

Effectiveness and Safety of Suction-Assisted Technologies in Pediatric Endourological Stone Surgery: A Systematic Review by the EAU-YAU Pediatric Urology Working Group

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ABSTRACT

Objective: Although new suction/vacuum technologies have been tested in adults in recent years, they remain uncommon in pediatric practice. This systematic review aimed to analyze the existing literature on the effectiveness and safety of new suction technologies for pediatric endourological stone interventions.

Materials and Methods: We conducted a systematic review (PROSPERO CRD420261335417) following the PRISMA 2020 and Cochrane guidelines, searching PubMed, Embase, MEDLINE, Web of Science, and Scopus to identify all published reports on new suction/vacuum technologies for pediatric endourological stone interventions through February 2026. The primary outcomes were intraoperative and postoperative complications and stone-free rates (SFRs). Secondary outcomes included operative time, hospital stay, and the need for ancillary procedures. We used the MINORS tool to assess the risk of bias in nonrandomized cohort studies.

Results: The review included a total of 367 patients (370 renal units) aged 1–17 years who underwent endourological stone surgery. The vacuum-assisted mini-PCNL group had a higher SFR of 81.3–100% and lower complication and reintervention rates of 0–27.8% and



0–12.5%, respectively, compared with conventional mini-PCNL. Furthermore, a higher SFR of 85.7–100% was observed with RIRS using FANS-UAS compared with an SFR of 60–88% in children who underwent conventional RIRS. The former group also had a lower reintervention rate (0–9.5% vs. 0–40%) and fewer grade III–IV complications (0% vs. 8.7%).

Conclusion: Current evidence, although limited and mainly based on observational studies, suggests that suction-assisted technologies may improve stone clearance and maintain acceptable safety profiles in selected pediatric endourological stone interventions. However, the absence of randomized trials, heterogeneous outcome definitions, and limited long-term follow-up prevent definitive conclusions.

Keywords: Children, flexible and navigable ureteral access sheath, kidney stones, percutaneous nephrolithotomy, RIRS, suction, vacuum.

INTRODUCTION

The development of new suction techniques in endourological procedures, such as percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS), has made these procedures more efficient and safer, particularly for adult patients.^{1,2} These technological advances have improved stone fragment clearance by enabling greater control of intrarenal pressure and providing better visualization during the procedure. Consequently, these technologies can achieve higher stone-free rates (SFRs), lower complication rates, and shorter operative times.^{1,2} The integration of suction ureteral access sheaths into RIRS improves the surgeon's visibility during the fragmentation of small stone fragments by minimizing the "snow globe effect."^{3,4} This suggests an increasing trend toward the use of RIRS in the endoscopic treatment of larger stone burdens. On the other hand, recent pediatric series suggest that vacuum-assisted mini-PCNL is a feasible and safe procedure for treating stones larger than 2 cm, even in very young children.⁵ Therefore, technological advances in minimally invasive endourological instruments have led to a reduction in the use of shock wave lithotripsy (SWL) in children in recent years.⁴

Irrigation and suction technologies were initially developed for adult patients but have recently begun to be integrated into pediatric endourological equipment. Consequently, new surgical outcomes are being reported in the pediatric literature.^{5–7} These advantages may be particularly important in children, in whom the smaller collecting system volume, increased vulnerability to elevated intrarenal pressure, infection-related risks, and technical limitations of miniaturized instruments make efficient fragment evacuation challenging. Suction-assisted systems may therefore improve visibility and stone clearance while potentially reducing operative

time and fluoroscopy exposure. Thus, the primary aim of this systematic review is to investigate the effectiveness and safety of new suction technologies for endourological interventions in children and adolescents with kidney or ureteral stones in terms of SFRs and complications according to the Clavien–Dindo classification. Secondary outcomes relate to surgical efficiency, including operative time, length of hospital stay, and the need for ancillary procedures.

MATERIALS AND METHODS

Data Sources and Search

Following registration of the study protocol in PROSPERO (registration ID: CRD420261335417), a review of the English-language literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 recommendations.⁸ All published reports on new suction/vacuum technologies for pediatric endourological stone interventions (PCNL and RIRS) up to February 1, 2026, were identified by searching electronic databases, including PubMed, Embase, Ovid MEDLINE, Web of Science, and Scopus. All procedures performed in our study were in accordance with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Studies were assessed for inclusion or exclusion using a predefined PICO (population, intervention, comparison, and outcome) approach (Appendix 1).

