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Initial Results for Flexible and Navigable Suction Access Sheath (FANS) In Retrograde Intrarenal Surgery (RIRS)

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Abstract

Background: Urolithiasis is an increasingly prevalent condition, and retrograde intrarenal surgery (RIRS) has become a widely used minimally invasive treatment. However, conventional RIRS is limited by elevated intrarenal pressure, suboptimal visualization, and a higher risk of postoperative infectious complications.

Aim: This review aims to evaluate the role of suction-assisted technologies, particularly the flexible and navigable suction access sheath (FANS), in improving the safety and efficacy of RIRS.

Methods: A narrative review of the current literature was conducted, focusing on the evolution of suction use in endourology, the technical characteristics of FANS, and its clinical outcomes in RIRS, including intrarenal pressure control, stone-free rates, operative time, and complications.

Conclusion: Available evidence suggests that the use of FANS during RIRS improves intrarenal pressure regulation, enhances stone clearance, and reduces postoperative infectious complications without increasing ureteral injury. FANS represents a promising advancement in RIRS, although further prospective and randomized studies are required to confirm its long-term benefits.

Keywords: Urolithiasis; flexible and navigable suction access sheath FANS; retrograde intrarenal surgery; RIRS

Introduction

Currently, the prevalence and recurrence rate of urolithiasis is steadily increasing worldwide. At a certain stage of life, urolithiasis affects about 12 % of the population of all ages, genders, and races. The presence of kidney stones is accompanied by hematuria and pain in the lumbar region. The presence of urolithiasis in a patient is also associated with an increased risk of developing chronic kidney disease. Nephrolithiasis is the cause of 2–3 % of cases of end-stage renal failure. According to the clinical recommendations of the European Association of Urologists **(1)**.

percutaneous nephrolithotomy (PCNL) is recommended for stones larger than 2 cm However, anticoagulant therapy must be discontinued before performing PCNL. In this regard, the procedure of choice for this group of patients is retrograde intrarenal surgery (RIRS), which minimizes the risk of bleeding. However, to achieve the maximum stone-free rate (SFR), several stages must be performed. This highlights the need for more effective and innovative methods of surgical treatment of multiple and large kidney stones in patients taking anticoagulants **(2)**.

The aim of this review is to comprehensively evaluate the role of suction-assisted technologies—particularly the flexible and navigable suction access sheath (FANS)—in retrograde intrarenal surgery (RIRS) for the management of renal stones.

Urolithiasis

Renal stones are formed within the kidneys, and this is called nephrolithiasis. Urolithiasis is a condition that occurs when these stones exit the renal pelvis and move into the remainder of the urinary collecting system, which includes the ureters, bladder, and urethra. Many patients with urolithiasis can be managed with expectant management, analgesic, and anti-emetic medications; however, stones that are associated with obstruction, renal failure, and infection require further increasingly critical interventions **(3)**.

Epidemiology of Urolithiasis

Urolithiasis is a common condition and affects about 1 out of 11 people in the U.S. It is estimated to create a 5 billion expenditure on the health care system and is responsible for approximately 1 million emergency department (ED) visits annually. Its prevalence is rising and primarily affects the working-age population. Men present more commonly than women, 10.6% vs. 7.1%. Obese and overweight individuals compared to normal-weight individuals present more commonly, and studies showed that obesity was an equalizer in the formation of kidney stones when comparing men to women. Variations between different ethnicities have been seen, however white males have the highest prevalence per recent studies, followed by black . Females are more likely than males to form struvite stones because they have urinary tract infections more frequently **(4)**.

A recurrence rate of up to 50% has been seen five years from the initial episode of symptomatic urolithiasis **(5)**.

Etiology of Urolithiasis

There are multiple types of kidney stones; however, 80% of stones are composed of calcium oxalate or phosphate. Other stone types include uric acid (9%), struvite (10%), and cystine (1%) stones and are significantly less common than stones composed of calcium oxalate or phosphate (80%). The different types of stones occur due to varying risk factors such as diet, prior personal and family history of stones, environmental factors, medications, and the patient's medical history **(6)**.

