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REVIEW ARTICLE

Experimental and clinical applications and outcomes of using different forms of suction in retrograde intrarenal surgery. Results from a systematic review

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KEYWORDS
Retrograde intrarenal surgery;
Suction device;
Stone-free rate;
Infectious complication

Abstract
Objective: To identify the latest advances in suction devices and evaluate their effect in Retrograde intrarenal surgery (RIRS) and ureteroscopy for stones.
Basic procedures: A systematic literature search was performed on 4th January 2023 using Scopus, PubMed, and EMBASE. Only English papers were included; both pediatric and adult studies were accepted. Duplicate studies, case reports, letters to the editor, and meeting abstracts were excluded.
Main findings: Twenty-one papers were selected. Several methods have been proposed for suction use in RIRS, such as through the ureteral access sheath or directly to the scope. Artificial intelligence can also regulate this system, monitoring pressure and perfusion flow values. All the proposed techniques showed satisfactory perioperative results for operative time,

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stone-free rate (SFR), and residual fragments. Moreover, the reduction of intrarenal pressure (induced by aspiration) was also associated with a lower infection rate. Even the studies that considered kidney stones with a diameter of 20 mm or higher reported higher SFR and reduced postoperative complications. However, the lack of well-defined settings for suction pressure and fluid flow prevents the standardization of the procedure.

Conclusion: Aspiration device in the surgical treatment of urinary stones favours a higher SFR, reducing infectious complications, as supported by the included studies. RIRS with a suction system provided to be a natural successor to the traditional technique, regulating intrarenal pressure and aspirating fine dust.

PALABRAS CLAVE
Cirugía intrarrenal retrógrada;
Dispositivo de aspiración;
Tasa libre de cálculos;
Complicación infecciosa

Aplicaciones clínicas, experimentales y resultados del uso de diferentes dispositivos de aspiración en la cirugía intrarrenal retrógrada. Revisión sistemática

Resumen

Objetivo: Identificar los últimos avances en los dispositivos de aspiración para la cirugía retrógrada intrarrenal (CRIR) y la ureteroscopia en el tratamiento de la litiasis, y evaluar los resultados de su aplicación.

Procedimiento: El 4 de enero de 2023 se realizó una búsqueda bibliográfica sistemática en Scopus, PubMed y EMBASE. Sólo se incluyeron artículos en inglés; se aceptaron estudios en la población pediátrica y estudios en adultos. Se excluyeron los estudios duplicados, los informes de casos, las cartas al editor y los resúmenes de congresos.

Hallazgos principales: Se seleccionaron 21 trabajos. Se han propuesto varios sistemas de aspiración para la CRIR: a través de la vaina de acceso ureteral o directamente por el endoscopio. La inteligencia artificial también puede desempeñar un papel, monitorizando los valores de la presión y del flujo de irrigación. Todas las técnicas propuestas mostraron resultados perioperatorios satisfactorios en cuanto a tiempo quirúrgico, tasa libre de litiásis (TLL) y fragmentos residuales. Además, la reducción de la presión intrarrenal (mediante la aspiración) también se asoció a una tasa de infección menor. Incluso los estudios que incluyen cálculos renales con un diámetro de 20 mm o superior informan de una mayor TLL y una reducción de las complicaciones postoperatorias. Sin embargo, la falta de parámetros bien establecidos para la presión de la aspiración y el flujo de líquido impide la estandarización del procedimiento.

Conclusión: Como ha sido demostrado en los estudios incluidos, el uso de dispositivos de aspiración en el tratamiento quirúrgico de los cálculos urinarios favorece la obtención de una TLL mayor y reduce las complicaciones infecciosas. La CRIR con sistema de aspiración podría sustituir a la técnica tradicional, gracias a sus ventajas asociadas al control de la presión intrarrenal y aspiración del polvo fino.

Introduction

Over the last few years, equipment miniaturization, limited uses of scope, newer scopes with improved optics, easier availability of disposables and more powerful lasers have contributed to the increased adoption of Retrograde IntraRenal Surgery (RIRS). The latter is the preferred treatment for renal stones up to 20 mm[1] and is also a preferred modality for stones in the pediatric age group[2] and has gained worldwide acceptance as a truly minimally invasive and safe endoscopic approach for renal stones in normal and anomalous kidneys.[3] However, despite its widespread adoption, recent data from a multicenter registry on 6669 patients quotes a possibility of 21.7% of patients having residual fragments (RF) and a 1.3% risk of sepsis.[4]

