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Enhanced stone-free rates with suctioning ureteral access sheath vs. traditional sheath in retrograde intrarenal surgery: a systematic review and meta-analysis

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Abstract

Background As a safe approach to the upper urinary tract, flexible ureteroscopic lithotripsy (fURL) is a widely accepted treatment for nephrolithiasis. Sometimes, this technique can rely on the natural expulsion of stones, increasing the risk of infections and stone recurrence. To mitigate these issues, some studies tried to use a suctioning ureteral access sheath (S-UAS).

Methods A systematic review was conducted across multiple databases for trials comparing S-UAS with traditional (T-UAS) in retrograde intrarenal surgery (RIRS). The primary endpoint was the stone-free rate (SFR), while adverse effects, operative time, fever rate, and hospital stay were analyzed as secondary outcomes.

Results We retrieved 8 articles, encompassing a total of 2,255 patients, with 978 in the S-UAS group and 1,247 in the T-UAS group. Our analysis revealed a higher SFR in the S-UAS group after 1 day, and also at later time points (one or three months) (OR 3.79; 95% CI 1.70–8.46; $p=0.001$; $I^2=89.2\%$) and (OR 1.98; 95% CI 1.52–2.59; $p<0.001$; $I^2=0\%$), respectively. Regarding surgical complications, we observed a lower incidence in the S-UAS group (OR 0.37; 95% CI 0.26–0.51; $p<0.001$; $I^2=0\%$), as well as a reduced fever rate (OR 0.34; 95% CI 0.24–0.48; $p<0.001$; $I^2=0\%$) and a shorter length of hospital stay (MD -0.11; 95% CI -0.16 to -0.05; $p<0.001$; $I^2=39.6\%$). No differences were found in the operative time between both approaches (MD -2.49; 95% CI -7.62–2.65; $p<0.343$; $I^2=88.3\%$).

Conclusion Our study suggests that using S-UAS in RIRS may enhance the SFR, and also reduce both complications and hospital stay.

Trial registration This systematic-review and meta-analysis was prospectively registered on PROSPERO under protocol CRD42024543084.

Keywords Ureterolithiasis, Urinary calculi, Systematic review, Meta-analysis

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Introduction

Reaching up to 13% prevalence in the United States, nephrolithiasis is among the most common urological diseases [1]. As a treatment for this condition, flexible ureteroscopic lithotripsy (fURL) has emerged over recent decades, driven by technological advancements that have enabled safe exploration and manipulation of the upper urinary tract [2]. However, this technique occasionally depends on the natural expulsion of calculi, which may take longer than desired, increasing the risk of infections and recurrence [3]. This issue has prompted the search for more effective methods to increase the stone-free rate (SFR), reducing postoperative complications associated with residual stones.

Since its introduction in 1974, the ureteral access sheath (UAS) has been widely used in retrograde intrarenal surgery (RIRS) with flexible ureteroscopes for the treatment of nephrolithiasis, primarily because it facilitates the drainage of intraureteral fluids, preventing injuries from high renal pelvic pressure [2–4]. Furthermore, several studies have hypothesized that the association between fURL and UAS would lead to higher SFRs. Their results, albeit divergent, indicate that there is no significant difference between using a traditional UAS (T-UAS) and not using an UAS at all [5, 6].

In this context, a new strategy has emerged: the adoption of Tip-Flexible Suctioning-UAS (S-UAS) as a method to improve the SFR by maintaining continuous suction flow during fURL, thus enhancing the removal of stone fragments. Despite its potential advantages, current guidelines from the European Association of Urology (EAU) and the American Urological Association (AUA) do not endorse the use of S-UAS with fURL. Instead, they recommend traditional T-UAS for large stones, with the EAU specifically advising its use in cases involving multiple stones or prolonged procedures [7, 8].

Given the lack of consensus on the actual impact and effectiveness of this technological advancement, we conducted a systematic review and meta-analysis to consolidate the current evidence and evaluate whether the use of S-UAS in RIRS truly increases SFR compared with T-UAS.

Material and methods

Search strategy

This systematic review and meta-analysis was conducted and reported in accordance with the Cochrane Collaboration Handbook for Systematic Review of interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement guidelines [9].

The authors performed a comprehensive search of MEDLINE, Embase, Scopus, Cochrane and Google Scholar databases for studies published up to August 2024. The search focused on randomized controlled trials and non-randomized trials comparing the efficacy of S-UAS with T-UAS, without a suctioning system, in RIRS for renal stones. The search strategy used was: (Perfusion OR suction* OR suctioning OR aspirat* OR "pressure control") AND ("ureteral access sheath" OR "ureteral access" OR "ureteral sheath" OR UAS OR FANS OR "suctioning ureteral access sheath" OR "S-UAS") AND ("Retrograde Intrarenal Surgery" OR RIRS OR "flexible ureteroscopy" OR "ureteral stones").

The references from all included studies were also manually searched for any additional trials. The prospective meta-analysis protocol was registered on PROSPERO under protocol CRD42024543084.

Eligibility criteria for study selection

The authors included studies that met the following criteria: (1) involved adult patients (aged ≥ 18 years); (2) utilized RIRS with fURL as the sole treatment option for renal stones; (3) compared the use of S-UAS with T-UAS; and (4) included patients without surgical contraindications. Only trials reporting at least one of the clinical endpoints of interest were considered.

The authors excluded the following types of studies and patient groups to ensure the accuracy and relevance of the presented data: (1) studies involving patients younger than 18 years; (2) studies lacking a treatment group or placebo group; (3) patients with anatomical abnormalities, such as horseshoe kidney or ureteral/urethral strictures; and (4) patients with active urinary tract infections. Additionally, articles were excluded if they fell under any of the following categories: (a) case reports, (b) systematic reviews, or (c) bibliographic reviews.

Endpoints

The primary endpoint of this study was the SFR in patients undergoing surgery with S-UAS compared to those with T-UAS. The SFR was evaluated at two time points: the immediate postoperative period (one day) and later intervals (30 or 90 days, depending on the study). Assessment methods included non-contrast computed tomography (NCCT), kidney-ureter-bladder X-ray (KUB), and ultrasonography (USG).

Secondary endpoints included the analysis of surgical complications using the Clavien-Dindo [10] classification, postoperative fever rate, incidence of sepsis and septic shock, operative time, and length of postoperative hospital stay (LOS).

Screening

After the deduplication process, in which the authors used Endnote online™ 20 (Clarivate, Philadelphia, PA), two independent researchers (FG and BT) screened the studies by title and abstract, and disagreements were solved by a third (JC). Following this process, full text screening was performed. No automation tools were used.

Data extraction and quality assessment

Two authors (BP and JS) independently extracted data following a predefined protocol, with any disagreements resolved by a third author (JC). Non-randomized studies were evaluated using the Risk of Bias in Non-randomized Studies of Interventions (ROBINS-I) tool, while the randomized trial was assessed using Version 2 of the Cochrane Risk-of-Bias tool for randomized trials (RoB 2) [11, 25]. The risk of bias assessment was conducted independently by two authors (BT and JS), and discrepancies were resolved through consensus after discussing the reasons for the differences.

Statistical analysis

Continuous outcomes are presented as a mean difference (MD) with 95% confidence interval (CI). Dichotomous data are presented as odds ratio (OR) with 95% CI. Pooled estimates were calculated with the random-effects model, considering that the patients came from different populations.

Results were considered to exhibit considerable heterogeneity if, following the statistical analysis, the I^2 is equal to or greater than 30%.