Common risk factors for stone formation include poor oral fluid intake, high animal-derived protein intake, high oxalate intake (found in foods such as beans, beer, berries, chocolate, some nuts, some teas, soda, spinach, and potatoes), and high salt intake. Oral hydration is recommended at a rate that produces approximately 2.5 L of urine per day, and acceptable choices for fluids include water, coffee, low sugar fruit juices except for tomato (high sodium content), grapefruit, and cranberry (high oxalate content). Consumption of citrate helps to prevent stone formation as it inhibits crystal aggregation by forming complexes with calcium salts within the urine. 60% of patients with calcium stones have been found to have hypocitraturia. Low calcium intake has been shown to increase the risk of kidney stone formation. Decreased oral calcium intake will reduce calcium levels within the GI tract, which would otherwise be available to bind to oxalate. This, in turn, will increase oxalate absorption and excretion, increasing the risk of stone formation. Vitamin C intake and fish oil have also been shown to increase the risk of calcium stones **(7)**.

A prior personal and family history of kidney stones will increase the patient's risk of developing subsequent stones substantially. Procedures such as Roux-en-Y gastric bypass and sleeve gastrectomy have shown a three-fold increase in calcium oxalate stone formation secondary to the malabsorptive post-surgical state, resulting in increased urinary oxalate levels, decreased production of urine, and decreased urine citrate **(8)**.

The presence of medical conditions such as chronic kidney disease, hypertension, gout, diabetes mellitus, hyperlipidemia, obesity, endocrine, and malignancies increase the risk of the development of kidney stones. Obesity, hyperlipidemia, and type 2 diabetes mellitus have a strong association with calcium oxalate and uric acid stones. Patients with histories of hyperlipidemia, hypertension, and type 2 diabetes mellitus often have diets that are high in animal-derived proteins, salt, and sugar, placing them at higher risk for stone formation. Insulin resistance in obesity and type 2 diabetes mellitus promotes metabolic changes that increase the risk of stone

formation secondary to increased urinary calcium and uric acid excretion. A recent study evaluating 4500 patients with a history of kidney stones and insulin resistance showed increased urinary pH and decreased urinary acid excretion, promoting nephrolithiasis/urolithiasis. A prospective, large study followed participants over the years and assessed initial weight, weight gain, dietary exposure, BMI, and waist circumference and strongly showed that while increased BMI does raise the risk of symptomatic stone formation, increased weight due to adiposity in adulthood plays a very key role **(9)**.

Drug-induced urolithiasis is rare and only compromises 2% of stones. Common drugs include protease inhibitors used for the treatment of HIV (atazanavir and indinavir) and sulfadiazine. Protease inhibitor stones are poorly visualized on unenhanced CT scans and are gelatinous in material, making them often unsusceptible to lithotripsy. They typically cause a high-grade urinary obstruction requiring ureteral stenting. **(10)**.

Struvite stones, also known as infection stones, are less common and can form slowly and before becoming symptomatic. This type of stone can form into a staghorn or large calculus that overwhelms the renal collecting system. They are composed of magnesium ammonium phosphate and form secondary to elevated urine pH, and this is largely caused by the presence of *Proteus* or *Klebsiella* species, which are urease formers. Urea breakdown yields ammonia as a by-product, which increases the urinary pH (typically to more than 8) and facilitates struvite stone formation **(11)**.

Uric acid stone formation is related to low urinary uric acid levels, low urine pH, and low urinary volume. Most commonly, these patients will present as idiopathic uric acid stone formers; however, metabolic disorders such as diabetes and obesity will also increase the risk of uric acid stones. Low urinary pH will promote uric acid crystal formation and deposition, typically under a pH of 5.5. Diets rich in animal proteins will increase uric acid load and precipitation. Gout, certain neoplastic disorders, and chronic diarrhea are also associated with uric acid stone formation **(12)**.

Cystine stones are rare and occur due to an inborn congenital disorder causing mutations in 2 genes, SLC3A1 and SLC7A9. These mutations cause defective cystine metabolism and transport, resulting in cystinuria and stones. They typically present in childhood or adolescence, but some cases have even been shown in infants. Of note, cystine stones can also form staghorn calculi **(13)**.

Surgical management Options for Renal Stones

Over the past 30 years, the management of paediatric and adult patients with symptomatic kidney stones has evolved from open surgical lithotomy to minimally invasive endourological approaches. The three most common treatment modalities for renal stones include extracorporeal SWL (40–50% worldwide use), rigid or flexible retrograde ureteroscopic stone fragmentation and retrieval (30–40%) and PCNL (5–10%) **(14)**.