Several factors occur to achieve a high SFR without compromising safety, such as intrarenal pressure [IRP] and temperature management.[5,6] Another impediment is the inability to extract all the stone fragments leading to residual fragments [RF], even the, namely, clinically insignificant ones [CIRF].[7] The surgeon must rely on spontaneous elimination or manual extraction of fragments. A meta-analysis by Gauhar et al.[8] showed that dusting alone or fragmentation and extraction are acceptable methods to minimize RF during lithotripsy, and both techniques are similar in efficacy and safety. However, they suggested that high-power laser leads to the dusting technique preference. The possible issue with this is that high power lasers may generate the ''snow globe effect'',[9] determining to hamper vision, increasing operative time and hiding RF. Improved irrigation and suction-based techniques[10,11] seem to be the one-stop solution to mitigate all these issues. Suction has been used in endourology for more than 25 years, although it was mainly limited to PCNL and its use during RIRS is a novel idea which gained popularity in the last five years.[12] In this paper, we aimed to review the different methods of using suction and their clinical benefits in RIRS and ureteroscopy for stones.

Evidence acquisition

Literature search

In this study, we performed a systematic review evaluating the influence of applying suction on outcomes of semirigid and flexible ureteroscopy for ureteral and kidney stones. The literature search was performed on 4th January 2023 using Scopus, PubMed, and EMBASE. The following term and Boolean operators were used: (suction OR vacuum OR aspiration or ureteral access sheath) AND (RIRS or retrograde intrarenal surgery OR ureteroscopy OR flexible ureteroscopy) AND (kidney stones OR urolithiasis OR renal stones)

Selection criteria

Only English papers were included. Both pediatric and adult studies were accepted. Preclinical studies were also included. Duplicate studies, case reports, letters to the editor, and meeting abstracts were excluded.

Study screening and selection

Two independent authors screened all retrieved papers through Covidence Systematic Review Management® (Veritas Health Innovation, Melbourne, Australia). Discrepancies were solved through discussion. The full text of the screened papers was selected if found relevant to the purpose of the present review.

Evidence synthesis

Literature screening

Literature search found 1119 studies. 310 duplicates were automatically deleted, and 809 studies were left for screening against title and abstract. Among the latter, 773 papers were excluded because were irrelevant to the purpose of this review. The remaining 36 full-text papers were additionally assessed for eligibility and 15 papers were excluded. Finally, 21 studies were considered eligible and included.[13–33] Fig. 1 summarizes the flow diagram of the literature search.

Study characteristics

There were 2 ex-vivo studies.[32,33] Among clinical studies, there were 11 retrospective[14–17,19–27,29,31] and 8 prospective studies[13,14,17,18,24,28–30] and 4 among the latter were randomized.[13,18,28,30]

in 13 papers only kidney stones were treated[13,14,16,19,20,22,24–28,30,31] in 5 studies only ureteral stones[15,18,21,23,29] and the remaining one both ureteral and kidney stones were included.[17] Three studies compared suctioning RIRS versus mini-PCNL.[19,22,31] Regarding suctioning methods, there were 11 studies using a suctioning UAS,[14,17–20,23,25,27,30,31,33] 3 studies a vacuum-assisted UAS,[22,24,32] 3 studies a suction catheter inside a UAS,[17,21,28] and the remaining 4 studies employed a direct in-scope suction technique.[13,15,16,26]

Table 1 shows study characteristics.

Discussion

According to Literature, suction devices have a role in endourology, and technological advances were developed to incorporate suction and pressure control capabilities in percutaneous and ureteroscopic lithotripsy.[12] Several methods have been proposed on how to use suction in RIRS. We provided an insight into the experimental and clinical studies describing the different technologies whilst highlighting their strengths and weaknesses.

Pressure-control systems

Pressure-control systems were primarily introduced in Mini-PCNL to establish a steady flow of irrigation fluid whilst monitoring intraluminal pressure. It ensures the presence of a streamlined flow of fluid in the pelvicalyceal system (PCS) and avoids the issues that could arise from the use of unmonitored fluid pump mechanisms (such as the sudden increase in IRP, forniceal ruptures and fluid extravasation), most commonly seen with handheld pump devices.[34] Their application was extendable to RIRS.

The first RCT evaluating the efficacy of a suction system during RIRS was presented in 2003 by Lechevallier et al.,[13] who described an automatic electronic-controlled irrigation/suction system, the ENDO FMS® UROLOGY (Future Medical Systems USA, Glen Burnie, MD). This system generated a constant irrigant flow and was applicated both in flexible and semirigid ureteroscopy. Despite the low number of participants, the authors demonstrate a significant reduction in operative time (42 ± 17 vs 65 ± 25, p 0.04) and better SFR than controls (92% vs 69%, p 0.048). Afterwards, the first two RCTs were published on this topic by Du et al. for ureteric stones and Chen et al. for renal stones in 2019.[18,19] In these two papers, the same patented perfusion and suctioning platform capable of maintaining the intrapelvic pressure at a low negative level and performing suction during holmium laser lithotripsy under negative pressure. In addition, the system was able to automatically maintain the intrapelvic pressure at a low negative level was used. A modified 12—14-Fr integrated pressure-measuring suctioning ureteral access sheath, and the pressure measurement and the suction interfaces of the sheath were, respectively, were connected with the intelligent irrigation and suctioning pressure control platform through the pressure measurement tube and the suction tube.

