THERAPEUTIC ADVANCES in
Urology

Editorial

Quadrifecta during retrograde intrarenal surgery: suction, irrigation, intrarenal temperature and pressure: achieving best clinical outcomes – an overview from EAU Endourology

Ther Adv Urol

2025, Vol. 17: 1–7

DOI: 10.1177/17562872251335268

Carlotta Nedbal, Vineet Gauhar, Steffi Kar Kei Yuen, Daniele Castellani, Thomas Herrmann, Olivier Traxer and Bhaskar Kumar Somani

Keywords: intrarenal pressure, kidney calculi, suction, temperature, ureteroscopy

Received: 17 February 2025; revised manuscript accepted: 28 March 2025.

Correspondence to:
Bhaskar Kumar Somani
University Hospitals Southampton, NHS Trust, Tremona Road, Southampton, SO16 6YD, UK
Section of EAU Endourology
bhaskarsomani@yahoo.com

Carlotta Nedbal
Polytechnic University of Le Marche, Ancona, Italy
EAU Section of Endourology
ASST Fatebenefratelli Sacco, Milano, Italy

Vineet Gauhar
Section of EAU Endourology
Department of Urology, Ng Teng Fong General Hospital, Singapore, Singapore

Steffi Kar Kei Yuen
Section of EAU Endourology
Department of Surgery, SH Ho Urology Centre, The Chinese University of Hong Kong, Hong Kong, China

Daniele Castellani
Section of EAU Endourology, European Association of Urology, Arnhem, The Netherlands
Urology Division, Azienda Ospedaliero-Universitaria Ospedali Riuniti di Ancona, Università Politecnica delle Marche, Ancona, Italy

Thomas Herrmann
Section of EAU Endourology
Department of Urology, Kantonspital Frauenfeld, Spital Thurgau AG, Frauenfeld, Switzerland

Introduction

European and American urological guidelines identify retrograde intrarenal surgery (RIRS) as the intervention of choice for renal stones with diameter <2 cm.[1] However, recent progress in technology and the consequent advancements in available instrumentation allow for a much wider scope of treatment in urolithiasis, pushing the classical limits of RIRS.[2] Different parameters play an important role in RIRS outcomes, with intrarenal pressure (IRP) and temperature (IRT) having been thoroughly linked to postoperative complications and long-term effects on renal function. For this, new devices with the ability to better regulate suction and irrigation have been developed, with methods to check and control for changes in IRP and IRT.[3] Suction, irrigation, IRT and IRP are subjects of great debate in recent times, as this quadrifecta can lead to optimised clinical outcomes, including a complete single-procedure stone clearance and lower complication rates, especially regarding infectious complications and sepsis.[4] In this editorial, we discuss the current concepts and future perspectives on achieving this quadrifecta which can lead to best clinical outcomes (Figure 1).

The quadrifecta

Irrigation

Fluid irrigation during ureteroscopy (URS) plays a critical role in ensuring visibility and procedural efficacy in RIRS since success heavily relies on clear visualisation of renal anatomy and stone characteristics.[5] The continuous infusion of sterile solution to maintain a clear field, by flushing out blood, debris and stone fragments, can be achieved by different methods. Irrigation devices range from simple manual irrigation, involving handheld syringes or gravity-fed systems where the saline solution is manually controlled by the surgeon or an assistant, to gravity-fed irrigation systems, providing a continuous flow of saline solution from an elevated bag, to more sophisticated and automated systems.[6] These include pressurised irrigation hand or foot or automated pumps, where the latter can offer more precise control over the irrigation flow and pressure via pedals or other controls to maintain a steady infusion rate, and are particularly beneficial in maintaining a stable and clear visual field. The most advanced option for irrigation is the automated irrigation system, able to mechanically regulate

Olivier Traxer
Section of EAU Endourology
Department of Urology, Sorbonne University, Tenon Hospital, AP-HP, Paris, France

