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# Is suction the future of endourology? Overview from EAU Section of Urolithiasis

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## Introduction

Endourological procedures have dramatically transformed the treatment of kidney stone disease (KSD) by applying minimally invasive techniques for stone removal. While the shift from open surgery to endourological methods for KSD represents a significant change in stone treatment, continuous technological advancements have allowed for improved clinical outcomes through the evolution of modern equipment.

The transition from fiberoptic to digital systems has significantly enhanced the intraoperative view.[1] In addition, the introduction of single-use scopes and the ongoing miniaturization of scopes have further advanced endoscopic stone surgery. The utilization of modern laser technologies, particularly holmium:YAG laser (Ho:YAG) and thulium fiber laser lithotripsy, has notably contributed to improved surgical outcomes. Retrograde intrarenal surgery (RIRS) is recommended by current guidelines as a first or second choice for renal stones including stones larger than 2 cm.[2] Despite the advantages of employing these technological advancements, achieving a high success rate in removing larger calculi can be challenging due to restricted interoperative views caused by the snow globe effect or residual fragments (RFs). While we aim for complete stone-free rate status, the presence of RFs remains a concern, often necessitating additional interventions and more costs for healthcare systems.[3] Although the concept of clinically insignificant RFs has been proposed, there is not a universally accepted standard for preventing, clearing, or managing RFs.[4] Effectively breaking down and eliminating stone debris remain critical challenges in achieving optimal results.

Intraoperative suction has been introduced as a tool to remove these RFs, potentially also avoiding the necessity of basketing them. Suction has been applied in endourology for over 25 years alongside ultrasound and ballistic devices and more recently through suction sheaths during percutaneous nephrolithotomy (PCNL).[5]

Of late, suction also has been employed in RIRS, offering multiple advantages in stone fragmentation, dusting, debris and fragment removal, intrarenal temperature and pressure reduction, as well as enhanced visualization.

As the landscape of urological interventions continues to evolve, the implementation of suction might push the limits of RIRS. Is suction the forerunner of a new era in endourological procedures?

## Role of suction

Video – https://www.youtube.com/watch?v=kT36Ja3aUPY [Figure 1(a) and (b)].

Suction in ureteroscopy can be facilitated through different mechanisms, each offering distinct advantages and disadvantages (https://www.youtube.com/watch?v=kT36Ja3aUPY).

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### *Suction scopes*

Suction scopes integrate suction capability directly into the endoscope [Figure 1(a)]. These single-use flexible scopes allow to removal of debris during laser lithotripsy and can therefore minimize visual loss through the snow globe effect during lithotripsy. They furthermore might be able to reduce intrarenal pressure (IRP) and temperature, allowing for longer periods of continuous lasering and thus potentially shorter procedural times.

### *Suction ureteral access sheaths*

Suction sheaths have already been established in PCNL. These sheaths feature built-in suction capabilities to assist in simultaneous stone fragment removal and irrigation. Suction ureteral access sheaths (SUAS) have been previously introduced for RIRS but have not shown clear benefits. There have been advancements in the developments in the SUAS, which now have flexible tips that can be advanced past the ureteropelvic junction and into the pelvicalyceal system enabling the surgeon not only to remove dust and debris but also stone fragments and reduce IRP and temperature [Figure 1(b)].

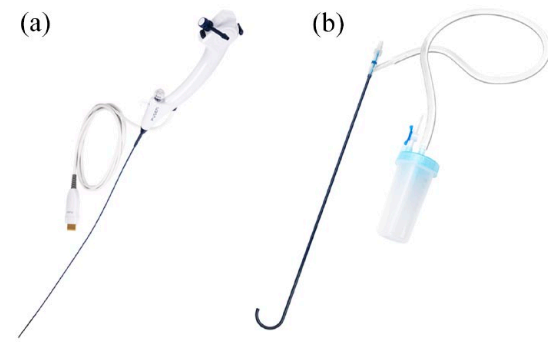


**Figure 1.** (a) Pusen 7.5F Suction flexible ureteroscope and (b) Seplou 10/12F suction ureteral access sheath.

## Advantages

### *IRP control*

Effective suction mechanisms can reduce IRP, preventing pressure build-up during the procedure and as a consequence pyelolymphatic/pyelovenous reflux. This is especially important in avoiding potential infections, and kidney injury, and ensuring patient safety.