RStudio Team [12]. RStudio [12]: Integrated Development for R. RStudio, PBC, Boston, MA, was used for statistical analysis.

Results

Study selection and characteristics

After performing the systematic search, the authors identified 255 articles. Following the deduplication and further screening process, 8 articles [3, 4, 13–18] were found to be relevant and eligible for inclusion in this review (Fig. 1PRISMA flow chart). Together, these studies encompassed a total of 2,255 patients, with 978 in the S-UAS group and 1,247 in the T-UAS group.

For a comprehensive summary of patient demographics across all included studies, refer to Table 1. Similarly, Table 2 provides a comparison of the clinical outcomes between the S-UAS and T-UAS groups. Lastly, details about the equipment used and stone sizes are outlined in Table 3.

Meta-analysis

The overall comparison of Late SFR between the S-UAS and T-UAS groups demonstrated significantly higher rates in the S-UAS group (OR 1.98; 95% CI 1.52–2.59; $p < 0.001$; $I^2 = 0\%$). Subgroup analyses further confirmed these findings, showing improved SFRs in the S-UAS group at 30 days postoperatively (OR 1.93; 95% CI 1.37–2.71; $p < 0.001$; $I^2 = 0\%$) and at 3 months postoperatively (OR 1.91; 95% CI 1.02–3.57; $p = 0.043$; $I^2 = 49.1\%$) (Fig. 2A). To complement the analysis of this endpoint, the authors generated a funnel plot, which was symmetrical, indicating a minimal risk of publication bias (Fig. 2B).

Furthermore, the analysis of 1-day SFR also revealed significantly higher rates in the S-UAS group compared to the T-UAS group (OR 3.79; 95% CI 1.70–8.46; $p = 0.001$; $I^2 = 89.2\%$) (Fig. 3A). Given the high heterogeneity in this result, the authors performed a leave-one-out sensitivity analysis, which unveiled substantially reduced heterogeneity when the study by Yu et al. [4] was omitted (OR 2.61; 95% CI 1.89–3.61; $I^2 = 20\%$) (Fig. 3B). To further explore the sources of heterogeneity, a Baujat plot was generated, clearly illustrating that a single study was the primary contributor to the high heterogeneity observed in the overall results for this endpoint (Fig. 3C).

The analysis of secondary endpoints related to postoperative adverse events strongly favored the S-UAS group over the T-UAS group. In terms of overall complications, assessed using the Clavien-Dindo [10] classification, the S-UAS group demonstrated a significantly lower rate of complications (OR 0.37; 95% CI 0.26–0.51; $p < 0.001$; $I^2 = 0\%$) (Fig. 4). Similarly, the S-UAS group exhibited significantly lower postoperative fever rates (OR 0.34; 95% CI 0.24–0.48; $p < 0.001$; $I^2 = 0\%$) (Fig. 5).

In addition to the analysis of general postoperative complications, our evaluation of infection-related outcomes revealed a significant reduction in sepsis rates with the use of S-UAS (OR 0.42; 95% CI 0.23–0.76; $p = 0.004$; $I^2 = 0\%$) (Fig. 6). In contrast, although there was a numerical trend toward fewer cases of septic shock in the S-UAS group, the difference did not reach statistical significance (OR 0.38; 95% CI 0.11–1.31; $p = 0.125$; $I^2 = 0\%$) (Fig. 7).

Regarding operative time, no significant difference was found between the S-UAS and T-UAS groups (MD -2.49; 95% CI -7.62–2.65; $p < 0.343$; $I^2 = 88.3\%$) (Fig. 8A). Due to the high heterogeneity, a leave-one-out sensitivity analysis was performed, which revealed persistently elevated I^2 values regardless of the study omitted (Fig. 8B). In order to investigate the sources of heterogeneity, a Baujaut plot was generated, identifying the study by Chen et al. [13] as the primary contributor to the heterogeneity, with other studies also showing notable contributions (Fig. 8C). This is consistent with the leave-one-out analysis, in which the exclusion of Chen et al.'s study still resulted in high I^2 values.

Postoperatively, the S-UAS group demonstrated a shorter LOS compared with the T-UAS group (MD