Study Selection

Studies reporting on the effectiveness and safety of new suction technologies for pediatric endourological stone interventions were eligible for inclusion (Appendix 1). Thus, only full-text articles that met the inclusion criteria according to the predefined PICO framework were included in the systematic review.

The exclusion criteria were as follows:

- Articles involving only children or adolescents with accompanying congenital anatomical abnormalities (e.g., UPJ obstruction, horseshoe kidney, ectopic kidney, duplex system, ureterocele, or ectopic ureter), because these conditions are strong confounders of SFR and complication outcomes
- Other systemic abnormalities (e.g., vertebral anomalies or scoliosis)
- Planned staged surgery for urinary tract stones
- Inability to complete at least 1 month of follow-up after surgery to assess residual fragments following a previous intervention (follow-up <1 month)
- Previous ureteral injury, known ureteral anomalies, or previous ureteral reconstruction (e.g., augmented bladder or kidney transplantation)
- Any medical history that would prevent the use of contrast medium during surgery
- Studies with inadequate outcome reporting or insufficient patient data
- Case reports, case series with <10 patients, letters, editorials, author replies, meeting abstracts, systematic reviews, narrative reviews, and meta-analyses

Data Collection and Extraction

The following search strategy was used: ("suction" OR "vacuum" OR "aspiration" OR "ureteral access sheath" OR "ClearPetra" OR "FANS-UAS" OR "DISS") AND ("RIRS" OR "retrograde intrarenal surgery" OR "ureteroscopy" OR "flexible ureteroscopy" OR "percutaneous nephrolithotomy" OR "PCNL" OR "Endoscopic Combined Intrarenal Surgery" OR "ECIRS") AND ("kidney stones" OR "urolithiasis" OR "renal stones" OR "ureteral stones" OR "ureteric stones") AND ("pediatric" OR "children" OR "paediatric" OR "adolescents").

All members of the European Association of Urology (EAU) Young Academic Urology (YAU) Paediatric Urology Working Group used Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia) to screen all retrieved articles. Initially, the titles and abstracts of all 281 identified studies were retrieved and assessed through double screening in accordance with the prespecified inclusion criteria. Subsequently, the full texts of potentially eligible studies were assessed by all members of the EAU-YAU Paediatric Urology Working Group. Two investigators (I.S. and N.B.) independently extracted data from the eight

included articles. Any inconsistencies arising during title and abstract screening, full-text review, or data extraction were resolved through discussion, with consultation from two independent members of the EAU-YAU Paediatric Urology Working Group (M.I.D. and A.K.). The PRISMA flowchart showing the included articles is presented in Appendix 2.

Data were extracted using a standardized form, including information on study identification (first author, year of publication, and country), participants (age, sex, and number of patients/renal units), study design (e.g., prospective or retrospective cohort or RCT), diagnostic imaging (e.g., KUB, US, CT, or IVP), stone characteristics (size, location, volume, and density [Hounsfield units]), patient characteristics (e.g., genetic etiology, cystinuria, obesity, or metabolic disorders), patient position (e.g., prone, supine, lithotomy, or modified), surgical modality (e.g., super-mini percutaneous nephrolithotomy [SMP], vacuum-assisted mini-PCNL, standard PCNL, RIRS, or ureteroscopy [URS]), access sheath size, if used, radiation guidance (e.g., fluoroscopy, ultrasound, combined guidance, or fluoroles), lithotripsy modality (e.g., Ho:YAG laser, thulium fiber laser, pneumatic, or ultrasonic), suction modality (e.g., flexible and navigable suction ureteral access sheath [FANS-UAS], direct in-scope suction [DISS] ureteroscopy, or suction-evacuation sheath), operative time, irrigation details (e.g., type, flow rate, and pressure, if available), postoperative drainage (DJ stent, nephrostomy, both, or tubeless), intraoperative complications according to the Clavien–Dindo classification (e.g., none, bleeding, ureteral injury, collecting system perforation, intraoperative sepsis, or other), postoperative complications according to the Clavien–Dindo classification (e.g., urinary tract infection, bleeding requiring transfusion, bleeding requiring embolization, urinary sepsis, need for reoperation, or other), definition of stone-free status, definition of clinically insignificant residual fragments (CIRFs), stone-free rate (SFR), follow-up period, ancillary procedures (e.g., SWL, RIRS, or second-look PCNL), follow-up imaging (e.g., KUB, US, or CT), crystallographic or metabolic analysis, and key findings.