Each of these therapies has its own particular adverse-effect profile and expected success rate depending on the experience of the treating physician, stone factors (size, location and composition) and patient characteristics (body habitus, medical co-morbidities and anatomy). With appropriate counselling and proper procedure selection, patients should expect high stone clearance rates, low associated morbidity and quick recovery times. A general decision-tree algorithm of the most common of these approaches, stratified by stone location, stone size and stone density, is presented in FIG. 1 **(14)**.

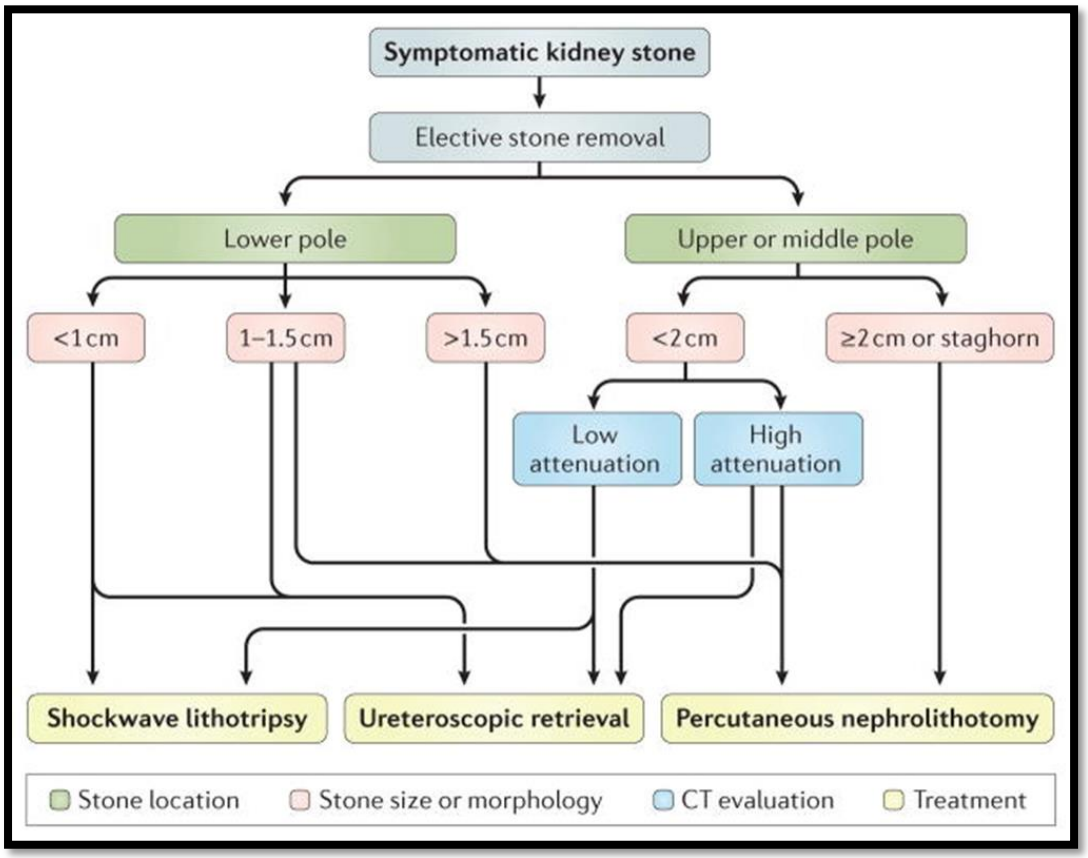

Figure 1 Algorithm for the most common approaches to surgical treatment of kidney stones. The decision of which surgical strategy to use is dictated by the location of the stone (with lower-pole stones being more difficult to treat), stone size and stone density **(14)**.

Retrograde Intrarenal Surgery (RIRS) was introduced as an alternative for the treatment of renal stones with the advantage of being a less invasive procedure and acceptable stone free rates **(15)**.

Retrograde Intrarenal Surgery

Retrograde intrarenal surgery (RIRS), defined as the use of flexible ureteroscopes (fURSs) and effective lithotripters such as holmium:yttrium aluminium garnet (holmium:YAG) lasers for intrarenal pelvic diseases, is a useful, versatile, and minimally invasive procedure for kidney stone management. The current guideline for management of kidney stones includes RIRS as the first or second recommended procedure in all categories, even for large stones of >2 cm **(16)**.