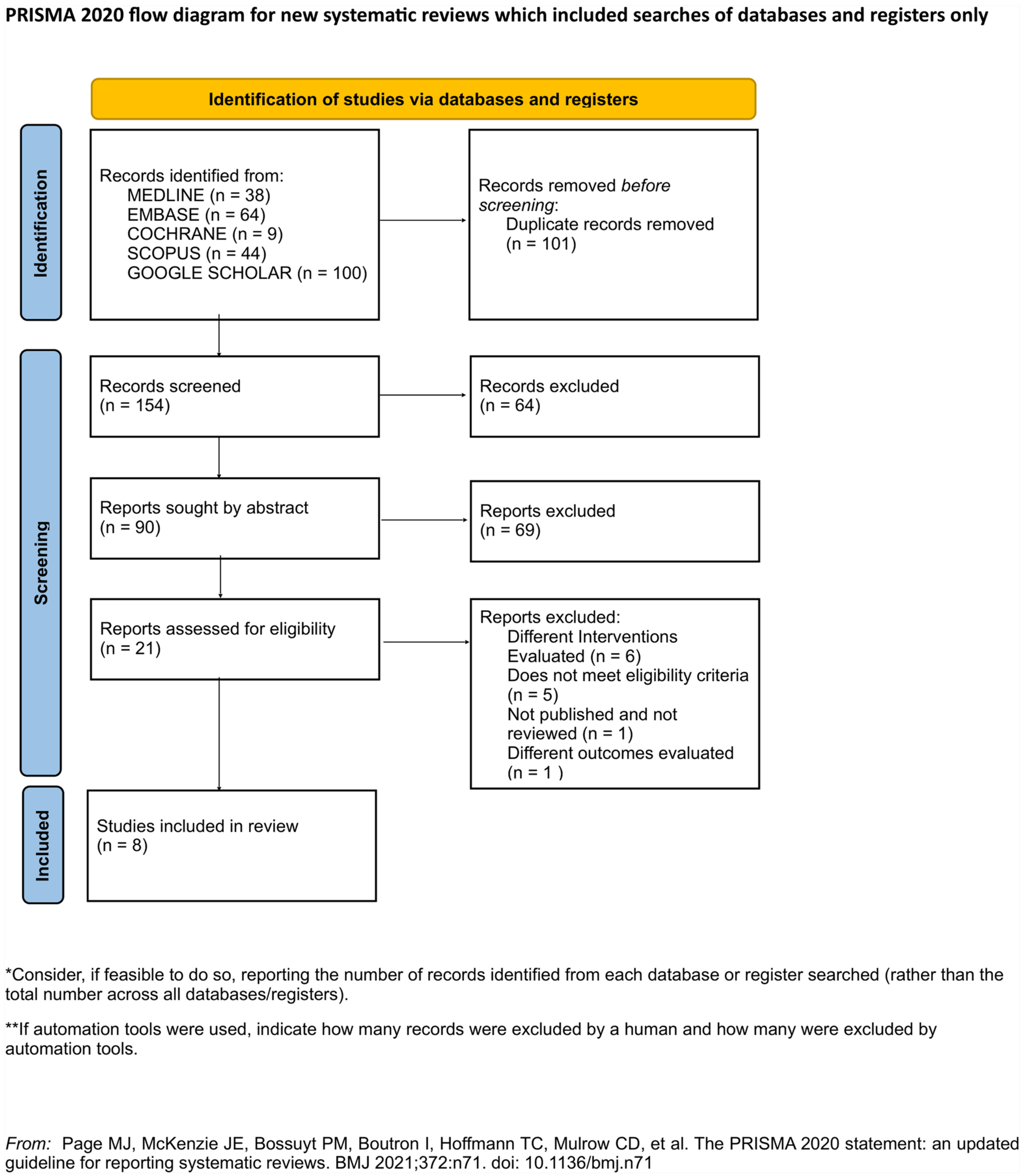

Fig. 1 Prisma flowchart

-0.11; 95% CI -0.16 to -0.05; $p < 0.001$; $I^2 = 39.6\%$) (Fig. 9A). Given the moderate heterogeneity observed, a leave-one-out sensitivity analysis was performed, which revealed 0% heterogeneity upon omitting the study by Wang et al. [16] (MD -0.10; 95% CI -0.15 to -0.04; $I^2 = 0\%$) (Fig. 9B). To further explore the sources of heterogeneity, a Baujat plot was generated, confirming that Wang et al. was the primary contributor to the observed variability in this endpoint (Fig. 9C).

Table 1 Patients' demographics

Study	Type of Study	Country	Patients enrolled (N), S-UAS/T-UAS	Male (%), S-UAS/T-UAS	Mean Age (years), S-UAS/T-UAS	BMI (Kg/m2), S-UAS/T-UAS	Pre-Stenting (N), S-UAS/T-UAS
Qian, 2022	Retrospective Cohort	China	81 / 81	52 (64.2%) / 56 (69.1%)	51 ± NS / 50 ± NS	23.7 ± NS / 24.2 ± NS	13 / 16
Chen, 2024	Retrospective Cohort	China	125 / 113	76 (60,8%) / 65 (57,5%)	45.6 ± 12.9 / 46.3 ± 14.9	25.2 ± 3.8 / 25.7 ± 4.3	NS
Erkoc, 2024 (stones < 2cm)	Retrospective Cohort	Turkey	80 / 248	84 (69%) / 284 (72%) **	45.56 ± 12.58 / 46.94 ± 12.12 **	25.27 ± 4.34 / 25.44 ± 3.56 **	NS
Erkoc, 2024 (stones ≥ 2cm)	Retrospective Cohort	Turkey	42 / 142	NS	NS	NS	NS
Zhang, 2023	Retrospective Cohort	China	102/112	55 (53.9%) / 71 (63.4%)	47.69 ± 9.18 / 46.75 ± 11.87	24.25 ± 2.97 / 23.54 ± 3.37	46 / 47
Yu, 2024	Retrospective Cohort	China	152 / 152	75 (49,3%) / 80 (52,6%)	51.1 ± 12.2 / 50.5 ± 11.8	24.3 ± 2.8 / 23.8 ± 2.8	11 / 14
Wang, 2024	Retrospective Cohort	China	71 / 74	47 (66%) / 51 (69%)	45.87 ± 14.90 / 46.30 ± 13.99	28.50 ± 5.77 / 28.32 ± 5.12	NS
Zhu, 2019	Retrospective Cohort	China	165/165	109 (66%) / 109 (66%)	53.9 ± 13.4 / 51.7 ± 15.8	22.9 ± 2.6 / 23.1 ± 3.4	NS
Zhu, 2024	Randomized Controlled Trial	China	160/160	89 (55.6%)/96 (60%)	53* ± NS / 52* ± NS	24.8* ± NS / 24.2* ± NS	19 / 22

Note: The continues variables were represents by mean ± SD. Abbreviations: SFR- stone-free rate; S-UAS- suctioning ureteral access sheath; T-UAS- traditional ureteral access sheath; BMI-body mass index; NS- not specified. *Median; Values from all the cohort

Table 2 Clinical outcomes comparison

Study	Postoperative Complications (Clavien-Dindo), S-UAS/T-UAS	SFR (events), S-UAS/T-UAS	Operative Time (minutes), S-UAS/T-UAS	Postoperative Fever (events), S-UAS/T-UAS	Postoperative Stay (days), S-UAS/T-UAS	Sepsis (events), S-UAS/T-UAS	Septic Shock (events), S-UAS/T-UAS
Qian, 2022	NS	1-day: 70 (86.4%) / 58 (71.6%); 30-day: 72 (88.9%) / 67 (82.7%)	72.9 ± 28.1 / 80 ± 29.5	3 (3.7%) / 12 (14.8%)	NS	NS	NS
Chen, 2024	NS	1-day: 109 (87.2%) / 83 (73.5%); 30-day: 119 (95.2%) / 97 (85.8%)	101.2 ± 25.6 / 86.2 ± 20.3	1 (0.8%) / 6 (5.3%)	1.53 ± 0.52 / 1.62 ± 0.63	NS	0 / 0
Erkoc, 2024 (stones < 2cm)	NS	3-month: 72 (90%) / 221 (89%)	40.48 ± 10.32 / 42.64 ± 11.68	4 (5%) / 20 (8%)	1.72 ± 0.32 / 1.84 ± 0.28	2 / 9	NS
Erkoc, 2024 (stones ≥ 2cm)	NS	3-month: 36 (85%) / 110 (78%)	57.78 ± 11.72 / 65.64 ± 13.86	4 (9.5%) / 18 (12.6%)	1.98 ± 0.46 / 2.02 ± 0.68	2 / 10	NS
Zhang, 2023	12 (11.8%) / 28 (25.0%)	1-day: 88 (86.3%) / 84 (75.0%); 30-day: 93 (91.2%) / 91 (81.3%)	;5.25 ± 11.42 / 59.36 ± 15.59	4 (3.9%) / 11 (9.8%)	2.86±1.11 / 2.76±1.51	5 / 10	1 / 3
Yu, 2024	15 (9.9%) / 34 (22.4%)	1-day: 116 (76.3%) / 11 (7.2%); 30-day: 144 (94.7%) / 142 (93.4%)	56.5 ± 13.9 / 59.9 ± 16.2	9 (5.9%) / 28 (11.9%)	1.3 ± 0.68 / 1.4 ± 0.73	NS	NS
Wang, 2024	NS	1-day: 63 (88.73%) / 56 (75.68%); 30-day: 66 (92.96%) / 63 (85.14%)	39.03 ± 18.01 / 49.73 ± 20.77	5 (7.04%) / 14 (18.92%)	1.57 ± 0.82 / 2.30 ± 1.62	2 / 8	1 / 2
Zhu, 2019	19 (11.5%) / 41 (24.8%)	1-day: 136 (82.4%) / 118 (71.5%); 30-day: 143 (86.7%) / 131 (79.4%)	49.7±16.3 / 57.0±14.0	9 (5.5%) / 23 (13.9%)	1.1±1.18 / 1.3±1.15	4 / 14	1 / 3
Zhu, 2024	9 (5.6%) / 28 (17.5%)	1-day: 130 (81.3%) / 79 (49.4%); 3-month: 140 (87.5%) / 112 (70.0%)	45.7 ± 23.2 / 40.9 ± 19.1	9 (5.6%) / 27 (16.9%)	0.93 ± 0.825 / 0.98 ± 0.77	NS	0 / 1

Note: The continues variables were represents by mean ± SD. Abbreviations: SFR- stone-free rate; S-UAS- suctioning ureteral access sheath; T-UAS- traditional ureteral access sheath; BMI-body mass index; NS- not specified. *Median; Values from all the cohort