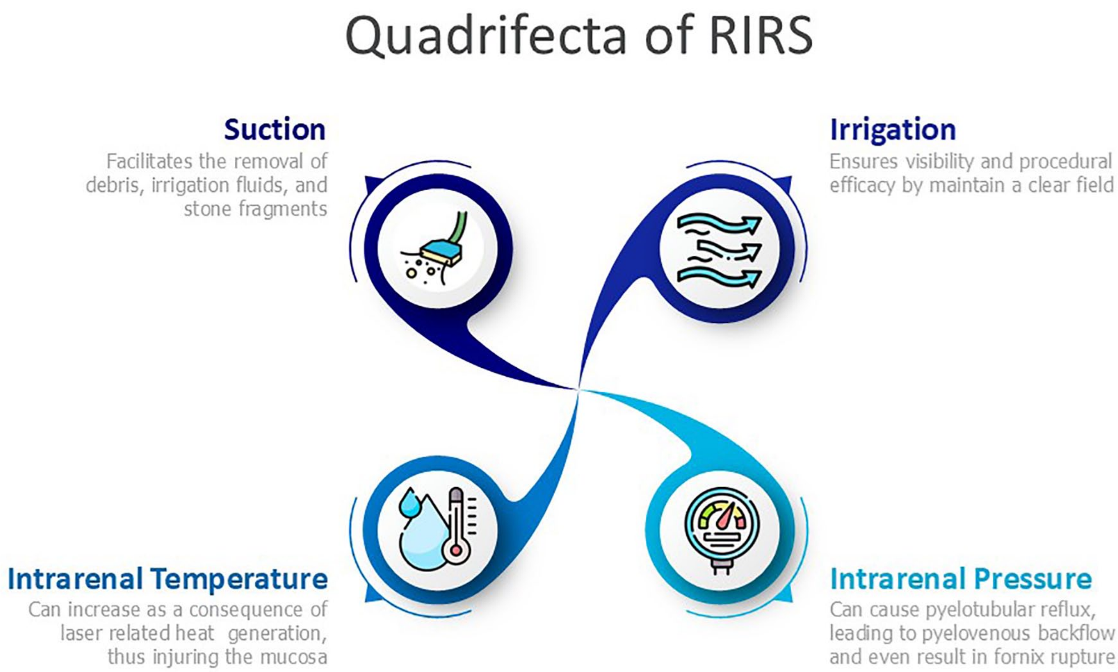

Figure 1. Quadrifecta in RIRS.
RIRS, retrograde intrarenal surgery.

the flow and the pressure of the irrigation fluid, adjusting the flow in real time according to sensors with microprocessors. This provides optimal visualisation whilst minimising the risk of intrarenal hypertension. The newest ureteroscope with integrated irrigation and suction systems has synchronised capabilities and represents the most innovative device for irrigation during RIRS. Constant monitoring of IRP and adjusted irrigation brings several benefits, including the reduction of calyceal overdistention and fluid reabsorption risk, with the consequent minimised risk of infectious complications. Nevertheless, high costs related to more advanced irrigation systems still represent a limitation in their usage. Hand-controlled and gravity-fed systems are still very well accepted and the irrigation device of choice of many surgeons worldwide.[7]

Suction

Suction plays a pivotal role in facilitating the removal of debris, irrigation fluids, and stone fragments during endourological procedures such as RIRS.[8] The stone basketing techniques, classically applied to remove larger fragments during RIRS and clear the view, can be time consuming and may leave fragments behind, leading to potential steinstrasse, postoperative pain and even reintervention. Moreover, multiple accesses to the renal cavities increase the risk of tissue damage and bleeding. The introduction of suction devices was clearly needed to overcome these limitations, and several methods have been proposed for this aim.[9] The simplest and less effective is where suction technique can be achieved by the manual aspiration from a syringe port of any rigid or flexible ureteroscope. Using the same irrigation channel can help remove debris and blood from the renal cavities, but is limited by the need to interrupt the lasering and the irrigation inflow. Integrated system can help achieve optimal suction via an additional channel.[10] An innovative way to get this outcome is via the direct-in-suction scopes (DISS), flexible ureteroscopes with suctioning channel that can be controlled whilst manoeuvring the instrument and activating the laser fibre. Suction can therefore be used to remove clots and debris, and even small fragments.[11] The ease of use is one of the main advantages, and the clear view obtained thereafter can speed the procedural times by avoiding laser interruptions. Moreover, suctioning ureteric access sheaths (SUAS) come with even better variations of usage. Suctioning system integrated into a UAS allows for a continuous flow, improved visibility and aspiration of debris, clots and even slightly larger fragments. Via 'attracting' the fragment through suction, it can be driven in the access sheath and removed, often without the need for manual basketing.[12] The most recent version of SUAS is represented by the flexible and navigable ureteral access sheath (FANS), a SUAS with a bendable tip able to follow the flexible ureteroscope movement and reach every calyx. Due to this mechanism, the potential for complete stone clearance is maximised.[13]

