stone treatment. As related technologies continue to mature and undergo clinical validation, ureteral suction sheaths are poised to play an increasingly significant role in clinical practice, propelling minimally invasive urological surgery to new heights.

5.2. Clinical Research Needs

While current studies suggest that ureteral suction sheaths provide considerable benefits in regulating intrarenal pressure and improving surgical safety, the evidence predominantly derives from single-center or small-sample observational studies and is insufficiently supported by large-scale, multicenter randomized controlled trials (RCTs). Nedbal *et al.* noted in their multicenter prospective study that suction technology demonstrates good feasibility and safety in clinical practice, yet broader clinical data are needed to support its universal applicability and long-term efficacy [35]. It's also vital to assess kidney stone patients' recovery and quality of life post-surgery. Nevertheless, current research exhibits a constrained emphasis on patient-reported outcomes (PROs) and is deficient in systematic long-term follow-up data. The 2023 American Kidney Fund Core Curriculum emphasized that integrating patient subjective experiences with objective clinical indicators for comprehensive evaluation is essential when promoting new urological technologies [36]. Future clinical research should focus on conducting multicenter RCTs to systematically collect multi-dimensional data, including renal pressure control efficacy, infection rates, operative time, complication incidence, and patient quality

of life. This will enable a comprehensive evaluation of the clinical value and safety of SUASs. Through rigorous evidence-based medical research, a solid foundation will be established for the widespread application of this technology in minimally invasive kidney stone treatment, advancing it as a key method to enhance surgical safety and efficacy.

5.3. Integration Potential in Day Surgery and Precision Medicine Models

With continuous advancements in medical technology, the day surgery model is increasingly becoming a key development direction for minimally invasive kidney stone treatment due to its efficiency, convenience, and resource-saving advantages. PEERAPEN and THONGBOONKERD noted that the organic integration of precision nutritional intervention with minimally invasive surgery can significantly improve postoperative recovery quality, providing a solid theoretical foundation for the widespread promotion of day surgery [37]. In this context, KACHKOUL *et al.* emphasize that deepening insights into the etiology of urinary stones have led to increasingly mature individualized treatment plans. This development lays a solid foundation for optimizing and personalizing surgical approaches within the precision medicine model [38]. QUHAL and SEITZ further propose that advanced surgical aids—such as ureteral suction sheaths—effectively control intrarenal pressure and reduce intraoperative complication rates, thereby significantly enhancing the safety and success rate of day surgery [39]. Based on this, the organic integration of ureteral suction sheath technology into day surgery and precision medicine systems enhances surgical efficiency and patient satisfaction and aligns with the future trend of personalized, high-quality healthcare development. Looking ahead, with continuous technological refinement and accumulated clinical experience, ureteral suction sheaths are expected to play an even greater role within the precision medicine framework, propelling minimally invasive kidney stone treatment toward greater safety, precision, and efficiency.

6. Conclusion

The ureteral SUAS, as a crucial auxiliary device in retrograde intrarenal surgery (RIRS), significantly enhances the safety and efficacy of minimally invasive kidney stone treatment through its core function of effectively controlling intrarenal pressure. Proper regulation of intrarenal pressure not only reduces the risk of intraoperative infection and renal tissue injury but also optimizes the surgical field, providing surgeons with a clearer operating environment. This, in turn, improves surgical precision and lithotripsy efficiency. Clinical practice demonstrates that the suction sheath effectively lowers peak intrarenal pressure during surgery and reduces the incidence of postoperative complications, exhibiting particular advantages in complex kidney stones and special patient populations. The application of this technology broadens the indications for RIRS, enabling more patients to benefit from minimally invasive treatment and reducing the need for traditional open surgery. Although challenges remain in operational techniques and equipment costs, the vac-

uum-assisted sheath is poised to become a standard component of RIRS procedures as technology matures and clinical experience accumulates. Aligned with precision medicine principles and the advancement of same-day surgery models, the vacuum-assisted sheath will further propel kidney stone treatment toward safer, more efficient, and personalized outcomes. The ureteral suction sheath serves not only as an effective tool for renal pressure management but also as a crucial safeguard for elevating the overall standard of minimally invasive kidney stone surgery. Its broad application prospects are highly anticipated.

Conflicts of Interest

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

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