Table 3 Equipments used & stone sizes

Study	Equipment, S-UAS	Equipment, T-UAS	Stone Size (range; cm), S-UAS	Stone Size (range; cm), T-UAS
Qian, 2022	TFS-UAS (12/14F) + DFU	T-UAS (12-14F) + DFU	1,7 - 2,3	1,7 - 2,3
Chen, 2024	TFS-UAS (12-14F) + DFU	T-UAS (12-14F) + DFU	1,25 - 4,37	1,26 - 4,10
Erkoc, 2024	TFS-UAS (11/13F) + DFU	T-UAS (10/12F) + DFU	1,16 - 2,80	1,07 - 2,63
Zhang, 2023	TFS-UAS (12/14Fr) + DFU	T-UAS (12/14Fr) + DFU	1,38 - 2,30	1,37 - 2,20
Yu, 2024	TFS-UAS (12/14Fr)	T-UAS (12/14 Fr) + DFU	1,35 - 1,75	1,33 - 1,71
Wang, 2024	TFS-UAS (12/14Fr)	T-UAS (12/14 Fr)	1,47 - 1,88	1,45 - 1,85
Zhu, 2019	TFS-UAS (12/14Fr) + DFU	T-UAS (12/14Fr) + DFU	1,3 - 2,3	1,27 - 2,20
Zhu, 2024	TFS-UAS (12/14F and 11/13F)	T-UAS (12/14F and 11/13F)	1,4*	1,1*

Abbreviations: S-UAS: suctioning ureteral access sheath; TFS-UAS: tip-flexible suctioning ureteral access sheath; DFU: disposal flexible ureteroscope; T-UAS- traditional ureteral access sheath*:Median

The authors should highlight that the primary endpoint, the SFR, incorporated data from all the studies in this review, with the exception of Erkoc et al. [14], which did not provide 1-day SFR data and was therefore only included in the analysis of Late SFR. As for the secondary endpoints, the length of postoperative hospital stay was derived from all studies, except for Qian et al. [3]. The analysis of overall complications, assessed using the Clavien-Dindo classification, was based on data from four studies [4, 15, 17, 18]. Regarding infection-related complications, sepsis was analyzed based on data from four studies [14–17], while septic shock was reported in five [13, 15–18]. For the studies by Zhang et al. [15] and Zhu et al. [17], we combined the cases identified as sepsis treated solely with antibiotics and those that progressed to septic shock in order to obtain the total number of sepsis events—whether managed conservatively or evolving into shock. All other endpoints were derived from data across all the articles included in this meta-analysis.

Quality assessment

Seven of the included studies were non-randomized trials, assessed using the ROBINS-I tool, while one was a randomized controlled trial, and underwent assessment using the RoB 2 tool. Out of the seven non-randomized trials, 2 presented low risk of bias [3, 17], while the other five studies [4, 13–16] had a moderate risk, primarily because of bias due to confounding factors (Fig. 10A). The randomized trial by Zhu et al. [18], on the other hand, exhibited a low risk of bias (Fig. 10B).

Discussion

A total of eight articles were included in this review (Table 1), evaluating the effectiveness and safety of S-UAS in RIRS for kidney stones. The analysis compared

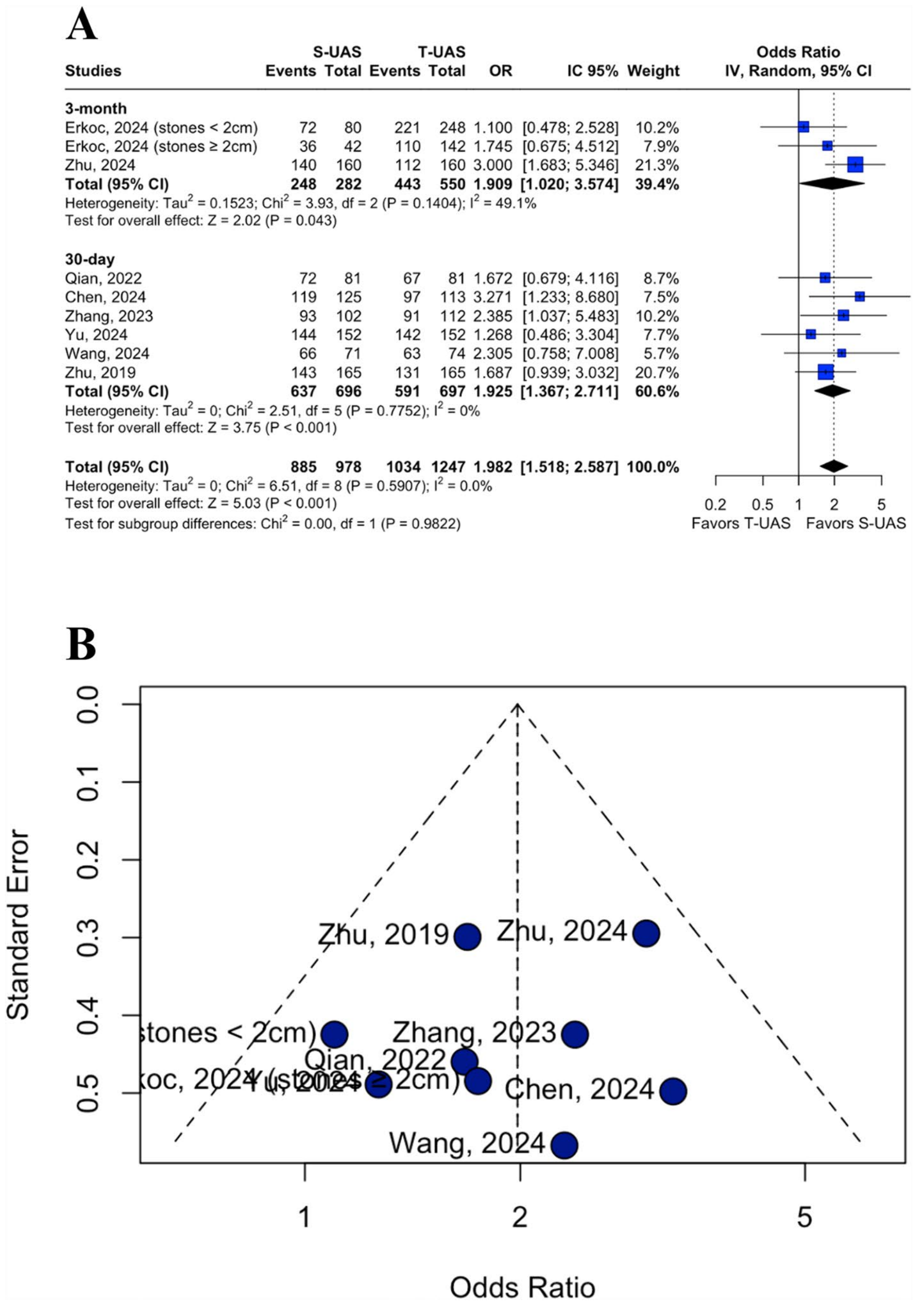

Fig. 2 Late SFR – **A**: Forest plot; **B**: Leave-one-out sensitivity analysis; **C**: Baujat plot

clinical outcomes between the S-UAS and T-UAS groups, focusing on endpoints such as SFR, surgical complications, postoperative fever, operative time, and LOS. Overall, the results demonstrated statistically significant advantages for the S-UAS group, including higher SFR across all time points, shorter LOS, and a lower incidence of both postoperative fever and complications. Notably, no significant difference was observed in operative time between the two groups.