Intrarenal temperature

IRT is directly connected with laser activation. During laser lithotripsy in a liquid medium, IRT can increase as a consequence of laser-related heat generation, thus injuring the mucosa. The proportion of emitted laser energy that reaches the stone determines the efficiency, and consequently the dissipated energy. Whilst in vitro studies have been performed to investigate energy dissipation, efficiency should be optimised at best, by using the lower energy rates required to ablate a stone.[14] High-power lasers were found to reduce operative time, but have higher joules/mm^3 values, indicating less efficiency. High power can also cause temperature increases and potential tissue damage, as not all energy targets the stone. This can lead to complications such as ureter strictures.

Temperature control during ureteroscopy is crucial. Studies showed that higher laser power increases fluid temperature, which can be mitigated by increasing irrigation flow.[15] The introduction of the thulium fibre laser (TFL) was controversial with high IRT related to a high frequency of use. However, the overall results are debatable and need further evaluation of its effect on IRT when compared to Holmium:YAG laser.

There is still a lack of standardisation and consensus on the laser setting to effectively and safely treat renal stones, but the main indication remains to start with low pulse energy and rate and to adjust the parameters according to the hardness of the stone. In summary, to maintain safe temperatures, open irrigation systems, chilled irrigation, UASs, laser power below 40 W and shorter laser activation intervals are recommended.[16] To reduce the risk of increased IRT, some tips and tricks can be used, such as proper irrigation with good inflow and outflow, and the use of chilled solution to lower the temperature. Moreover, the timing of laser lithotripsy needs to be monitored, and on-and-off strategies might be applied to reduce the heating effect.[17]

Intrarenal pressure

The normal IRP ranges from 0 to 20 cmH_2O (15 mmHg). Increased IRP up to 40 cmH_2O (30 mmHg) can cause pyelotubular reflux, and higher IRP can lead to pyelovenous backflow and even result in fornix rupture. High IRP is linked to complications and kidney damage.[18]

Pyelorenal backflow occurs when the contents of the renal pelvis and calyceal system leak into surrounding tissues, including the peripelvic sinus, renal vein, collecting ducts and tubules, or renal interstitium. Studies have shown pyelovenous backflow can occur at pressures lower than 30 cm H_2O (22 mgHg) and becomes evident at over 40 cm H_2O. Pyelosinous backflow and forniceal rupture have been observed at higher IRP in animal studies. Pyelovenous backflow can cause excessive irrigation fluid absorption, leading to fluid overload, electrolyte imbalance and cardiovascular instability. Fluid absorption during RIRS is usually low due to the smaller instrument calibre, but high-pressure irrigation can still pose risks.[19]

Infectious complications such as urinary tract infections and sepsis during endourological procedures are linked to increased IRP and backflow, with irrigation volume being a significant risk factor for systemic inflammatory response syndrome.[20] High IRP can also cause irreversible kidney damage, with significant pathological changes observed at higher IRP ($>$204 cm H_2O). Forniceal rupture can lead to complications such as perirenal pseudocysts, retroperitoneal oedema and perinephric abscess. Increased IRP can also result in calyceal urothelium denudation and renal tubule damage, oxidative damage due to venous outflow obstruction and compression of microvessels. Other complications include ureteric stricture formation, potential for stone growth due to papillary damage, subcapsular haematomas and perirenal bleeding.[21] During RIRS for urothelial cancer, there is a potential risk of tumour seeding due to high IRP, although further investigation is needed.