Intraluminal pressure was adjusted to 0 mmHg on the intelligent pressure control platform, which can adjust pressure (5 to −15 mm Hg) and perfusion flow value (50—150 ml/min) once it is connected to the system. It was determined according to experimental animal pressure studies conducted by the same group. Both groups concluded that intelligent pressure-controlled FURS could be used as an effective and safe treatment method for 2—3 cm-sized stones.

In 2018, Li et al.[15] presented a novel Semirigid Ureterorenoscope with Vacuum Suctioning System named ''Sotn'', with a dedicated ureteral access sheath allowing intermittent or continuous suction during the procedure. In a retrospective study of 386 patients for proximal ureteral and renal pelvic stones less than 3 cm in diameter. the final overall SFR was 94.3%. A similar device was presented by Zhang et al.[30] in 2022. The authors emphasize that the advantages over standard ureteroscopy are improved endoscopic vision, control of intrapelvic pressure and reduced operative time. Indeed, The pressure systems have proved to be highly successful in regulating the suction and irrigation system to maintain a controlled IRP. However, their utility was reported only by Chinese single-centre studies. Considering their patented nature, the pressure systems

Table 1 Studies concerning the application of suction device during retrograde intrarenal surgery.

Author year	Country	Retrospective/ prospective	Grouping	Stone size	Suction device/technique	SFR	Operative time (min)	Complications	Final conclusion
Lechevallier et al. 2003[13]	France	Randomized trial	10 fURS with suction 12 traditional fURS	–	ENDO FMS® UROLOGY irrigation/suction system	–	37 ± 20 min	–	Lower operative time with suction system
Zeng et al. 2016[14]	China	Prospective study	57 fURS suctioning lithotripsy	–	Modified UAS with an oblique suction-evacuation port	100% after 1 month	27.3 ± 9.1	Fever: 3.5% False passage: 1.8%	The modified UAS reduced stone retropulsion, improved stone clearance, improved visual field, and probably reduced the intraluminal pressure
Li et al. 2018[15]	China	Retrospective study	Semirigid or f-URS with suction for: • 94 stones < 10 mm (Group 1) • 208 stones 10–20 mm (Group 2) • 84 stones >20 mm (Group 3)	All sizes	Suction system which mantains negative pressure	After 1 month Group 1: 97.5% for semirigid and 95.7% for fURS Group 2: 89.8% for semirigid and 89.4% for fURS Group 3: 42% for semirigid andn 69% for fURS	Group 1: 38.3 ± 30.1 Group 2: 46.7 ± 26.1 Group 3: 66.7 ± 41.5	Fever: 8.5% for Group 1, 11.1% for Group 2 and 13.1% for Group 3 Ureter injury: 10.6% for Group 1, 12.0% for Group 2 and 15.5% for Group 3	Vacuum suction system facilitates the SFR for renal pelvic stones

Table 1 (*Continued*)

Author year	Country	Retrospective/ prospective	Grouping	Stone size	Suction device/technique	SFR	Operative time (min)	Complications	Final conclusion
Peng et al. 2018[16]	China	Retrospective study	fURS suctioning lithotripsy: • 47 in the oblique supine lithotomy position • 35 in the supine lithotomy position	All sizes	Automatic control of renal pelvic pressure	After 1 month: 85.7% 97.9%	31.81 ± 2.2 23.4 ± 14.9	–	fURS in patients with oblique supine lithotomy position is more effective that in supine lithotomy position
Huang et al. 2018[17]	China	Retrospective study	40 fURS in patients with solitary kidney	2.37 ± 0.43	irrigation and suctioning platform	87.5% after 4 weeks	25.2 ± 14.5 min	Fever: 2 (5%)	fURS with Pressure Control had satisfactory SFR and low complication rate
Du et al. 2019[18]	China	Randomized trial	62 fURS suctioning lithotripsy 60 traditional fURS	$\geq$ 15 mm	negative pressure using the perfusion and suctioning platform	100%	25.3 ± 5.6	Fever: 1,6%	This system improves SFR for stones $\geq$ 1.5 cm below L4 level
Chen et al. 2019[19]	China	Retrospective study	46 fURS suctioning lithotripsy 45 mPCNL	20–30 mm	Intelligent irrigation and suctioning pressure control platform	93.1% (after 4 weeks)	65.62 ± 22.54	Fever or postoperative pain: 11.3%	fURS with suction was associated with less complication and bleeding
Zhu et al. 2019[20]	China	Retrospective study	167 fURS with suctioning UAS 167 traditional fURS	8.4 ± 2.53	suctioning ureteral access sheath	88.8%	49.7 ± 16.3	Fever: 9/165 (5.5%) Hematuria 5/165 (3.0%) Urosepsis requiring only additional antibiotics: 3/165 (1.8%) Ureteral stricture: 1/165 (0.6%) Septic shock: 1/165 (0.6%)	Suctioning UAS determined a lower incidence of infectious complications and a shorter operative time