Our primary endpoint of interest was the SFR, a critical parameter for assessing the technical success of calculi extraction procedures and determining the likelihood of future complications, such as stone recurrence or infections [3]. Lower SFRs are associated with higher rates of stone regrowth, surgical complications—such as the formation of stone streets—and the need for reintervention [19, 20]. In this context, the use of a S-UAS represents a promising strategy

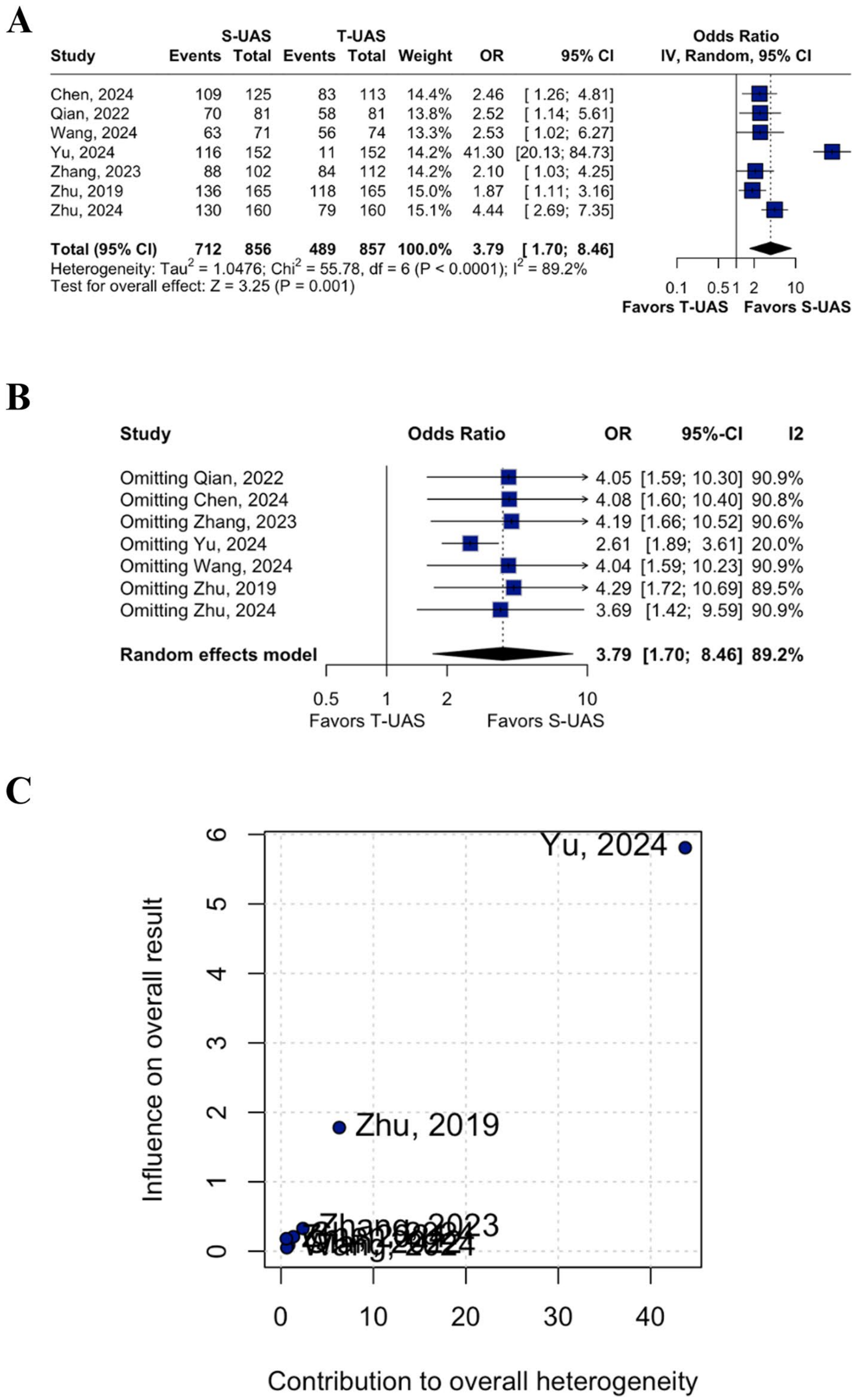

Fig. 3 1-day SFR—**A**: Forest plot; **B**: Leave-one-out sensitivity analysis; **C**: Baujat plot

to enhance intraoperative stone removal. The aspiration device is expected to improve SFRs by providing superior intraoperative visualization and facilitating the effective removal of small fragments through suction [20]. Consistent with these expectations, our findings revealed significantly higher SFRs both in the