IRP during ureteroscopy is influenced by irrigation flow, UAS use and whether the working channel is free or occupied. When irrigation flow exceeds 6 mL/min, the ureter acts like an open tube, making flow and pressure directly proportional. IRP can rise significantly to unacceptable levels when irrigation pressure is increased without a UAS. At the same time, using a UAS allows for stronger irrigation flow, whilst preserving IRP. These results have been confirmed by several studies on different ureteroscopes and UAS, finding a correlation with UAS and ureteroscope size ratio, ensuring a good outflow.[22] Nevertheless, studies suggest that whilst a UAS can help reduce IRP, it does not always guarantee a safe level of IRP.

Up to date, gravity-based irrigation is the preferred method to perform RIRS safely. Innovative technologies now enable a continuous control of IRP by incorporating sensors that provide real-time data that allows for immediate adjustment. Advanced automated systems are even able to modulate irrigation and suction in response to pressure readings, ensuring a consistent and safe pressure level throughout the procedure.

Interplay between suction, irrigation, temperature and pressure

Suction, irrigation, IRP and IRT are deeply intersected during RIRS, and their role is interdependent.[23,24] Balancing the parameters allows for a safe and effective stone treatment, optimising outcomes for best practice. Good irrigation, alongside the use of suction, helps lower IRT and IRP, thus enabling fast and continuous laser lithotripsy, even at high energy settings. It must be kept in mind, though, that laser settings should generally remain low even with the aid of suctioning devices. Once a good balance of the quadrifecta is obtained, the expert endourologist is now able to 'play' with the parameters, adjusting inflow and laser settings at their best whilst remaining in a safe clinical environment.

Future directions

Whilst suction, irrigation, IRT and IRP are so deeply connected, technological advancements are moving towards the creation of automated systems that monitor and adjust the different parameters to ensure safety. Real-time sensors delivering information on the intrarenal status will allow for a precise and immediate control of inflow and outflow, whilst providing information on the safety of laser lithotripsy. These systems still have high related costs, and their main limitation is the restricted availability outside research settings, especially for countries with a public national health system. Perhaps, there would also be an increasing role of artificial intelligence amidst all of these system integrations.[25]

Suction is attracting huge interest in the endourological world, and attention is drawn to the possible combination of suctioning devices.[26,27] The concurrent use of DISS and suctioning UAS would possibly represent an ideal method to remove debris or larger fragments, ensuring a continuous optimal view for lithotripsy.[28] Nevertheless, such a strong suctioning system would necessarily require strong irrigation devices, with unknown effects on IRP. In vitro and ex vivo studies will be required to investigate the outcomes and safety of more advanced irrigation and suctioning systems.

Moreover, hands-on training sessions with simulators would help trainees and expert endourologists gain confidence with the newest technologies, by providing a safe environment to train and test new devices without the risk of endangering the patient. Ensuring the availability of simulators would probably help endourologists to accept and introduce suctioning devices and automated systems in their practice, spreading a best practice of RIRS with optimisation of the quadrifecta and operative outcomes.

Take home messages

1. The interplay between suction, irrigation, temperature and pressure in RIRS is complex and pivotal for achieving optimal outcomes. Understanding and managing these parameters can significantly enhance the effectiveness and safety of the procedure.
2. Irrigation is essential to clear the surgical field by flushing out blood, stone fragments and other debris. However, excessive irrigation can increase IRP, risking renal damage or related complications.
3. Suction aims to remove the irrigating fluid and debris. If suction is too aggressive, it can lead to inadequate irrigation, resulting in poor visibility. Conversely, insufficient suction can lead to fluid buildup, increasing IRP.
4. IRT can increase significantly during laser lithotripsy, especially if irrigation and outflows are not optimised. It is mandatory to ensure safety levels of delivered energy and

to maximise laser efficiency and low dissipation to prevent thermal damage.