Table 1 (*Continued*)

Author year	Country	Retrospective/ prospective	Grouping	Stone size	Suction device/technique	SFR	Operative time (min)	Complications	Final conclusion
Wu et al. 2020[21]	China	Prospective study	78 semi-rigid URS with suction	11.8 (range 5–19)	Negative pressure induced by a F5 ureter catheter and a T joint	100% after 1 month	35.8 ± 6.44	Fever : 1.3%	This technique may reduce stone fragment retropulsion, and shorten the operative time
Lai et al. 2020[22]	China	Retrospective study	28 fURS suctioning lithotripsy 56 for mPCNL	35.3 ± 6.3	V-UAS with negative pressure aspirator	89.3% after 3 months	72.4 ± 21.3	Fever: 7% Emesis: 3.5% Infection: 3.5% Perforation: 3.5% Steinstrasse: 3.5%	V-UAS improves the SFR in RIRS for 2–4 cm renal stone
Zhang et al. 2021[23]	China	Retrospective study	56 fURS suctioning lithotripsy 54 traditional fURS 50 rigid URS	13.9 ± 4.7	The vacuum suction device was connected to the end of UAS	96.4 % after 1 month	46.4 ± 17.9	Fever: 3.6%	The suction improved SFR, with similar complication rate
Chen et al. 2022[24]	China	Prospective study	53 fURS with FV-UAS	17.1 (11–25) mm	FV-UAS connected with a vacuum suction device	69.8%	70.8 (36–154) mean-range	–	The FV-UAS increased SFR
Gao et al. 2022[25]	China	Retrospective study	310 fURS	All sizes	Intelligent pressure-control system	82.26% (after 1 month)	81.7 ± 37.2	CD I: 96.8% CD II: 2.6% CDII: 0.7%	Suction improves perioperative outcomes, especially for stones < 40 mm
Gauhar et al. 2022[26]	Singapore, India	Retrospective study	28 fURS with suction UAS 30 fURS with DISS technique	13.3 ± 2.5	ClearPetra™ system	64.3% (after 3 weeks)	49.8 ± 14.7	Fever: 25% Haematuria: 7.1%	Similar SFR and shorter surgical time for suction UAS

Table 1 (*Continued*)

Author year	Country	Retrospective/ prospective	Grouping	Stone size	Suction device/technique	SFR	Operative time (min)	Complications	Final conclusion
Qian et al. 2022[27]	China	Retrospective study	81 fURS with suctioning UAS 81 traditional fURS	19.7 ± 4.5	suctioning UAS with the negative pressure pump	88.9% after 1 month	72.9 ± 28.1	Fever: 3.7% SIRS: 1.2%	Suctioning UAS was associated with higher SFR and lower complication rate
Sur et al. 2022[28]	United States of America	Randomized trial	9 fURS with suction 8 fURS with basket removal	≤15mm	steerable ureteroscopic renal evacuation (SURE) system	100% after 1 month	54 ± 17	Ileus: 11.1%	SURE system was more effective in stone removal postlaser lithotripsy than basket
Wu et al. 2022[29]	China	Prospective study	76 semi-rigid URS with suction 82 Traditional-semi-rigid URS	All sizes	Negative pressure induced by a F5 ureter catheter and a T joint	94.7% after 1 month	38.18 ± 6.37	Fever: 3.9%	Vacuum suction is associated with shorter operating time, lower fever rate, and a higher SFR
Zhang et al. 2022[30]	China	Randomized trial	30 fURS suctioning lithotripsy 30 traditional fURS	18.2 ± 5.3	Soton URS system with negative pressurecontrol	91.3% after 1 week	57.3 ± 10.6	Fever: 3%	Soton URS is associated with fewer substantially infection following lithotripsy
Deng et al. 2022[31]	China	Retrospective study	57 fURS suctioning lithotripsy 70 for mPCNL	23.1 ± 6.5	UAS with pressure-measuring suctioning	80.7% after 1 month and 91.2 % after 3 months	61.8 ± 21.1	Fever: 5 (8.8) Ascites : 1 (1.8) Steinstrasse: 1 (1.8)	fURS required a higher operative time than mPCNL, but deteremines less bleeding, length of stay
Chen et al. 2022[32]	China	Randomized trial on porcine kidneys with human stones	10 fURS with flexible vacuum-assisted UAS 10 fURS with traditional UAS	≤5mm	flexible vacuum-assisted ureteral access sheath	70% vs 0%	44.2 ± 7.7	–	Flexible vacuum-assisted UAS is associated with higher SFR