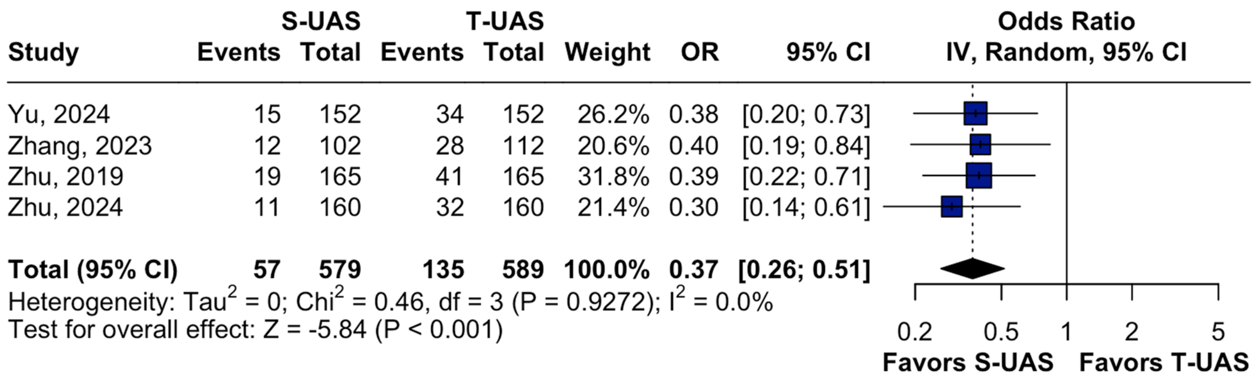

Fig. 4 Surgical complications, assessed through Clavien-Dindo classification

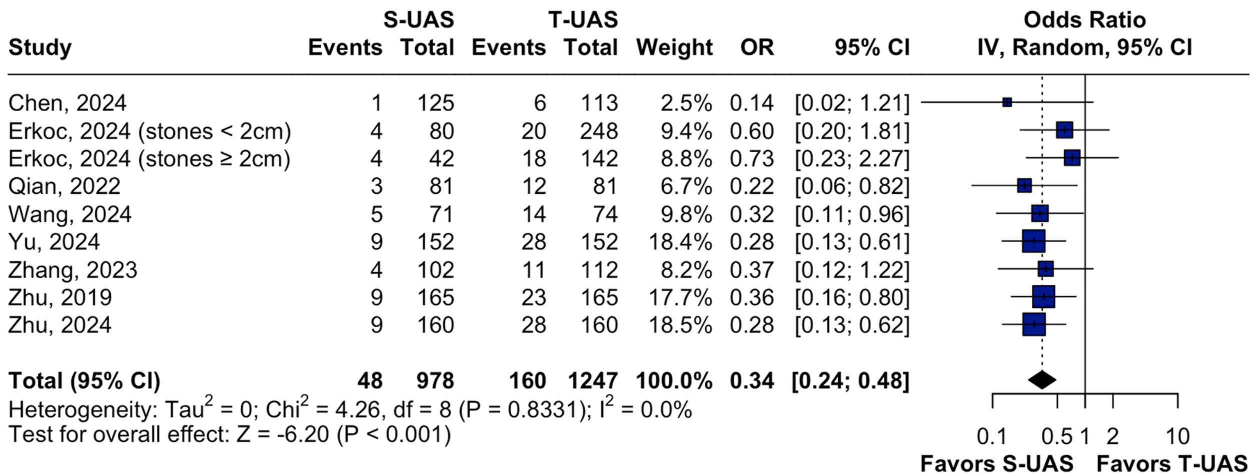

Fig. 5 Postoperative fever, measured by number of events

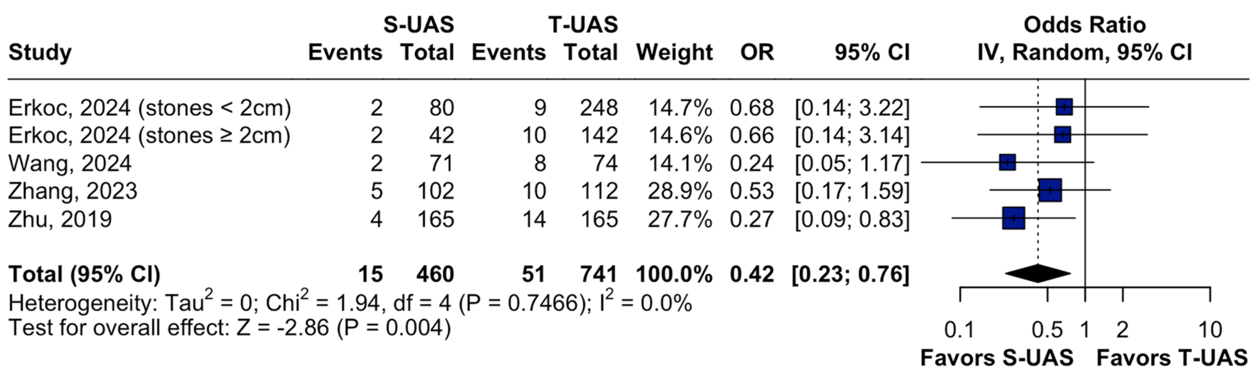

Fig. 6 Postoperative sepsis, measured by number of events

immediate postoperative period (one day) and at later time points (one or three months) for patients undergoing RIRS with an S-UAS (Figs. 2 and 3). These results underscore the enhanced stone extraction capabilities and technical superiority of this approach, leading to improved surgical outcomes and prognoses.

Beyond assessing the SFR, another outcome examined was surgical complications, for which the Clavien-Dindo classification was employed. Despite only four out of the eight studies incorporating this classification, our statistical analysis (Fig. 4) revealed a significant reduction in complications associated with the use of suctioning

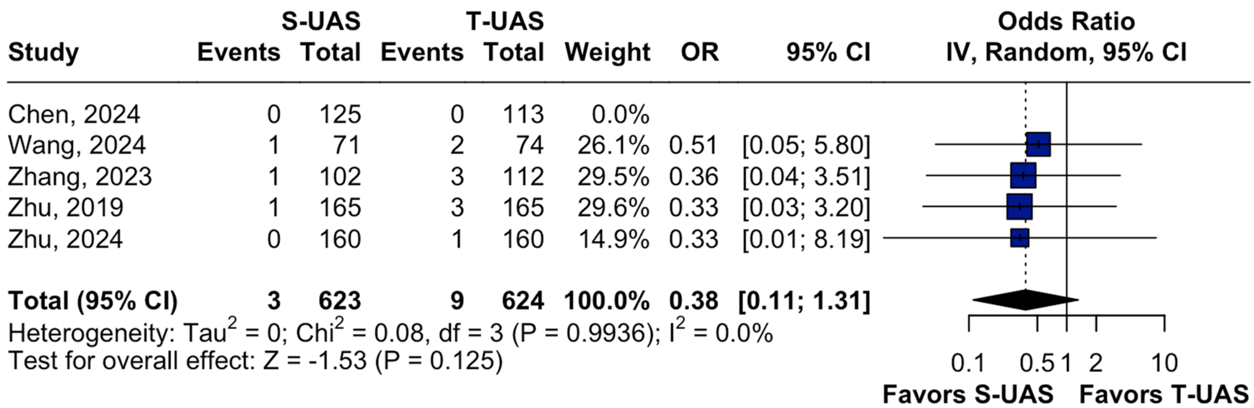

Fig. 7 Postoperative septic shock, measured by number of events

ureteral sheaths, with no heterogeneity (OR 0.37; 95% CI 0.26–0.51; $p<0.001$; $I^2=0\%$). This phenomenon can be explained by the fact that renal pelvic pressures (RPPs) greater than 30 mmHg induce backflow in the pyelovenous-lymphatic and pyelotubular systems, facilitating the entry of local bacteria and endotoxins into the lymphatic system and subsequently the bloodstream [3]. This mechanism also helps to explain our finding of a significant reduction in the incidence of postoperative sepsis with the use of S-UAS (OR 0.42; 95% CI 0.23–0.76; $p=0.004$; $I^2=0\%$) (Fig. 6), reinforcing the role of pressure control in minimizing infectious complications. In a similar fashion, although the reduction in septic shock cases did not reach statistical significance (OR 0.38; 95% CI 0.11–1.31; $p=0.125$; $I^2=0\%$) (Fig. 7), the numerical trend favoring S-UAS is noteworthy and likely limited by the very low incidence of this outcome—only 3 events in the S-UAS group versus 9 in the T-UAS group. Therefore, it is concluded that suctioning sheaths, by providing better control over RPP, contribute to reducing the incidence of backflow and, as a result, the occurrence of surgical complications or infections.

Regarding the other endpoints, our analysis revealed no significant difference in operative time (Fig. 8). On the other hand, postoperative fever and LOS were significantly reduced, as shown in Figs. 5 and 9, respectively. Although LOS is influenced by multiple factors, studies using comprehensive clinical data on surgical patients suggest that prolonged hospitalization primarily occurs due to intra- and postoperative complications [21]. In the context of surgical treatment for renal calculi, postoperative fever ranks as one of the most prevalent complications [22, 23] and warrants attention as it indicates infection. If poorly managed, it can lead to sepsis, a more severe complication that can be fatal. The reduction in RPP may explain the decrease in fever and, alongside, the shorter LOS observed when using aspirating UASs. This underscores that the use of suctioning sheaths reduces complication rates, thereby facilitating a more efficient and faster resolution of the surgical procedure.

After an exhaustive literature review, we found no meta-analysis comparing ureteral access sheaths with and without a suctioning system. Several review articles have explored the existing suctioning devices and techniques used to enhance the treatment of renal stones [20, 23, 24]. These papers collectively analyzed a wide range of studies, including in vitro, in vivo, *ex vivo*, human and animal models. The findings from the reviews by Solano et al., Geavlete et al., and Yuen et al. highlight several benefits of suctioning techniques during RIRS and ureteroscopies. They reported better management of intrarenal pressure and improved visualization of the operating field during procedures. Solano's and Geavlete's studies also emphasized higher SFRs achieved through the aspiration of stone fragments instead of using the stone basketing technique. Additionally, Solano's study noted lower rates of fever and sepsis when using S-UAS. However, none of these articles included statistical analysis of these outcomes. Our study aligns with these reviews, enhancing their findings by incorporating a meta-analysis.