5. High IRP can lead to forniceal rupture, postoperative pain, infection and fluid extravasation, potentially causing perirenal hematoma or urinoma. Proper regulation of irrigation flow and suction is crucial to maintain a safe IRP, reducing the risk of backflow and urosepsis.
6. By meticulously managing the quadrifecta interplay, surgeons can significantly improve the safety and efficacy of RIRS, leading to better patient outcomes and reduced complication rates.
7. Using devices that provide real-time feedback on IRP and IRT allows endourologists to adjust irrigation and suction dynamically. This ensures that the surgical field remains clear without risking pressure- or temperature-related complications.
8. Urologists must be trained to understand the complex interplay between these parameters and to use technology effectively to manage them, and the use of simulators would represent a safe and efficient instrument in doing so.

Conclusion

The successful execution of RIRS hinges on the careful balancing of suction, irrigation, temperature and pressure. The interdependence of these factors requires continuous monitoring and adjustments to optimize surgical outcomes and minimize complications. Proper training and technological advancements, such as pressure sensors and automated fluid management systems, can enhance the surgeon's ability to control these variables effectively, ensuring safer and more efficient RIRS procedures.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Author contributions

Carlotta Nedbal: Methodology; Project administration; Writing – original draft.

Vineet Gauhar: Conceptualization; Writing – review & editing.

Steffi Kar Kei Yuen: Conceptualization; Writing – review & editing.

Daniele Castellani: Conceptualization; Writing – review & editing.

Thomas Herrmann: Conceptualization; Writing – review & editing.

Olivier Traxer: Conceptualization; Writing – review & editing.

Bhaskar Kumar Somani: Conceptualization; Project administration; Supervision; Writing – review & editing.

Acknowledgements

None.

Funding

The authors received no financial support for the research, authorship and/or publication of this article.

Competing interests

The Associate Editor of Therapeutic Advances in Urology is an author of this paper.

Availability of data and materials

Not applicable.

ORCID iDs

Steffi Kar Kei Yuen https://orcid.org/0000-0002-9956-1558

Daniele Castellani https://orcid.org/0000-0001-7354-9190

Bhaskar Kumar Somani https://orcid.org/0000-0002-6248-6478

References

1. Skolarikos A, Jung H, Neisius A, et al. EAU guidelines on urolithiasis [Internet]. Edn. presented at the EAU Annual Congress Milan 2023, https://uroweb.org/guidelines/urolithiasis (2023, accessed 11 Oct 2023).
2. Juliebø-Jones P, Keller EX, Haugland JN, et al. Advances in ureteroscopy: new technologies and current innovations in the era of tailored endourological stone treatment (TEST). *J Clin Urol* 2023; 16(3): 190–198.