We contacted the corresponding authors by email to request access to any missing or incomplete data from the included studies. Some missing data were obtained in this way. Based on the responses received, data not reported in the existing articles were also recorded as "N/A" in the tables.

This systematic review included eight studies that provided relevant data on the topic. Because the included articles exhibited methodological and clinical heterogeneity, a meta-analysis was deemed inappropriate. Instead, a synthesis of the data was performed.

Risk of Bias and Quality Assessment

The risk of bias in each included study was independently evaluated by two investigators (I.S. and N.B.). The quality of the included studies was assessed using the validated Methodological Index for Non-Randomized Studies (MINORS) tool for nonrandomized cohort studies (maximum score, 16 points) and comparative studies (maximum score, 24 points). Any disagreements between the reviewers were resolved through discussion and consensus with two independent members of the EAU-YAU Paediatric Urology Working Group (M.I.D. and A.K.).

RESULTS

Following a search of the PubMed, Embase, Ovid MEDLINE, Web of Science, and Scopus databases, eight of 281 articles were found to be eligible for inclusion in this review.^{5–13} The main demographic and clinical characteristics of the patients in these articles are presented in Table 1 and Appendix 3. The articles included two prospective cohort studies and six retrospective cohort studies. These eight articles reported on a total of 367 patients (370 renal units) who underwent endourological stone surgery. The included studies comprised both single-center and multicenter cohorts, with participating centers from China, Türkiye, Italy, Spain, India, Singapore, the United Kingdom, and Uzbekistan. The patients had an average age of 7 years, ranging from 1 to 17 years. The overall male-to-female ratio across all studies was 217:150 (59.1% male). These patients were treated using various methods, including vacuum-assisted mini-PCNL in 139 patients, RIRS with a flexible and navigable suction ureteral access sheath (FANS-UAS-RIRS) in 140 patients, and RIRS with a conventional ureteral access sheath in 88 patients.

Stone-Free Rate

The SFR 1 month after the first attempt at vacuum-assisted mini-PCNL in children with a median age of 4.7 years (range, 0.5–15 years) was reported as 81.3–100% for a median stone size of 16.9 mm (range, 8–48 mm).^{5,6,13} Three studies reported an initial SFR of 60–88% 1 month after the first RIRS attempt in children with a median stone size of 15.8 mm (range, 7–28 mm) and a median age of 8.9 years (range, 1.5–14 years), in whom RIRS with a conventional ureteral access sheath (UAS) was used.^{5,10,12} On the other hand, five studies showed a higher single-stage SFR of 85.7–100% with RIRS using FANS-UAS for a median stone size of 10.7 mm (range, 9–23 mm) in children with a median age of 7.5 years (range, 1–17 years), compared with conventional RIRS.^{7,9–12} Details are provided in Appendices 3 and 4.

Intraoperative and Postoperative Complications

No significant intraoperative complications were reported with vacuum-assisted mini-PCNL. However, postoperative Clavien–Dindo grade I–II complications, including fever (6.3–

27.8%) and hematuria (0–8.1%), and grade IIIa complications, including urinary extravasation requiring nephrostomy (2.7–5.6%), were observed.^{5,6,13}

Intraoperatively, patients who underwent RIRS with FANS-UAS experienced Traxer grade 1 ureteral injury (0–14.3%) and grade 1 calyceal neck or forniceal injury during sheath placement (0–4.3%), whereas Traxer grade 1 ureteral injury (0–8.6%) and grade 2 ureteral injury (0–4.3%) were observed in patients who underwent RIRS with a conventional UAS.^{7,9–12}

Postoperatively, patients who underwent RIRS with FANS-UAS experienced similar Clavien–Dindo grade I–II complications, such as fever, pain, UTI, nausea/vomiting, hematuria, and incontinence due to stent migration, at rates of 0–19%, compared with those who underwent RIRS with a conventional UAS, who experienced fever, UTI, persistent hematuria, and pain at rates of 0–17.4%. However, more serious grade III–IV complications were observed in the latter group, including urethral stricture at a rate of 8.7%.^{7,9–12}