### *Temperature control*

As newer laser technologies evolve with higher power and frequency settings; the management of intrarenal temperature is essential. Effective suction could regulate the intrarenal temperature during the procedure.

### *Enhanced visualization*

Suction assists in maintaining a clear field of vision by removing debris, dust, blood, and RFs. This allows for better intraoperative views and thus can prevent injury to the pelvicalyceal system, leading to more precise laser lithotripsy and exposing RFs hidden by dust or snow globe effects. This, therefore, can increase patient safety and minimize laser-off times, potentially leading to faster procedures, optimizing surgical efficiency, reducing operative times, and better stone-free rate (SFR).

### *Pushing procedural limits*

Suction-assisted devices might enable surgeons to push the boundaries of what is achievable in flexible ureteroscopy. This could allow for the successful management of more complex cases or larger stones, minimizing the snow-globe effect, and challenging the traditional limitations of RIRS, perhaps with a much better immediate SFR.

## Disadvantages

### *Operational complexity*

Managing suction devices during endourological procedures can introduce an additional layer of complexity to the procedure due to an additional tube and control mechanism that comes with it.

### *Undefined suction parameters*

The lack of standardized suction values or clear guidelines regarding optimal suction levels could lead to variations in practice, potentially impacting outcomes or causing unintended tissue trauma.

### *Increased irrigation usage*

The use of suction requires higher volumes of irrigation fluid to maintain optimal conditions, sometimes with higher pressure, during the procedure, to prevent collapse of the pelvicalyceal system.

While suction devices in endourology offer substantial benefits in terms of visualization, pressure and temperature control, removal of debris and stone fragments and might allow us to push the limits of RIRS, its use can introduce complexities in the procedures and lack standardized parameters, necessitating careful consideration of its implementation and management during procedures.

## Evidence

A recent systematic review including 12 studies; 4 *in vitro* or experimental and 8 clinical studies; examined different suction methods during RIRS. The included studies showed shorter procedural times, favorable SFR, lower complication rates, and better intraoperative views (Table 1). However, the authors conclude that randomized controlled trials are warranted to confirm these findings.[3]

Chen *et al.* used a flexible vacuum assistant ureteral access sheath (FV-UAS) 12/14F in a manometric model with porcine kidneys to assess IRPs. The FV-UAS actively regulated IRP to under 10 cm $H_2O$. Compared to a traditional UAS the FV-UAS significantly lower residual stone volume: 33.7 mm$^3$ for FV-UAS *versus* 92.5 mm$^3$ for traditional UAS ($p = 0.017$). In addition, the mean stone volume clearance rates were significantly higher for FV-UAS at 98.5% compared to 95.9% for traditional UAS ($p = 0.017$).[6]

Zeng *et al.* modified a traditional UAS by incorporating an oblique suction–evacuation port with pressure regulation. The overall SFR was 97.3% immediately after the procedure and 100% at the 1-month follow-up. The authors conclude that their modification of UAS has improved stone clearance, and interoperative view, and probably reduced the intraluminal pressure.[7]

Deng *et al.* designed an intelligent system including an irrigation and suctioning platform and a UAS with a pressure-sensitive tip to regulate inflow and control of the vacuum suctioning by real-time monitoring of IRP. SFR was 90.0% on the first postoperative day and 95.6% on postoperative day 30.[8]

Huang *et al.*[9] connected a pressure-measuring suctioning UAS to an irrigation and suctioning platform achieving SFRs of 87.5%, 4 weeks postoperatively, and 92.5% 3 months after surgery.