3. Geraghty R, Davis N, Tzelves L, et al. Best practice in interventional management of urolithiasis: an update from the European association of urology guidelines panel for urolithiasis 2022. *Eur Urol Focus* 2023; 9(1): 199–208.
4. Dybowski B, Bres-Niewada E, Rzeszutko M, et al. Risk factors for infectious complications after retrograde intrarenal surgery – a systematic review and narrative synthesis. *Central Eur J Urol*; 2021; 74: 437–445.
5. Zeng G, Traxer O, Zhong W, et al. International alliance of urolithiasis guideline on retrograde intrarenal surgery. *BJU Int* 2023; 131(2): 153–164.
6. Wang T, Chen X and Qu H. Economical and efficient autonomous ureteroscopic irrigation systems. *Asian J Surg* 2021; 44: 409–411.
7. Salka B, Bahaee J, Plott J, et al. Under pressure: irrigation practice patterns during flexible ureteroscopy. *Ther Adv Urol* 2023; 15: 17562872231179009.
8. Yuen SKK, Traxer O, Wroclawski ML, et al. Scoping review of experimental and clinical evidence and its influence on development of the suction ureteral access sheath. *Diagnostics* 2024; 14: 1034.
9. Giulioni C, Castellani D, Traxer O, et al. Experimental and clinical applications and outcomes of using different forms of suction in retrograde intrarenal surgery. Results from a systematic review. *Actas Urologicas Espanolas* 2024; 48: 57–70.
10. Solano C, Chicaud M, Kutchukian S, et al. Optimizing outcomes in flexible ureteroscopy: a narrative review of suction techniques. *J Clin Med* 2023; 12: 2815.
11. Gauhar V, Somani BK, Heng CT, et al. Technique, feasibility, utility, limitations, and future perspectives of a new technique of applying direct in-scope suction to improve outcomes of retrograde intrarenal surgery for stones. *J Clin Med* 2022; 11(19): 5710.
12. De Coninck V, Somani B, Sener ET, et al. Ureteral access sheaths and its use in the future: a comprehensive update based on a literature review. *J Clin Med* 2022; 11: 5128.
13. Gauhar V, Traxer O, Castellani D, et al. A feasibility study on clinical utility, efficacy and limitations of 2 types of flexible and navigable suction ureteral access sheaths in retrograde intrarenal surgery for renal stones. *Urology* 2023; 178: 173–179.
14. Panthier F, Pauchard F and Traxer O. Retrograde intra renal surgery and safety: pressure and temperature. A systematic review. *Curr Opin Urol* 2023; 33: 308–317.
15. Rice P, Somani BK, Nagele U, et al. Generated temperatures and thermal laser damage during upper tract endourological procedures using the holmium: yttrium–aluminum-garnet (Ho:YAG) laser: a systematic review of experimental studies. *World J Urol* 2022; 40: 1981–1992.
16. Pauchard F, Ventimiglia E, Corrales M, et al. A practical guide for intra-renal temperature and pressure management during RIRS: what is the evidence telling us. *J Clin Med* 2022; 11: 3429.
17. Corrales M, Panthier F, Solano C, et al. Laser safety, warnings, and limits in retrograde intrarenal surgery. *Actas Urol Esp* 2024; 48: 19–24.
18. Tokas T, Tzanaki E, Nagele U, et al. Role of intrarenal pressure in modern day endourology (Mini-PCNL and Flexible URS): a systematic review of literature. *Curr Urol Rep* 2021; 22: 52.
19. Doizi S. Intrarenal pressure: what is acceptable for flexible ureteroscopy and percutaneous nephrolithotomy? *Eur Urol Focus* 2021; 7(1): 31–33.
20. Corrales M, Sierra A, Doizi S, et al. Risk of sepsis in retrograde intrarenal surgery: a systematic review of the literature. *Eur Urol Open Sci* 2022; 44: 84–91.
21. Doizi S, Uzan A, Keller EX, et al. Comparison of intrapelvic pressures during flexible ureteroscopy, mini-percutaneous nephrolithotomy, standard percutaneous nephrolithotomy, and endoscopic combined intrarenal surgery in a kidney model. *World J Urol* 2021; 39(7): 2709–2717.
22. Tokas T, Skolarikos A, Herrmann TRW, et al. Pressure matters 2: intrarenal pressure ranges during upper-tract endourological procedures. *World J Urol* 2019; 37(1): 133–142.
23. Kronenberg P, Hameed BMZ and Somani B. Outcomes of thulium fiber laser for treatment of urinary tract stones: results of a systematic review. *Curr Op Urol* 2021; 31(2): 80–86.
24. Hughes T, Ho HC, Pietropaolo A, et al. Guideline of guidelines for kidney and bladder stones. *Turkish J Urol* 2020; 46 (Suppl. 1): S104.
25. Hameed BMZ, Dhavileswarapu AVLS, Raza SZ, et al. Artificial intelligence and its impact on urological diseases and management: a

comprehensive review of the literature. *J Clin Med* 2021; 10(9): 1864.

26. Somani B, Davis N, Emiliani E, et al. Intrarenal pressure monitoring during ureteroscopy: a delphi panel consensus. *Eur Urol Open Sci* 2025; 73: 43–50.

27. Jahrreiss V, Nedbal C, Castellani D, et al. Is suction the future of endourology? overview from EAU section of urolithiasis. *Ther Adv Urol* 2024: 16: 17562872241232275.

28. Nedbal C, Yuen SKK, Akram M, et al. First clinical evaluation of a flexible digital ureteroscope with direct in scope suctioning system (Pusen DISS 7.5Ch): prospective multicentric feasibility study. *World J Urol* 2024; 42(1): 560.