Indications of RIRS

In the beginning, the indications of RIRS included failure of previous SWL, lower calyx stones and stones smaller than 1.5 cm. However, the limitations in the indication of RIRS has been reduced recently, where it can be used for stones smaller than 2 cm as a first-line treatment option besides SWL, and can be an alternative to PCNL for the stones in lower calyx. The relatively lower morbidity of RIRS has caused it to be used increasingly. Although its absolute indications have not been reported, the potential indications can be listed as below **(17)**:

- Medium-sized stones that are not suitable for SWL or PCNL.
- SWL-resistant stones.
- Non-opaque stones.

- Existence of anatomic abnormalities (acute IPA, long lower pole calyx, narrow infundibulum).
- Co-existence of renal and ureteral stones.
- Multiple kidney stones including nephrocalcinosis.
- Bleeding disorders.
- People who have to be treated completely stone-free
- Percutaneous antegrade approach for ureteral stones in patients with urinary diversion.
- Combined or ancillary procedures following PCNL.
- Renoureteral malformations.
- Patient habitus (obese, musculoskeletal deformities).
- Stones >3 cm (may require two or more sessions).

Retrograde intrarenal surgery is an efficient and reliable treatment method for patients with obesity, musculoskeletal deformities, renoureteral malformations, infundibular stenosis, bleeding disorders **(17)**.

Surgical technique of RIRS

The surgical technique in RIRS will probably continue to change in the future with the improvements in design of the instruments. The new instruments have the potential to increase the efficiency and cost-benefit ratio, while decreasing the complication rates. The list of the equipment and instruments used during RIRS is given below **(17)**:

- Flexible ureterorenoscope and semi-rigid ureterorenoscope.
- Cystoscope.
- C-arm fluoroscope.
- Guidewires (diameter: 0.025–0.038 inch; length: 80–260 cm).
- Ureteral catheter or dual lumen catheter.
- Ureteral dilatator.
- Ureteral access sheath.
- Holmium:YAG laser with laser fibers with different core size (200, 270, 365 μm).
- Stone basket.
- Irrigation pump.
- Contrast agent.

The procedure is performed under general anesthesia with the patient in the dorsal lithotomy position. The bladder is entered either with a cystoscope or a semi-rigid ureterorenoscope. Guidewires, ureteral stents or dilatators can be used to enter the ureter. In the traditional technique, guidewire is sent to the ureter – preferably under fluoroscopic guidance – when the ureteral orifice is seen. If desired, a second guidewire (safety wire) can be passed by the other guidewire via a cystoscope or a dual lumen catheter. **(17)**.

For the first generation flexible ureteroscopes, the intramural part of the ureter had to be dilated to get access to the ureter in the vast majority of the patients, , dilatation of the ureter is seldom needed. In our routine practice, after the guidewire is sent, we advance the semi-rigid ureteroscope towards the renal pelvis through the ureter under direct vision. By this way, the ureter can be evaluated for a possible stricture, a co-incidental ureteral stone can be treated, and the ureter can be dilated mechanically. After the renal pelvis is reached, the semi-rigid

ureteroscope is removed, and the flexible ureteroscope is advanced either via a UAS or through the guidewire directly under fluoroscopic control. Afterwards. All collecting system is observed under direct vision until the stone is found. Sometimes fluoroscopic vision or addition of a contrast agent can facilitate access to the stone. Especially repositioning of lower calyx stones with a basket catheter can both facilitate access to the stone and prolong the lifetime of the flexible device. After the stone is reached, the laser fiber should be advanced if the ureteroscope can not be deflected. The stone is fragmented with the laser until clinically unimportant residual fragments are left. If stone analysis is desired, a little stone fragment can be retrieved with a 1.7 Fr or 2.2 Fr basket catheter. There is no need to place a DJ stent if the procedure is completed without any complication and the clinically insignificant residual stone fragments are left **(17)**.

Instrumentation

Tendency to use RIRS in the treatment of kidney stones has risen with the technological improvements in the design of flexible ureteroscope, laser lithotripters, UAS, guidewires, stone baskets and forceps. For a successful result, the surgeon has to know the advantages and disadvantages of the equipments he/she uses.