Our study has several limitations that warrant consideration. Firstly, due to the scarcity of existing literature on this specific topic, we were only able to include one randomized controlled trial in our analysis, which limits the generalizability of our findings. Secondly, we observed that some studies contributed disproportionately to the heterogeneity of certain outcomes, notably Yu [4] for the one-day SFR and Wang [16] for LOS. Although we addressed this through heterogeneity analyses, it is important to scrutinize the methodological designs of these studies. Thirdly, our analysis of complications was limited by the fact that only four studies reported Clavien-Dindo classification, while infection-related complications such as sepsis and

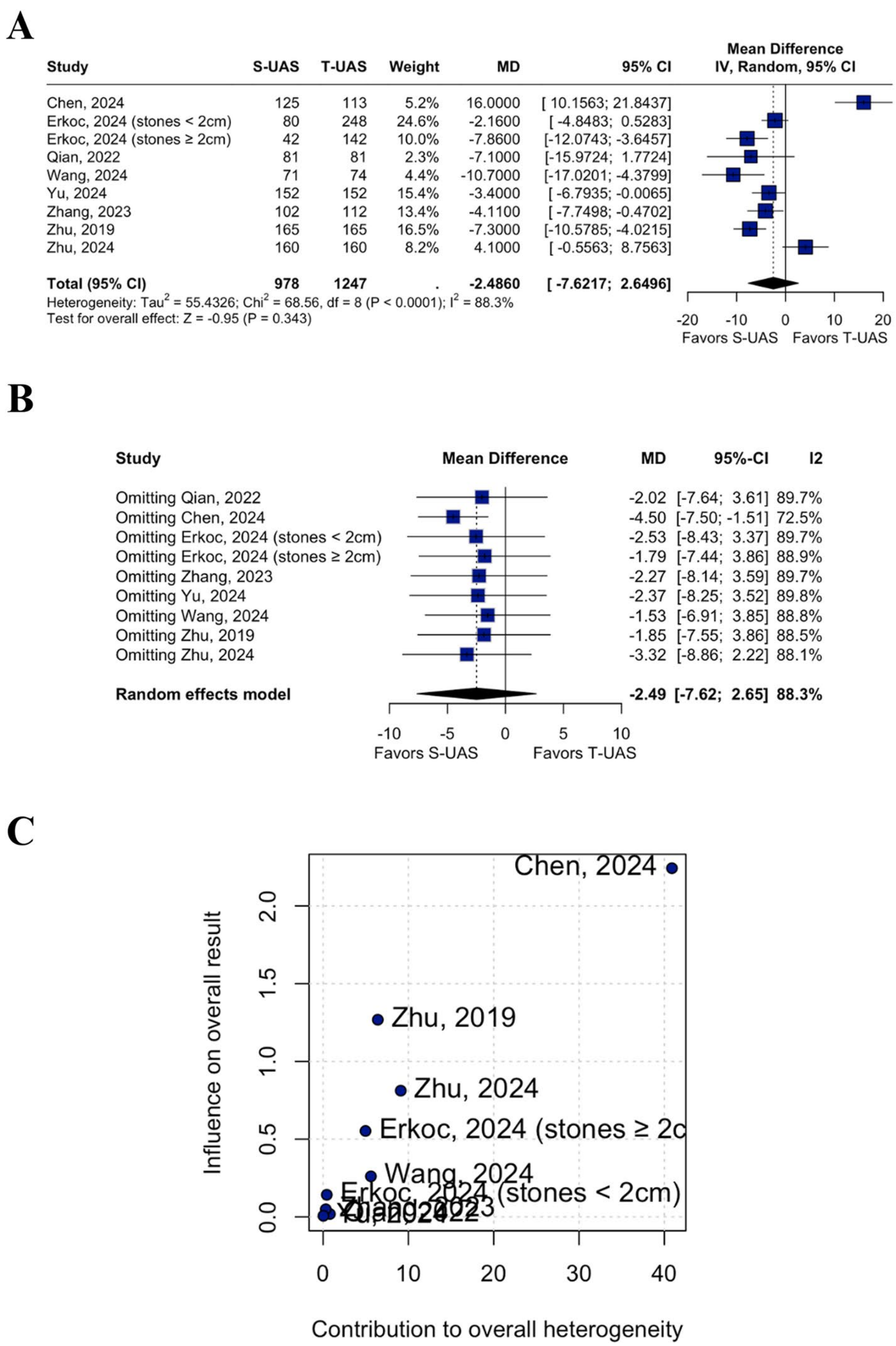

Fig. 8 Operative Time—**A**: Forest plot; **B**: Leave-one-out sensitivity analysis; **C**: Baujat plot

septic shock were reported in only four and five studies, respectively. This restricted our ability to comprehensively assess the potential influence of the S-UAS on surgical complications. Fourthly, the assessment of SFR varied across the studies, with some utilizing NCCT, USG, or KUB—and, in certain cases, employing more than one of these methods within the same study. This lack of standardization introduces potential bias into the analysis of our primary endpoint. Fifthly, five of the eight included studies exhibited a moderate risk of bias, mainly due to unadjusted confounding factors in their methodologies. This is unsurprising, as the use of S-UAS is still a relatively new topic in urology. For this reason, many studies in this area lack well-defined