Operative Time, Hospital Stay, and Reintervention Rate

In patients who underwent vacuum-assisted mini-PCNL, the median operative time was 34.2 minutes (range, 27–167 minutes), and the median hospital stay was 2.8 days (range, 1–7 days). The reintervention rate was 0–12.5%.^{5,6,13}

On the other hand, the studies found that patients who underwent RIRS with FANS-UAS had a shorter operative time (median, 55.5 minutes [range, 26–86 minutes] vs. 82.7 minutes [range, 46–167 minutes]), a shorter hospital stay (median, 1.9 days [range, 1–3.4 days] vs. 3.1 days [range, 1–4 days]), and a lower reintervention rate (0–9.5% vs. 0–40%) than those who underwent RIRS with a conventional UAS.^{7,9–12}

Risk of Bias Assessment

The risk-of-bias summary for the eight included articles is presented in Appendix 5. Based on the MINORS assessment, four studies achieved relatively higher methodological quality scores.^{5,10,12,13} The remaining four studies showed limitations mainly related to retrospective design, absence of prospective sample size calculation, nonstandardized outcome assessment, and limited follow-up.^{6,7,9,11} These studies also raised concerns primarily related to data collection, sample size calculation, and outcome measurement.^{6,7,9,11}

DISCUSSION

The aim of this review was to investigate the effectiveness and safety of new suction technologies for pediatric endourological stone interventions. As most articles in the literature have focused on adult patient populations, comparative studies involving pediatric patients are extremely rare. The two suction

Table 1. Demographic characteristics of patients in the included articles								
Author, year [ref.]	Study period	Country	Study design	Total number of patients/ renal units	Mean/median age at admission	Male/female ratio, n	Patient group	Diagnostic imaging
Collura, et al., 2024 ⁵	November 2018–September 2022	Italy	Retrospective cohort study	30 patients/30 renal units	Median, 6.6 years (range, 1–12)	8/7	Vacuum-assisted mini-PCNL (n=15)	Noncontrast CT
	Median, 7.7 years (range, 1.5–14)				8/7	RIRS (n=15)	Noncontrast CT	
Gallioli et al., 2022 ⁶	January 2017–December 2018	Italy and Spain	Prospective cohort study	13 patients/16 renal units	Median, 119 months (IQR, 97–160)	8/5	Semi-closed-circuit vacuum-assisted mini-PCNL (n=13)	CT, US, or KUB
Gauhar et al., 2024 ⁷	September 2023–May 2024	Singapore, Spain, the UK, India, Türkiye, Italy, China, and Uzbekistan	Retrospective cohort study	50 patients/50 renal units	Mean, 6.6±3.38 years (min, 1; max, 15)	33/17	FANS-UAS RIRS (n=50)	Low-dose noncontrast CT
Peng et al., 2024 ⁹	January 2022–November 2023	China	Retrospective cohort study	21 patients/21 renal units	Mean, 9.6 years (min, 6; max, 17)	11/10	Tip-flexible pressure-controlling ureteral access sheath (TFPC-UAS) (n=21)	US, CT, or IVP
Turedi et al., 2024 ¹⁰	January 2021–August 2024	Türkiye	Retrospective cohort study	46 patients/46 renal units	10.2±6.1 years	12/11	FANS-UAS RIRS (n=23)	CT
					9.2±4.8 years	13/10	Conventional UAS RIRS (n=23)	CT
Vaddi et al., 2025 ¹¹	October 2023–November 2024	India and Türkiye	Prospective cohort study	21 patients/21 renal units	Median 12.00 months (IQR, 8.00-21.25)	11/10	FANS-UAS RIRS (n=21)	Low-dose noncontrast CT and KUB
Wang et al., 2025 ¹²	January 2023–August 2025	China	Retrospective cohort study	75 patients/75 renal units	9.9±5.8 years (2–14)	13/12	FANS-UAS RIRS (n=25)	Low-dose noncontrast CT
					9.2±4.9 years (2–14)	29/21	Conventional UAS RIRS (n=50)	Low-dose noncontrast CT
Zhao et al., 2017 ¹³	September 2014–April 2016	China	Retrospective cohort study	111 patients/111 renal units	3.9±3.5 years (0.5–15)	71/40	Super-mini-PCNL (n=111)	N/A

CT: Computed tomography; FANS-UAS: Flexible and navigable suction ureteral access sheath; IQR: Interquartile range; IVP: Intravenous pyelography; KUB: Kidney–ureter–bladder radiography; Max: Maximum; Min: Minimum; N/A: Not applicable; PCNL: Percutaneous nephrolithotomy; Ref: Reference; RIRS: Retrograde intrarenal surgery; TFPC-UAS: Tip-flexible pressure-controlling ureteral access sheath; UAS: Ureteral access sheath; UK: United Kingdom; US: Ultrasonography.