Role of Ureteral Access Sheaths (UAS) in RIRS

Ureteral access sheath (UAS) has been developed with the same concept of designing percutaneous Amplatz sheath. It is being used for decreasing the intrarenal pressure during endourological procedures of the upper urinary tract, and facilitating the FURS. It has some major advantages including facilitating multiple or recurrent accesses into the kidney, and decreasing the intrarenal pressure by drainage of the irrigation fluid around the scope. Thus fURS also facilitates removal of small stone fragments by this way. It have shown that it decreases the operation time, protects the flexible ureteroscope, and increases the SFR. Despite these advantages, its benefit, risk and cost should be kept in mind **(18)**.

Placement of a UAS can cause a decrease in ureteral blood flow causing ureteral ischemia or a direct ureteral injury during the procedure. UAS can cause some peri- and post-operative complications such as mucosal laceration, ureteral perforation, urine extravasation, ureteral avulsion and ureteral stricture. Traxer et al. evaluated the incidence and severity of ureteral injury due to use of UAS during RIRS in a series of 359 patients treated in two different centers. They found a rate of 46.5% for ureteral wall injury, while a rate of 13% was identified for severe injuries including the muscular layer of the ureter. Risk factors for severe injuries were identified as age, male sex and absence of preoperative stent **(19)**.

Ureteral access sheath should be placed cautiously with keeping the risk of false passage and overdistention in mind. The placement should always be performed over a guidewire under fluoroscopic control. The use of a guidewire is generally advised as it stabilizes the ureter while advancing the UAS and facilitates placement of a DJ stent after the procedure. An appropriate UAS should be chosen according to the flexible ureteroscope used. Attention should be paid to have no or minimal friction during the procedure. The diameters of the available UASs differ between 9.5 Fr to 14 Fr**(20)**.

Contraindications and complications of RIRS

Except an untreated UTI and other anesthesia contraindications, no specific contraindication exists for fURS. RIRS can be performed in all patients including especially the ones in whom SWL or PCNL is contraindicated or not suitable. With the improving technology and increasing use and experience, more procedures are being performed with less morbidity. Its complications can be listed as hemorrhage, intrapelvic hematoma, mucosal injury, ureteral perforation and avulsion, UTI and sepsis. Overall complication rates remain low with most complications being minor **(20)**.

In the prospective URS study of CROES, among a total of 11.885 patients, 1.781 (15%) underwent only fURS where 10.7% had a combined treatment with flexible and semi-rigid URS. Overall postoperative complication rate was found to be 3.5%, which were mostly (2.8%) grade 1 and 2 according to Clavien-Dindo classification. Only 0.2% of the patients needed blood transfusion, and 5 mortalities were reported within the first 30 days postoperatively due to sepsis, pulmonary embolism, multi-organ dysfunction and cardiac reasons. Besides, 8.4%

of the patients re-admitted to hospital during the first 3 months postoperatively with flank pain and discomfort mainly due to indwelling ureteral stent. **(21)**

Role of Suction in Endourology and RIRS

In endourology, suction plays a pivotal role in facilitating the removal of debris, irrigation fluids, and stone fragments during various minimally invasive procedures. The validity of employing these instruments has been increasingly delineated, particularly in percutaneous nephrolithotomy (PCNL), as per the EAU guidelines. A recent systematic review has introduced various suction devices for RIRS, including those deployed through the UAS or directly attached to the scope, offering control of IRP **(23)**. Evidence from this review underscores the effectiveness of these devices in RIRS. In terms of procedural safety, the regulation of IRP and the ability to enhance irrigation flow during the procedure help mitigate the risks associated with fluid-pump mechanisms, which may result in mucosal injury within the collecting system and the reabsorption of irrigation fluid containing bacteria and endotoxins caused by pyelovenous backflow. Additionally, thorough cleansing of the pelvocalyceal system from debris and residual fragments appears linked to a reduced incidence of postoperative infectious complications. It may be attributed to decreased reliance on accessory instruments, such as baskets, and manipulation of the scope **(24)**.

Suction devices have also demonstrated improved efficacy in RIRS, leading to reduced operative times and increased SFR. These outcomes can be justified by several factors. First, the removal of debris enhances intraoperative visibility, mitigating the “snow-globe effect” and facilitating the identification of fragments hidden beneath it. Moreover, this accessory obviates the need for fragment extraction, a time-consuming process impractical for fragments smaller than 2 mm. **(25)**.