Table 1 (*Continued*)

Author year	Country	Retrospective/ prospective	Grouping	Stone size	Suction device/technique	SFR	Operative time (min)	Complications	Final conclusion
Jiang et al. 2022[33]	United States of America	Randomized trial on porcine kidneys with human stones	6 Ho:YAG-fURS without UAS nor suction 6 Ho:YAG-fURS with suction and no UAS 6 Ho:YAG-fURS with 14 Fr UAS and no suction 6 Ho:YAG-fURS with 14 Fr UAS and suction 6 MOSES-fURS without UAS nor suction 6 MOSES-fURS with suction and no UAS 6 MOSES-fURS with 14 Fr UAS and no suction 6 MOSES-fURS with 14 Fr UAS and suction 6 sTFL-fURS without UAS nor suction 6 sTFL -fURS with suction and no UAS 6 sTFL -fURS with 14 Fr UAS and no suction 6 sTFL -fURS with 14 Fr UAS and suction	5—9 mm	Intermittent suction with stopcock	64.8% 79.5% 66.1% 78.6% 67.7% 82.1% 74.2% 86.7% 66.1% 91.2% 88.5% 94.3%	9.34 9.22 9.00 9.98 9.51 9.81 10.31 10.90 8.62 8.80 10.27 10.37	–	Aspiration is associated with higher SFR

SFUI: suctioning flexible ureteroscopy with Intelligent pressure-control; mPCNL: minimally invasive percutaneous nephrolithotomy; FV-UAS: flexible vacuum-assisted ureteric access sheath; DISS: direct in-scope suction; SFR: Stone-free rate.