Du *et al.* used a patented perfusion and suctioning platform and UAS in the treatment of large ureteral stones ⩾1.5 cm below the L4 level. Compared to the control group this approach had significantly higher stone clearance rates, shorter operation time, fewer postoperative episodes of fever, as well as fewer ancillary procedures.[10]

Zhu *et al.* compared the efficiency and safety of SUAS and traditional UAS in a matched-pair analysis. While the SUAS group had significantly higher SFR on the first postoperative day (82.4% *versus* 71.5%; $p = 0.02$) SFR 1 month after the procedure was comparable in the two groups. Operating time was significantly lower in the SUAS group (49.7 + 16.3 *versus* 57.0 ± 14.0 min; $p < 0.001$).[11] Overall complications were significantly higher in the traditional UAS group (24.8% *versus* 11.5%; $p < 0.001$) but there was no significant difference in the incidence of septic shock, hematuria, steinstrasse, or ureteral stricture.[11]

Gao *et al.* conducted a retrospective observational study to evaluate the safety and efficacy of suctioning flexible ureteroscopy with intelligent pressure control (SFUI) and reported that SFRs postoperatively and at 1 month were 80.65% and 82.26%, respectively. They concluded SFUI to be a safe and efficient treatment for KSD.[12]

Gauhar *et al.* compared patients who underwent RIRS with the direct in-scope suction (DISS) technique to patients who underwent RIRS with an 11Fr/13Fr SUAS. The median surgical time was significantly longer in the DISS group compared to the SUAS group 80 and 47.5 min, respectively ($p < 0.001$); while stone size was significantly larger in the DISS group 22 *versus* 13 mm ($p < 0.001$).[13] There was no significant difference in postoperative complications or RFs between the groups. However, 33.3% of patients required a further RIRS in the DISS group while 3.6% of patients in the SUAS group underwent shock wave lithotripsy. The authors conclude the use of DISS to be a safe and efficient method for stone treatment.[13]

Quian *et al.* compared patients undergoing RIRS with a traditional UAS to patients treated with

**Table 1.** Studies reporting on suction *via* scope or sheath.

| Author | Year | Study type | Mechanism of suction | Control group | Results |
|---|---|---|---|---|---|
| Zeng *et al.* | 2016 | Clinical observation | SUAS | No | Improved stone clearance, better intraoperative view |
| Deng *et al.* | 2016 | Clinical observation | SUAS | No | High stone-free rates on postoperative days 1 and 30 |
| Huang *et al.* | 2018 | Clinical observation | SUAS | No | SFRs of 87.5% at 4 weeks postoperatively, 92.5% at 3 months |
| Du *et al.* | 2019 | Clinical observation | SUAS | Yes | Higher stone clearance rates, shorter operation time, fewer complications |
| Zhu *et al.* | 2019 | Matched-pair analysis | SUAS *versus* UAS | Yes | Higher SFR on postoperative day 1, lower operating time, fewer overall complications |
| Gao *et al.* | 2022 | Retrospective study | DISS | No | SFRs of 80.65% postoperatively, 82.26% at 1 month |
| Gauhar *et al.* | 2022 | Comparative analysis | DISS *versus* SUAS | Yes | Longer surgical time in the DISS group. Similar postoperative complications |
| Quian *et al.* | 2022 | Matched-pair analysis | SAUS *versus* SUAS | Yes | Higher SFR on postoperative day 1 and lower incidence of fever and SIRS |
| Chen *et al.* | 2022 | Manometric model | SUAS | No | Lower residual stone volume, higher stone volume clearance rates |
| Gauhar *et al.* | 2023 | Comparative analysis | FANS *versus* FANS | Yes | Higher SFR and ease of use with 10F FANS compared to 12F FANS |

DISS, direct in-scope suction; FANS, flexible and navigable access sheath; SFR, stone-free rate; SUAS, suction ureteral access sheaths.