CT: Computed tomography; FANS-UAS: Flexible and navigable suction ureteral access sheath; IQR: Interquartile range; IVP: Intravenous pyelography; KUB: Kidney–ureter–bladder radiography; Max: Maximum; Min: Minimum; N/A: Not applicable; PCNL: Percutaneous nephrolithotomy; Ref: Reference; RIRS: Retrograde intrarenal surgery; TFPC-UAS: Tip-flexible pressure-controlling ureteral access sheath; UAS: Ureteral access sheath; UK: United Kingdom; US: Ultrasonography.

modalities, vacuum-assisted PCNL and FANS-UAS RIRS, are used for different stone-burden scenarios and were therefore analyzed separately; no direct comparison between them was possible based on the available data. In addition, because of the methodological and clinical heterogeneity among the eight included articles, a narrative synthesis of the data was conducted rather than a meta-analysis.

Two main strategies have been developed for applying suction during PCNL: through sheaths or by integrating suction into an energy device. Both techniques have been found to decrease intrarenal pressure, which may prevent pyelorenal backflow, fluid reabsorption, and bacterial translocation.² Although sheath size may affect intrarenal pressure to some extent, suction sheaths and suction nephroscopes help provide continuous flow from the renal cavities to the outside by creating direct negative pressure that balances the inflow. This mechanism has been reported to reduce both intrarenal pressure and infectious complication rates.² For this purpose, several different suction techniques have been developed for PCNL. “Double-sheath vacuum suction” involves separating the inflow and outflow channels using two suction sheaths (16 Fr and 20 Fr). This creates a one-way flow channel that prevents the obstruction that may occur in single-sheath systems.¹⁴ Another suction technique described for PCNL is “SuperPerc.”¹⁵ This technique involves using a 10/12-Fr suction sheath together with a pediatric ureteroscope as a nephroscope. Although different techniques are available, the use of negative pressure during suction/aspiration has two fundamental common effects. First, it prevents renal backflow caused by overdistension and, consequently, pyelovenous and pyelolymphatic backflow, which can lead to bacteremia, sepsis, and fever in cases of infected stones.⁴ Second, it enhances fragment extraction through the whirlpool effect.⁴

Studies involving the use of different suction/aspiration sheaths during PCNL in adults have reported an SFR of 71.3–100%, an overall complication rate of 1.5–38.9%, an infection rate of 0–27.8%, and a bleeding rate of 0–8.9%.¹⁶ These techniques have become widespread in the pediatric population only in recent years; therefore, pediatric outcomes have only recently begun to be reported, with a higher SFR of 81.3–100% and lower complication rates, including an overall complication rate of 0–27.8%, fever in 6.3–27.8%, hematuria in 0–8.1%, and grade IIIa complications such as urinary extravasation requiring nephrostomy in 2.7–5.6%.^{5,6,13} Cross-modality SFR comparisons between vacuum-assisted PCNL (median stone size, 16.9–32 mm) and FANS-UAS RIRS (median stone size, 10.7–19.8 mm) should be interpreted cautiously because the two groups were not treated for equivalent stone burdens. More reliable evidence of efficacy comes from within-modality comparisons: both Turedi et al.¹⁰ and Wang et

al.¹² used propensity-matched or similarly distributed cohorts comparing FANS-UAS with conventional UAS for stones of comparable size, and both consistently demonstrated higher SFRs and lower reintervention rates with suction.