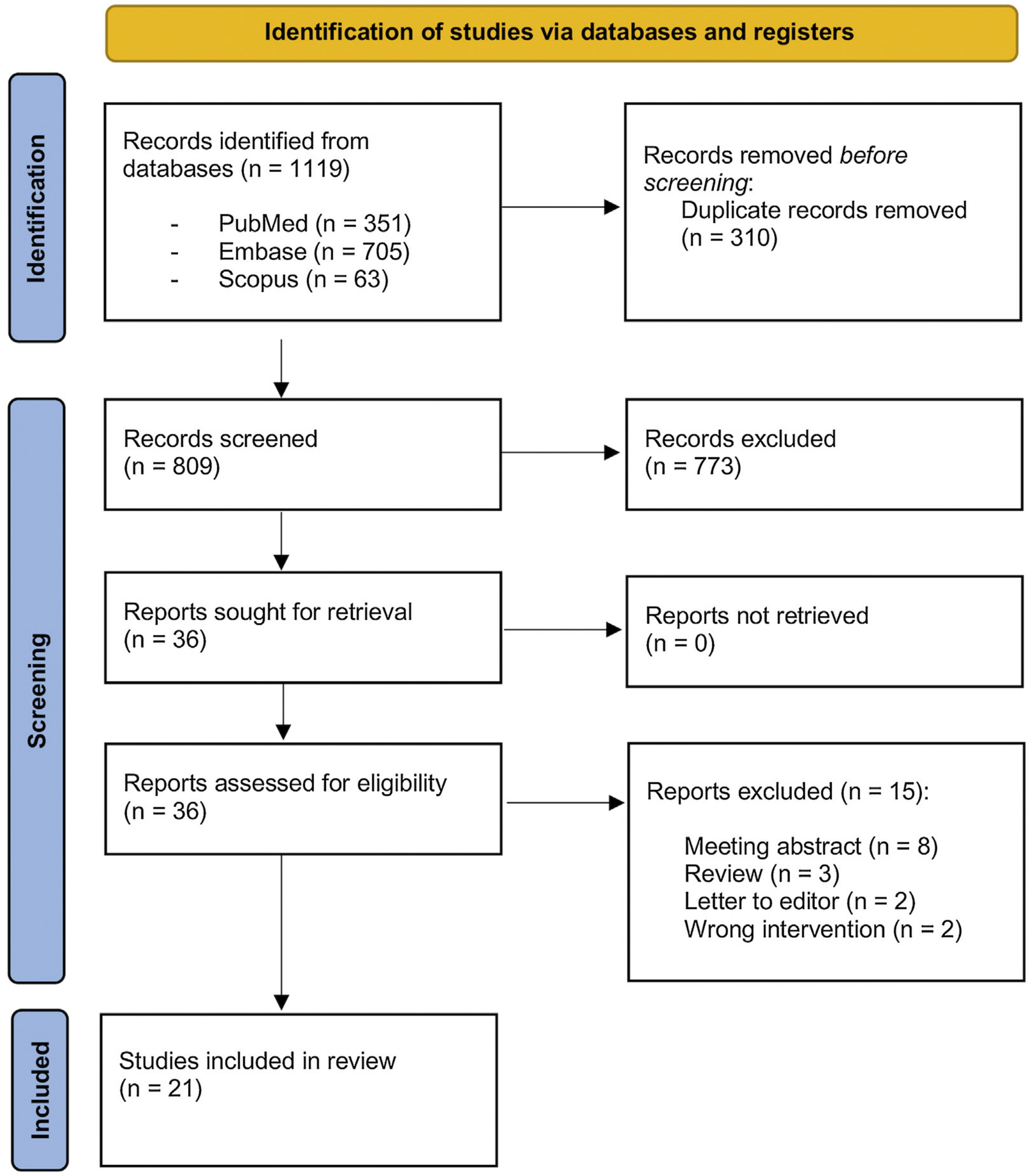

Figure 1 Suction RIRS.

utility may be limited widely by the need for using consumables suiting these systems alone.

Aspiration systems

As more and more powerful lasers are being used in RIRS, endourologist seek options to aspirate the fine dust generated to minimize RF and the sequelae of clinical events.[7,9]

The direct in-scope suction (DISS) technique introduces the rationale of performing a simultaneous or alternating suction during or after the laser lithotripsy, using the scope as a conduit for fragments/dust extraction. Gauhar et al.[26] first presented a simple system that can easily be mounted on the operative channel of any ureteroscope using two simple three-way stoppers attached. By allowing a contemporary connection to a suction tube and irrigation (by gravity or using a dedicated flow pump), the suction can be activated at the surgeon's request, aspirating stone fragments or dust. The procedure appeared feasible independently from the UAS use and versatile enough to use with any flexible ureteroscope. In this paper, the authors compared DISS with a traditional suction ureteral access sheath (SUAS). Despite operative time being significantly longer in the DISS group (80.0 vs 47.5 min, $p < 0.001$), hospital stay was significantly shorter in the DISS group [1.00 (0.667–1.00) vs 1.00 (1.00–2.00) days, $p = 0.02$]. Moreover, the incidence of RF did not significantly differ between the two groups [10 (33.3%) in the DISS group vs 10 (35.7%) in the SUAS group, $p = 0.99$]. They reported from their audit that RIRS with DISS technique was feasible with an acceptable rate of retreatment, compared to RIRS with SUAS with the added advantage of being cheap, effective, and versatile.

Jiang et al.[33] reported on an ex-vivo study with a porcine kidney model using bego stones the outcomes of a single session of intrarenal laser lithotripsy with different laser sources (Ho:YAG, Ho:YAG with MOSES effect and superpulse TFL).Procedures were performed combining the use of ureteral access sheath (UAS) and active suction using a specific dual-channel fiberoptic ureteroscope with a Tip of 5.2F, a 9.9 F shaft and a dedicated irrigation port of 3.3F and the suction port of 3.3F. It allowed for aspiration via the sheath while maintaining steady irrigation and suction during

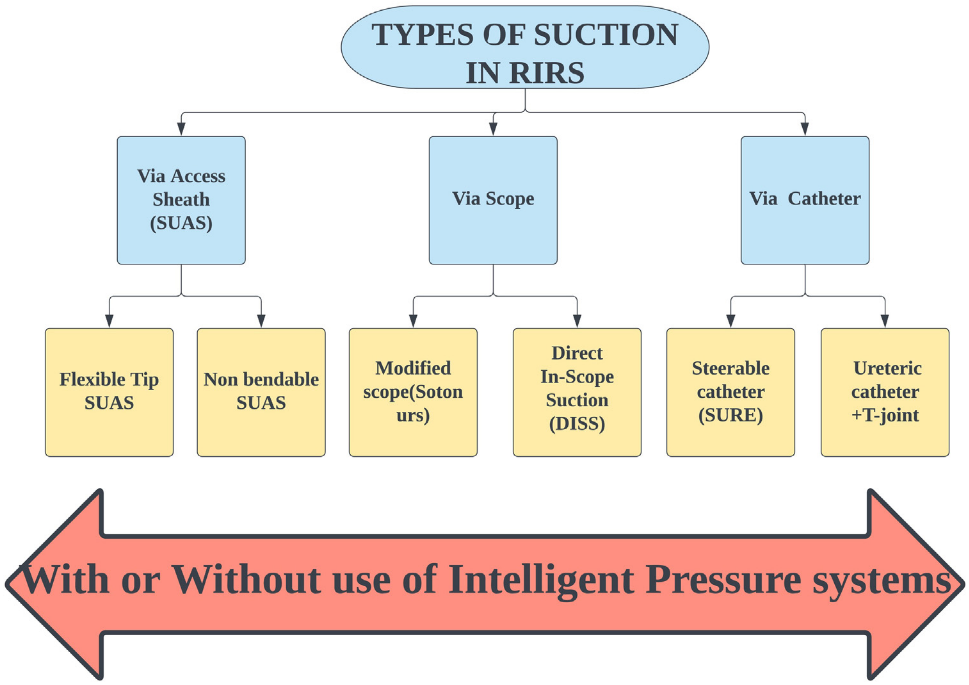

Figure 2 Suction RIRS.