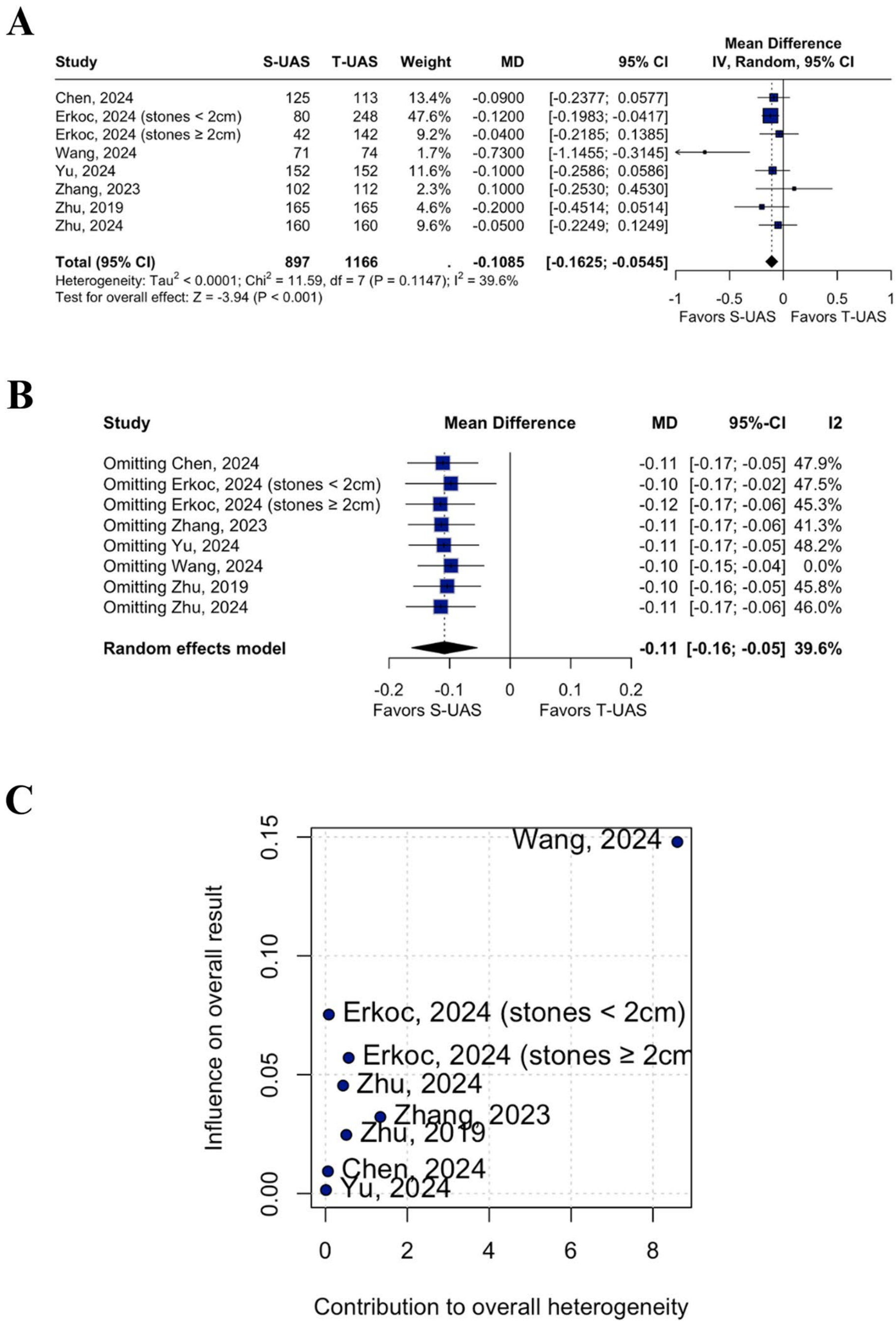

Fig. 9 LOS, in days—**A**: Forest plot; **B**: Leave-one-out sensitivity analysis; **C**: Baujat plot

methods to evaluate its effectiveness while adequately accounting for confounders. Lastly, the limited number of included studies and the fact that all were conducted in a narrow geographic context—seven in China and one in Turkey—raise considerations regarding the diversity of clinical settings and practices represented. This, together with the variability in UAS models employed, may influence how broadly our findings can be interpreted across different healthcare systems.

Based on our findings, the use of S-UAS in RIRS appears to be both safe and effective, offering improvements in SFR while reducing complications and LOS. Moreover, with ongoing technological advancements in endourology, future innovations may be integrated with

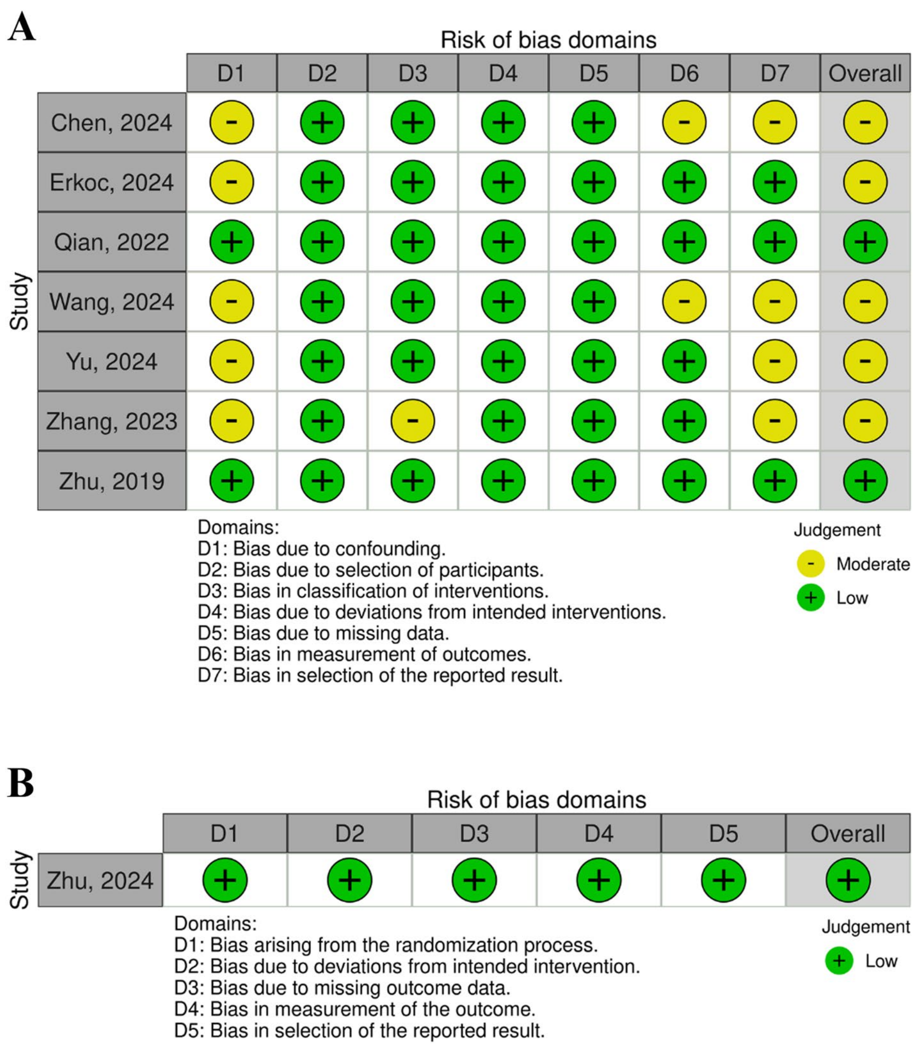

Fig. 10 Risk of bias of included studies

S-UAS, further amplifying its potential. However, our study is not without limitations, which must be addressed in future research. Thus, it would be premature to consider this review a definitive contribution to the field; robust, well-designed studies are needed to further substantiate the evidence.

Conclusion

In summary, this comprehensive meta-analysis explored the nuanced effects of using a S-UAS in RIRS. Our findings highlighted significant advantages, including a higher SFR, reduced surgical complications, fewer post-operative fever events, and shorter LOS. These results suggest that suctioning ureteral access sheaths in RIRS perform better than the traditional ones, allowing a more resolutive surgery, with better prognosis.

Despite the meticulous approach of this analysis, several limitations must be acknowledged, including the risk of bias due to confounding factors, the high heterogeneity among studies, and the limited number of randomized trials addressing this topic—only one of which assessed SFR. Consequently, further research and larger-scale trials are crucial to validate and expand upon the promising outcomes observed in this study.

Abbreviations

fURL	Flexible Ureteroscopic Lithotripsy
UAS	Ureteral Access Sheath
S-UAS	Suctioning UAS
T-UAS	Traditional UAS
RIRS	Retrograde Intrarenal Surgery
SFR	Stone-Free Rate
EAU	European Association of Urology
AUA	American Urological Association
NCCT	Non-Contrast Computed Tomography
KUB	Kidney-Ureter-Bladder X-ray

USG Ultrasonography
LOS Length of Postoperative Hospital Stay
RPP Renal Pelvic Pressure

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
Substantive scientific and intellectual contributions to the study: Conception and design: JC, FG, and BP; Acquisition of data: FG and BP; Analysis and interpretation of data: BT, JS, CP; Technical procedures: FG and BP; Statistics analysis: RS, BT, and JC; Manuscript preparation: FG, BP, and JC; Manuscript writing: JS, BP, and JO; Critical revision: JO and JC.

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Declarations

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Competing interests
The authors declare no competing interests.

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