The widespread use of super-mini-PCNL (SMP) has led to the implementation of suction technology in pediatric PCNL cases.^{13,14} It has been demonstrated that simply switching from older- to newer-generation instruments and adding suction can extend the size limits for stone removal with SMP (a 7–8-Fr nephroscope with a 12–14-Fr sheath) to include large kidney stones measuring 2–4 cm.^{13,14} It has been reported that using the ClearPetra® suction sheath can reduce the PCNL access size to 14 Fr for ultra-mini-PCNL procedures. This enables a single-tract procedure for pediatric staghorn stones without complications.¹⁷ This suggests that suction could make PCNL less invasive without compromising effectiveness or safety. Of note, Zhao et al.¹³ used a metal suction-evacuation sheath rather than the ClearPetra® system used in other PCNL studies; therefore, the outcomes should be interpreted with this technical heterogeneity in mind.

The role of suction in RIRS for the pediatric population has also gained attention in recent years. A common method of achieving effective aspiration during RIRS is the direct in-scope suction (DISS) technique. The working channel of the scope allows alternating irrigation and aspiration through the flexible ureteroscope.¹⁸ Using smaller DISS scopes with this technique reduces intrapelvic pressure during stone dusting and improves visibility by eliminating the “snow globe effect.”¹³ Although DISS currently has limited capacity for removing larger stone fragments and may be affected by fragments becoming lodged in the working channel, it is anticipated that technological advances will make these procedures more efficient and may eliminate the need for a UAS.¹⁹

Another innovative technology is the use of flexible and navigable suction UASs. These devices can continuously aspirate dust and larger particles from both the renal pelvis and individual renal calyces because they are flexible and can reach every part of the collecting system.^{7,20} Owing to the flexibility of their tips, these suction UAS devices can closely follow the movement of the ureteroscope. This enables surgeons to aspirate dust and particles from all parts of the kidney.^{7,20} In particular, the thulium fiber laser (TFL) produces smaller dust particles than holmium lasers and causes substantially less retropulsion. This prevents the laser energy from continuously dispersing debris and allows the suction system to actively evacuate the dust. Therefore, combining TFL with active suction access sheaths may help eliminate the so-called “snow globe effect” and maintain clear visibility. Matching the super-pulsed, high-frequency dusting capabilities of TFL with continuous or intermittent vacuum

aspiration enables surgeons to continuously clear floating stone dust from the visual field.^{7,10,11} Additional advantages include a reduced need for basket extraction and improved removal of fine dust. A higher single-stage SFR of 85.7–100% was observed with RIRS using FANS-UAS compared with an SFR of 60–88% in children who underwent RIRS with a conventional UAS. The former group also had a lower reintervention rate (0–9.5% vs. 0–40%) and fewer grade III–IV complications (0% vs. 8.7%).^{7,9–12} The unusually high reintervention rate in the RIRS group may be attributed to a higher stone burden in one of the studies.⁵ Even in children younger than 5 years, a low incidence of high-grade complications has been reported during follow-up when more miniaturized equipment was used, including a 9.5/11-Fr UAS and a 7.5-Fr flexible URS.²¹

The ongoing miniaturization of endoscopic instruments, coupled with the adaptation of new suction systems initially designed for adults to pediatric use, is undoubtedly paving the way for innovations in pediatric endourology. Although suction techniques have been tested in adults, they remain uncommon in pediatric practice. Studies using suction- or vacuum-assisted mini-PCNL, SMP, and RIRS with FANS-UAS or DISS have demonstrated the safety and effectiveness of these techniques in children.^{5,10,12,22} Most included studies reported favorable SFRs with suction-assisted technologies; however, the limited number of comparative studies prevents firm conclusions regarding their superiority over conventional approaches. Furthermore, to our knowledge, no studies have specifically compared two suction techniques or technologies in children.

Despite our thorough approach, this review is not without limitations. First, because of our strict inclusion criteria, only a small number of studies were eligible. The included studies differed in methodology, patient demographics, and outcome measures, resulting in heterogeneity in the data. Thus, generalization of the results is difficult because of variability in the definition of SFR, the use of equipment of different sizes, differences in laser type and energy settings, and inconsistent reporting of outcomes by age group across studies. Second, the small number of patients treated with each technique makes comparisons difficult. It was not possible to directly compare mini-PCNL procedures performed with and without suction or procedures using laser or ultrasonic lithotripsy with and without suction. Therefore, the lack of comparable studies using similar techniques makes it difficult to draw firm conclusions. Third, although the included studies were conducted in different countries, the small number of studies highlights the need for additional multicenter studies to strengthen the global applicability of the clinical outcomes. In addition, the follow-up duration and imaging modalities used to determine stone-free status varied among studies. Another limitation of the included studies evaluating RIRS is the lack of