laser litotripsia. The authors concluded that stone clearance was optimized using the TFL, 14F UAS, and applying aspiration. This combination resulted in 94% of total SFR, while the 6% remaining fragments were all <2 mm. Nevertheless, they also stated that these benefits of TFL were lost without aspiration, emphasizing the need for using it to remove fine dust.

Suction and aspiration through a ureteral catheter

In 2020 Wu et al. used a suction system composed of a modified 5F ureteral catheter attached to a vacuum aspiration system through a T- joint, introduced in a semirigid ureteroscope.[21]

It could efficiently provide a continuous flow whilst the irrigation fluid, out of the ureteroscope, is immediately suctioned through a constant negative pressure during ultrasonic lithotripsy.

Continuous suction and active irrigation throughout the lithotripsy maintained adequate visibility, achieved by a simple gravity-based paired with handheld syringe irrigation. The authors showed a 100% SFR after one month from surgery.

Two years later, Wu et al. repeated their study in a series of impacted ureteral stones compared to ''classic'' URS, showing shorter operative time (38.18 ± 6.37 min vs 46.65 ± 5.66 min; p < 0.001), reduced rate of fever >38 °C (3.9% vs 14.6%; p < 0.022) and higher early SFR (88.2% vs 72.0%; p = 0.011).[29]

A recent study by Sur et al.[28] compared stone fragments extraction after RIRS with a traditional basket with the steerable ureteroscopic renal evacuation catheter (SURE) system connected to the ureteral access sheath at the end of lithotripsy, called CVAC Aspiration System (Calyxo, Inc.). Despite a small sample size, the SURE system achieved a 100% SFR at 30 days vs 75% for extraction, although this difference was not statistically significant (p = 0.20). The procedure appeared safe, without any registered complications.

Therefore, aspiration through the scope, sheath, or steerable catheter seems promising. The caveat for these is to be effective in generating fine dust, which is possible only with high-power lasers like TFL and Holmium with MOSES.[8] The ease of using any scope, UAS or catheter for dust aspiration with a wall-mounted suction system and a simple irrigation system makes this a versatile technique, which is likely to gain momentum once multicenter clinical studies can help standardize the procedure.

Suction through ureteral access sheath

UAS use has been controversial due to the risk of ureteric injury and failure to deploy the same in some unstented patients.[35] However, it is proven beyond doubt that UAS is associated with lower IRP and temperature during RIRS.[5,6] With the advent of intelligent pressure monitoring systems,[18,20] the simple UAS has been successfully modified into a SUAS to simplify the application of suction with simultaneous aspiration.

In 2016 Zeng et al. introduced a new concept of UAS modified with a suction-evacuation port and pressure regulating mechanism in ureteroscopy for ureteral stone management.[14]

Patients in the experimental group had 100% immediate stone clearance and no stone retropulsion. In 2019 Zhu et al. retrospectively evaluated the safety and efficacy of RIRS using a modified suction UAS in 165 patients compared to 165 controls treated with the standard one.[20] All patients were followed-up at 1 and 6 months after surgery. One-day postoperative SFR and rate of postoperative fever were in favour of the experimental group (p < 0.02 and p < 0.009, respectively). Later in 2020, RIRS aided by a modified UAS was compared to miniPCNL for up to 4 cm renal stones treatment.[22] Although SFR in 3 months was comparable between the groups, less bleeding and pain were observed in the experimental group.

Zhu et al.[20] tested a modified 3-channel sheath with active suction. The device had three channels on the back end of the UAS: one lateral, binding it to a general vacuum device to achieve a suctioning effect, one central with an elastic rubber film allowing passage of the ureteroscope and another lateral valve able to regulate the negative pressure acting as an air door. Authors compared the outcomes of 250 patients with renal stones treated with RIRS using the vacuum-assisted sheath or a ''classical'' one, finding a higher early SFR in the first group (82.4% vs 71.5%; p = 0.02), even if 1-month SFR was comparable in the two groups (p = 0.13). Moreover, the traditional UAS group was associated with a higher incidence of fever

(13.9% vs 5.5%; p = 0.009) and urosepsis requiring only additional antibiotics (6.7% vs 1.8%; p = 0.029). Operative time was shorter in the suctioning UAS group (49.7 + 16.3 min vs 57.0 ± 14.0 min; p < 0.001).