The introduction of this new technology could prove even more beneficial in challenging cases involving voluminous calculi. Therefore, the utilization of suction devices in RIRS has led to significant improvements in patient outcomes, enhancing SFR, and contributing to a decreased need for secondary interventions. The suction ureteral access sheath (SUAS) is the first prototype in the evolution of such technical advancement, followed by the flexible and navigable ureteral access sheath (FANS) with the use of suction in ureteroscopy. **(26)**.

The Influence of Pressure with the Use of FURS and FANS in RIRS

The normal physiological intrarenal pressure is approximately 10 mmHg. The threshold for pyelovenous and pyelosinous backflow has been shown to be 30–45 mmHg. The intrarenal pressure can be dramatically increased up to more than 300 mmHg during retrograde intrarenal surgery, raising concerns for increased risk of sepsis. Studies have proven that the use of UAS can prevent the elevation of intrarenal pressure **(27)**.

IRP was measured by a percutaneously placed pressure transducer catheter in the renal pelvis or a pre-existing nephrostomy tube in both animal and clinical studies. It was only in 2008 that retrograde ureteral catheters were innovatively used to record IRP. The first report was on the placement of a ureteral catheter at the renal pelvis connected to a transducer, followed by studies on a FANS with a pressure-measuring function, and studies on the off-label utilisation of a pressure-sensor flexible wire commonly used in cardiovascular interventions **(28)**.

With the evolution of suction application in retrograde intrarenal surgery and the advancing technologies that allow for IRP measurement and a better physiological understanding of the detrimental effects of high IRP, the use of SUAS and FANS in RIRS has gained momentum to prevent the complications related to high IRP and temperature **(29)**.

Real-time monitoring of pressure profiles with the use of FANS is changing the way urologists are able to perform RIRS even for bigger stones by not only improving the laser efficiency of high-power lasers but almost mitigating septic complications even when using a smaller diameter UAS compared to an older larger diameter traditional UAS **(30)**.

Complications of FANS

Among 104 consecutive patients undergoing FURS for ureteral stones with FANS , only a few complications were observed, such as two cases of fever and one minor ureteral false passage. **Zhu et al**. **(32)** compared cases

undergoing FURS with FANS versus traditional UAS for renal stones and found a significantly lower incidence of overall complications, fever, and urosepsis in the FANS group, yet no significant differences were noted for septic shock, haematuria, steinstrasse or ureteral stricture. Similarly, **Qian et al. (33)** evaluated patients undergoing FURS with FANS and traditional UAS and reported a lower incidence of postoperative fever or systemic inflammatory response syndrome (SIRS) in the FANS the traditional UAS group.

Various complications in the use of FANS have been reported. **Chen et al. (34)** reported only two cases of fever in a cohort of 53 patients who underwent FURS with FANS, while **Liang et al. (35)** recorded an even lower fever rate (2/224). In another study, 10/12 Fr FANS have been compared to 12/14 Fr, reporting four cases of fever for the first group and no infectious complications for the second group. Some studies have compared FANS to traditional UAS. **Zhang et al. (36)** reported a lower infection and fever rate for FURS with FANS compared to traditional UAS. Gauhar et al. evaluated the efficacy of a flexible ureteroscopic approach to renal stones using two combinations of flexible ureteroscopes and flexible UAS. The 10F flexible UAS combined with 7.5F ureteroscopes achieved better stone-free rates than the 12F flexible UAS with 8F scopes, with a probable explanation that the thinner UAS proved better flexibility. The study reported an excellent stone-free rate by comparison to studies employing standard UAS **(Gauhar et al., 2023) (35)**

Two groups compared the flexible ureteroscopic approach using a flexible-tip UAS with minimally invasive percutaneous nephrolithotomy for treating larger stones between 2 and 3 cm. As expected, the retrograde technique was associated with less hemoglobin drop, shorter postoperative stay, and lower overall complications, bleeding, and pain rates. **(Grosso et al., 2021**) **(36)** Other studies compared flexible ureteroscopy using a flexible-tip UAS with the same procedure using the standard one, and in all of them, both the immediate and the one-month stone-free rates were better for the flexible-tip UAS group. In one of the studies, significant differences were recorded, even for larger stones of between 2 and 3 cm **(John et al., 2025)(37)**

Conclusion

The introduction of suction-assisted technology, particularly the flexible and navigable suction access sheath (FANS), represents a significant advancement in retrograde intrarenal surgery. By improving intrarenal pressure control, visualization, and stone fragment evacuation, FANS enhances procedural efficiency and reduces postoperative infectious complications. Although further high-quality randomized studies are needed, current evidence supports the safety and effectiveness of FANS as a valuable adjunct in the management of renal stones during RIRS.