SAUS in a matched pair analysis. SFR on the first postoperative day for the SUAS group was significantly higher than that in the traditional UAS group 86.4% and 71.6% ($p = 0.034$), while it was there was no significant difference after 1 month 88.9% *versus* 82.7% ($p = 0.368$).[14] The incidence of postoperative fever and SIRS was significantly lower in the SUAS group with reported rates of 3.70% *versus* 14.8% ($p = 0.030$) and SIRS rates at 1.23% *versus* 12.3% ($p = 0.012$).[14]

Gauhar *et al.*[15] also looked at a feasibility study on the clinical utility, efficacy, and limitations of doing RIRS *via* flexible and navigable SUAS (FANS). The results showed a higher SFR with the 10F FANS compared to their 12F counterparts, with better manipulation and ease of use.[15]

The use of suction has also been described *via* a modified UAS (mUAS) *via* a semi-rigid ureteroscope.[7] Recently, Sur *et al.*[16] also reported on the safety and feasibility of steerable ureteroscopic renal evacuation using the CVAC aspiration system *via* a steerable catheter.

In summary, various innovative suction methods during RIRS show promising outcomes, including reduced procedural times, improved stone clearance rates, lowered complication rates, postoperative infections, and enhanced intraoperative visibility.[17] These advancements, highlighted across multiple studies, underscore the potential for improved efficacy and safety in treating kidney stones.[18,19] Over time, with improvements in ureteroscope deflection and vision, better predictive algorithms and smaller-sized scopes with incorporated suction mechanisms are likely going to revolutionize stone surgery.[20–22] However, further randomized controlled trials are necessary to validate and establish the full scope of these benefits with the inclusion of not just clinical but patient-reported outcomes too.[23]

## Future developments

The future of suction in endourology appears promising. Further advancements could address current limitations and enhance its benefits:

### *Larger scope channels*

The development of scopes with larger channels holds immense potential. Enlarging the channel diameter within the scope could significantly improve suction capabilities. This enhancement could allow for the removal of small- or mid-sized stone fragments or more efficient removal of debris through the scope, reducing the need for multiple insertions of the scope and optimizing procedural efficiency.

### *Enhanced hand-controlled suction*

Refinements in the design and control mechanisms of suction devices could further enhance their usability. Improved ergonomics and hand-controlled suction systems could offer surgeons greater precision and control during procedures facilitating tailored suction levels to the specific requirements of different stages of the surgery. As robotics furthers precision navigation and ergonomic enhancement of endourology intervention, it is likely to incorporate suction mechanisms to provide better RIRS surgical outcomes.[24]

Combining different methods of suction: Applying different methods of suction simultaneously could combine the observed advantages of the different suction mechanisms and therefore amplify their efficacy.

## Conclusion

Suction has emerged as a potentially transformative tool, not only in PCNL but also in RIRS. Recent studies investigating various suction mechanisms during RIRS show its benefits including shorter procedures, higher SFR, and lower complication rates.

Innovations like SUAS and intelligent pressure-control systems and in-scope suction devices show promise in reducing IRP and temperature as well as improving intraoperative visibility. However, implementing suction introduces complexities and lacks standardized parameters, necessitating cautious practice.

The future holds the potential to refine existing suction tools to address current limitations. Despite great promise and initial results, further research, especially randomized trials, is needed to validate these advancements. Suction mechanisms could potentially transform stone treatments and push the limits of RIRS.

## Declarations

### *Ethics approval and consent to participate*

Not applicable as this is a review paper.

### *Consent for publication*

Not applicable.

### *Author contributions*

**Victoria Jahrreiss:** Conceptualization; Methodology; Software; Writing – original draft.

**Carlotta Nedbal:** Software; Writing – review & editing.

**Daniele Castellani:** Writing – review & editing.

**Vineet Gauhar:** Writing – review & editing.

**Christian Seitz:** Writing – review & editing.

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**Patrick Juliebø-Jones:** Writing – review & editing.

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**Panagiotis Kallidonis:** Writing – review & editing.

**Ewa Bres-Niewada:** Writing – review & editing.

**Bhaskar Somani:** Conceptualization; Methodology; Supervision; Writing – original draft; Writing – review & editing.

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