Similar findings were reported by Quian et al.[27] that compared 81 vs 81 patients through propensity score analysis, where suctioning UAS resulted in increased early SFR (86.4% vs 71.6%; p = 0.034), whereas it was comparable after one month (88.9% vs 82.7%; p = 0.368). The postoperative fever or SIRS incidence was lower than in the control group (fever: 3.70% vs 14.8%; p = 0.030; SIRS: 1.23% vs 12.3%; p = 0.012).

Whilst the SUAS had satisfactory clinical outcomes, there is a lack of identification on the ideal irrigation rate and vacuum/ suction pressure needed and how to manoeuvre this for maximum efficacy.

Specialized suctioning platform and UAS with a pressure-sensitive tip

In 2018 Huang et al. presented their retrospective study of 40 patients treated with a specialized suctioning platform and UAS with a pressure-sensitive tip and automatic control of renal pelvis pressure.[17] The stone-free rate at 4 and 12 weeks was 87.5% and 92.5%, respectively. Their reports were confirmed by Du et al.[18] They used perfusion and suctioning platform and ureteral access sheath with channels for suction for large ureteral stones treatment.

Patients in the experimental group had higher SFR, shorter operation time, fewer cases of postoperative fever, and a lower rate of secondary surgery than in the control group (our ref). The same set of equipment and disposables were used for the treatment of kidney stones 2—3 cm in comparison with traditional miniPCNL by Chen et al. in 2019.[19] RIRS with the suction group was associated with less complication and bleeding but the same effectiveness. In 2022 a very similar comparison was conducted by Deng et al. in patients with solitary kidneys. Although SFR at the 3-month follow-up was comparable in both groups (91.2% vs 95.7%, p > 0.05) the haemoglobin decline value and patients requiring blood transfusions were in favour of the experimental group.[31] In the same year, Gao et al. presented results of RIRS in 310 patients, showing that patients with stone size<40 mm or Guy's stone score of Grade I have a high stone-free rate(80.65%) after just one session of treatment.[25]

Flexible tip UAS with pressure control

Chen et al.[32] recently presented an experimental study on porcine kidney models to test the efficacy of a novel flexible vacuum-assisted UAS (FV-UAS) (12/14F, 46 cm; ZHANGJIAGANG, Jiang Su, China connected to vacuum suction device YB-DX23B; SMAF, Shangai, China). The peculiarity of this new device was its capacity to bend with the ureteroscope and its flexible tip, which allows it to access the entire pelvic caliceal system whilst ensuring a constant intra-pelvic pressure during the procedure by automated regulation of the suction monitored by an intrapelvic manometer. The latter never exceeds the ten cmH2O even with different irrigation fluid velocities (from 30 to 100 ml/min). The authors cited using a 60 ml/min fluid rate and a suction pressure of 50—150 cmH_2O in their retrospective case study of 53 patients with high-volume kidney stones (mean 17.1 mm range 11–25). The negative-pressure system allowed stone dust ($\leq$1 mm) to be evacuated from the gap between the fURS and FV-UAS, and larger fragments (>1 mm) can be discharged when withdrawing the fURS slowly, increasing the final SFR. Only two patients developed fever after surgery, and the mean stone volume clearance rate was 97.7%, with complete stone clearance in 37 (69.8%) cases.

This UAS is preferable since it can use the scope to deflect the sheath in various parts of the pelvic caliceal system, and even stone fragments can be efficiently cleaned by vacuum assistance, obviating the need for baskets.

Key Take home messages

A summary flow chart (Fig. 2) shows all the available options by which suction, and aspiration continues to evolve as a promising adjuvant to enhance RIRS outcomes. The pros and cons are summarized below:

A) Pressure monitoring systems are very important for monitoring IRP during RIRS especially when using suction and high-power laser lithotripsy. However independent patents for each may limit outreach of these systems and make standardization difficult alongside adding added cost by mandating use of compatible consumables.
B) Optimized suction pressure, regulated fluid flow rate, sustained low pressure vacuum, fine dusting and subsequent aspiration are the 5 key components if a urologist wants to consider using suction in RIRS. However, there is again a lack of standardization and paucity of data on which technological invention can achieve all the above.
C) Suction aided RIRS definitely helps to mitigate ill effects of IRP, reduce infectious complications, improve SFR, reduce RF and is proving to be a natural successor to traditional RIRS. It remains to be seen if UAS with and without flexible tips or aspiration catheters and scopes will perform the best in different clinical settings in real world practice.

Conclusion

Our review provides an insight into all the technological and technical advancements being proposed whilst using suction and aspiration to improve RIRS outcomes. It is likely that with definitive improvements seen in SFR and reduction in infectious complications RIRS with suction may become universally adopted into mainstream practice.

Conflict of interest

The authors declare that they have no conflict of interest.

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