References

1. **Courbebaisse M, Prot-Bertoye C, Bertocchio JP, Baron S, Maruani G, Briand S, et al.** Nephrolithiasis of adult: From mechanisms to preventive medical treatment. La Revue de medecine interne. 2016;38(1):44-52.
2. **Tikkinen KA, Cartwright R, Gould MK, Naspro R, Novara G, Sandset PM, et al.** Thromboprophylaxis in urological surgery. EAU Guidelines Office. 2017.
3. **Scales Jr CD, Smith AC, Hanley JM, Saigal CS, Urologic Diseases in America P.** Prevalence of kidney stones in the United States. European urology. 2012;62(1):160-5.
4. **Thakore P, Liang TH.** Urolithiasis. StatPearls. Treasure Island (FL) ineligible companies. Disclosure: Terrence Liang declares no relevant financial relationships with ineligible companies.: StatPearls Publishing

5. **Khan SR, Pearle MS, Robertson WG, Gambaro G, Canales BK, Doizi S, et al.** Kidney stones. Nature reviews Disease primers. 2016;2:16008.
6. **Caudarella R, Vescini F.** Urinary citrate and renal stone disease: the preventive role of alkali citrate treatment. Arch Ital Urol Androl. 2009;81(3):182-7.

7. **Chung MJ.** Urolithiasis and nephrolithiasis. JAAPA : official journal of the American Academy of Physician Assistants. 2017;30(9):49-50.

8. **Espino-Grosso PM, Canales BK.** Kidney stones after bariatric surgery: risk assessment and mitigation. Bariatric Surgical Practice and Patient Care. 2017;12(1):3-9.

9. **Aune D, Mahamat-Saleh Y, Norat T, Riboli E.** Body fatness, diabetes, physical activity and risk of kidney stones: a systematic review and meta-analysis of cohort studies. European journal of epidemiology. 2018;33(11):1033.

10. **Izzedine H, Lescure FX, Bonnet F.** HIV medication-based urolithiasis. Clinical kidney journal. 2014;7(2):121-6.

11. **Parkhomenko E, De Fazio A, Tran T, Thai J, Blum K, Gupta M.** A multi-institutional study of struvite stones: patterns of infection and colonization. Journal of endourology. 2017;31(5):533-7.

12. **Ma Q, Fang L, Su R, Ma L, Xie G, Cheng Y.** Uric acid stones, clinical manifestations and therapeutic considerations. Postgraduate medical journal. 2018;94(1114):458-62.

13. **Eggermann T, Venghaus A, Zerres K.** Cystinuria: an inborn cause of urolithiasis. Orphanet journal of rare diseases. 2012;7(1):19.

14. **Khan SR, Pearle MS, Robertson WG, Gambaro G, Canales BK, Doizi S, et al.** Kidney stones. Nature reviews Disease primers. 2016;2(1):1-23.

15. **Kassem A, Torad H, Essam A, Abdel Hamid M, Zamel S, Elkady A.** Retrograde intra renal surgery (RIRS) versus percutaneous nephrolithotomy (PNL) as a primary treatment for large renal stones: A prospective randomized controlled trial. Arab Journal of Urology. 2025:1-7.

16. **Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP, et al.** Surgical management of stones: American urological association/endourological society guideline, PART I. The Journal of urology. 2016;196(4):1153-60.

17. **Van Cleynenbreugel B, Kılıç Ö, Akand M.** Retrograde intrarenal surgery for renal stones - Part 1. Turkish journal of urology. 2017;43(2):112-21.

18. **Traxer O, Wendt-Nordahl G, Sodha H, Rassweiler J, Meretyk S, Tefekli A, et al.** Differences in renal stone treatment and outcomes for patients treated either with or without the support of a ureteral access sheath: The Clinical Research Office of the Endourological Society Ureteroscopy Global Study. World journal of urology. 2015;33(12):2137-44.

19. **Traxer O, Thomas A.** Prospective evaluation and classification of ureteral wall injuries resulting from insertion of a ureteral access sheath during retrograde intrarenal surgery. The Journal of urology. 2013;189(2):580-4.