comparison with sheathless RIRS. None of the included studies reported systematic intrarenal pressure measurements; therefore, the pressure-reducing benefit of suction in children, which may differ from that in adults because of smaller collecting system volumes, remains to be quantified. Finally, the inclusion of only eight articles significantly limits our ability to draw definitive conclusions regarding the efficacy and safety of suction-assisted techniques in children. Although excluding children with congenital urinary tract anomalies may improve the internal validity of the study, it limits the generalizability of the findings to real-world pediatric stone populations.

CONCLUSION

This systematic review suggests that new suction technologies, such as vacuum-assisted mini-PCNL and RIRS with FANS-UAS, are promising and appear feasible in selected pediatric patients, with acceptable complication rates and satisfactory stone-free rates. These methods also show promise for larger stone burdens. However, larger multicenter comparative studies are needed to assess the potential of these technologies in pediatric stone management. The lack of standardization in outcome reporting also needs to be addressed.

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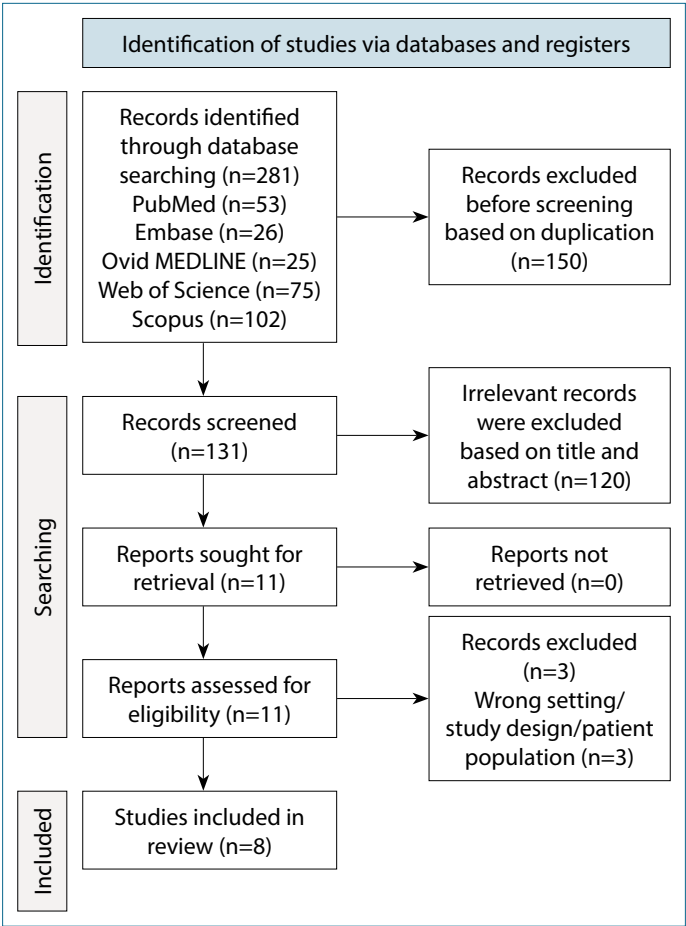
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Appendix 1. PICO criteria used to create the data extraction sheet

PICO component	Criteria
Patients (P)	Children and adolescents younger than 18 years with kidney or ureteral stones
Intervention (I)	Use of different suction/vacuum techniques during PCNL or RIRS
Comparators (C)	Suction vs. no suctionConventional endourological techniques without suction or nonsuction arms within comparative studies using the same surgical modalitySubgroup analysis, if available: comparison between different suction technologies (e.g., FANS-UAS vs. DISS)
Outcomes (O)	Primary outcomes: Complications and stone-free rates (1-month SFR or 3-month SFR, when available)Secondary outcomes: Operative time, hospital stay, and the need for ancillary procedures

DISS: Direct in-scope suction; FANS-UAS: Flexible and navigable suction ureteral access sheath; PCNL: Percutaneous nephrolithotomy; PICO: Population, intervention, comparator, and outcome; RIRS: Retrograde intrarenal surgery; SFR: Stone-free rate.



Appendix 2. The PRISMA flowchart.