20. **Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M, et al.** EAU guidelines on interventional treatment for urolithiasis. European urology. 2016;69(3):475-82.

21. **Castro EP, Osther PJS, Jinga V, Razvi H, Stravodimos KG, Parikh K, et al.** Differences in ureteroscopic stone treatment and outcomes for distal, mid-, proximal, or multiple ureteral locations: the Clinical Research Office of the Endourological Society ureteroscopy global study. European urology. 2014;66(1):102-9.

22. **Oguz U, Resorlu B, Ozyuvali E, Bozkurt OF, Senocak C, Unsal A.** Categorizing intraoperative complications of retrograde intrarenal surgery. Urologia internationalis. 2014;92(2):164-8.

23. **Giulioni C, Castellani D, Traxer O, Gadzhiev N, Pirola GM, Tanidir Y, et al.** Experimental and clinical applications and outcomes of using different forms of suction in retrograde intrarenal surgery. Results from a systematic review. Actas Urológicas Españolas (English Edition). 2024;48(1):57-70.

24. **Quhal F, Zeng G, Seitz C.** Current evidence for suction in endourological procedures: comprehensive review of literature. Current Opinion in Urology. 2023;33(2):77-83.

25. **Song B, Cheng Y, Lu Y, Rong H, Huang T, Shi J, et al.** Factors affecting the intraoperative calculi excretion during flexible ureteroscopy lithotripsy: an in vitro analysis. World Journal of Urology. 2024;42(1):130.

26. **Yuen SKK, Traxer O, Wroclawski ML, Gadzhiev N, Chai CA, Lim EJ, et al.** Scoping review of experimental and clinical evidence and its influence on development of the suction ureteral access sheath. Diagnostics. 2024;14(10):1034.

27. **Hong A, du Plessis J, Browne C, Jack G, Bolton D.** Mechanism of urosepsis: relationship between intrarenal pressures and pyelovenous backflow. BJU international. 2023;132(5):512-9.

28. **Dumbill R, Mellati A, Yang BD, Ploeg R, Turney B, Hunter J.** Ureterorenoscopy during normothermic machine perfusion: effect of varying renal pelvis pressure. Bju International. 2022;131(1):50.

29. **Pauchard F, Bhojani N, Chew B, Ventimiglia E.** How to measure intra-renal pressure during flexible URS: Historical background, technological innovations and future perspectives. Actas Urológicas Españolas (English Edition). 2024;48(1):42-51.

30. **Doizi S, Letendre J, Cloutier J, Ploumidis A, Traxer O.** Continuous monitoring of intrapelvic pressure during flexible ureteroscopy using a sensor wire: a pilot study. World Journal of Urology. 2021;39(2):555-61.

31. **Zeng G, Wang D, Zhang T, Wan SP.** Modified access sheath for continuous flow ureteroscopic lithotripsy: a preliminary report of a novel concept and technique. Journal of endourology. 2016;30(9):992-6.

32. **Zhu Z, Cui Y, Zeng F, Li Y, Chen Z, Hequn C.** Comparison of suctioning and traditional ureteral access sheath during flexible ureteroscopy in the treatment of renal stones. World journal of urology. 2019;37(5):921-9.

33. **Qian X, Liu C, Hong S, Xu J, Qian C, Zhu J, et al.** Application of suctioning ureteral access sheath during flexible ureteroscopy for renal stones decreases the risk of postoperative systemic inflammatory response syndrome. International Journal of Clinical Practice. 2022;2022(1):9354714.

34. **Chen Y, Zheng L, Lin L, Li C, Gao L, Ke L, et al.** A novel flexible vacuum-assisted ureteric access sheath in retrograde intrarenal surgery. Bju International. 2022;130(5):586.

35. **Liang H, Liang L, Lin Y, Yu Y, Xu X, Liang Z, et al.** Application of tip-bendable ureteral access sheath in flexible ureteroscopic lithotripsy: an initial experience of 224 cases. BMC urology. 2023;23(1):175.

36. **Zhang Z, Xie T, Li F, Wang X, Liu F, Jiang B, et al.** Comparison of traditional and novel tip-flexible suctioning ureteral access sheath combined with flexible ureteroscope to treat unilateral renal calculi. World Journal of Urology. 2023;41(12):3619-27.