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Comparison between flexible and navigable suction ureteral access sheath and standard ureteral access sheath during flexible ureteroscopy for the management of kidney stone: systematic review and meta-analysis

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Abstract

Objectives Flexible ureteroscopy (FURS) is a commonly chosen technique for kidney stone treatment. The use of ureteral access sheaths (UAS) enhances both access and the procedure's effectiveness. This study performs a systematic review and meta-analysis to assess the efficacy and safety of flexible and navigable suction UAS (FANS-UAS) versus standard UAS (S-UAS) in FURS.

Methods This systematic review and meta-analysis involved searching databases such as PubMed/Medline, Scopus, Embase, Cochrane, and Web of Science until October 2024. The results were categorized into two groups: FANS-UAS as the intervention and S-UAS as the control. The outcomes measured included stone-free rate (SFR), duration of lithotripsy, length of hospitalization, and incidence of complications.

Findings Eight studies were incorporated into the analysis. The findings revealed that the SFR on the first day in the intervention group was over twice that of the control group (RR = 2.12, 95% CI: 1.13–3.98, P = 0.019). Furthermore, the SFR during follow-up was 15% greater in the intervention group than in the control group (RR = 1.15, 95% CI: 1.06–1.25, P = 0.0008), with these differences being statistically significant. However, the standardized mean differences for the outcomes of duration of lithotripsy and postoperative hospitalization between the groups were minimal and not statistically significant ($P > 0.05$). The intervention group had 67% fewer fevers (RR = 0.33, 95% CI: 0.22–0.48, $P < 0.001$) and 43% fewer cases of sepsis (RR = 0.57, 95% CI: 0.23–1.39, P = 0.215) than the control group.

Conclusion Use of FANS-UAS significantly improves both first-day SFR and follow-up SFR. It is superior to S-UAS in minimizing postoperative complications. Both these factors contribute to significantly improved perioperative outcomes in flexible ureteroscopy.

Keywords Ureteroscopy, Kidney Calculi, Ureteroscopic Surgeries, Ureteral access sheath

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Introduction

Kidney stones, or nephrolithiasis, have a relatively high prevalence in many parts of the world, and their incidence is rising [1]. This condition affects between 7 to 13% of the population in North America, 5% to 9% in Europe, and 1% to 5% in Asia [2]. Kidney stones form from the precipitation of minerals in the renal calyces or pelvis [3]. Approximately 75% of kidney stones comprise calcium oxalate, while the remainder comprises calcium phosphate, struvite, urate, and cystine [4]. Significant advancements have been made in the treatment of kidney stones.

Various methods are available for the treatment of kidney stones. In recent decades, less invasive techniques have replaced open surgical procedures. Kidney stones can be fragmented by extracorporeal shock wave lithotripsy (ESWL), allowing them to be passed in the urine [3]. However, this method has limitations, including contraindications in pregnant women, severe obesity, renal or aortic aneurysms, and distal ureteral obstruction to the stone [5]. As a result, retrograde intrarenal surgery (RIRS) or percutaneous nephrolithotomy (PCNL) is used for such patients and larger kidney stones. In the more invasive PCNL method, access to the kidney stone is achieved percutaneously, followed by fragmentation and removal of the stone. Due to its more invasive nature, PCNL carries higher risks of bleeding and infection [6]. Due to advancements in medical equipment, flexible ureteroscopy or RIRS is now recommended for treating all kidney stones under 2 cm [7]. With the widespread use of this surgical method, considerable effort has been made to develop tools that facilitate the insertion and removal of the ureteroscope during the procedure [8]. One such new tool is the ureteral access sheath (UAS).

The ureteral access sheath (UAS) was developed to facilitate the surgical process of flexible ureteroscopy (FURS), offering benefits such as reduced intrarenal pressure, minimized risk of infection, improved drainage, and enhanced visualization during stone retrieval [9]. Its use in RIRS has been widely adopted, with studies demonstrating its role in shortening operative time and improving surgical outcomes [10]. Among the latest advancements in UAS design, flexible and navigable suction ureteral access sheaths (FANS-UAS) have been introduced as a more versatile alternative to standard ureteral access sheaths (S-UAS). Unlike S-UAS, which maintains a fixed, rigid structure, FANS-UAS incorporates a flexible and bendable tip, allowing for greater maneuverability and improved navigation within the renal collecting system. This flexibility at the distal tip enables easier access to complex calyces, reducing ureteroscope deflection and enhancing stone retrieval efficiency [11]. Compared to conventional S-UAS, FANS-UAS improves access to complex renal calyces, reducing ureteroscope deflection and enhancing stone retrieval efficiency [8]. Several studies have highlighted the potential benefits of FANS-UAS. Bai et al. (2024) reported an effectiveness rate exceeding 90% on the first postoperative day for kidney stones larger than 2 cm, demonstrating its clinical utility [12]. These modifications aim to optimize stone retrieval, reduce operative time, and minimize postoperative complications [13].

Numerous studies have highlighted several advantages of utilizing FANS-UAS for kidney stone treatment during FURS. However, these effects have not been comprehensively compared to S-UAS types. This systematic review and meta-analysis comprehensively investigate the effects, complications, and safety of FANS-UAS for treating kidney stones and compares it with S-UAS.

Materials and methods

Study design

This systematic review and meta-analysis has been reported in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [14]. Furthermore, this study was carried out in adherence to the AMSTAR (A Measurement Tool to Assess Systematic Reviews) guidelines for evaluating the methodological quality of systematic reviews.

Search strategy and resources

The literature search was conducted in databases including PubMed/Medline, Scopus, Embase, Cochrane Library, Web of Science, and Google Scholar until October 2024. Additionally, gray literature was explored to identify further studies under consideration. This search was conducted with no restrictions on time or language. Key search terms included:"Ureteroscopy","ureteroscope s","flexible ureteroscope","FURS","Kidney Calculi","Nephr olithiasis","Sheath","Access sheath","Standard","Conventio nal","Traditional","Bendable", and"Flexible". A multi-step process was followed to determine the search keywords and design the search syntax, utilizing commonly used free keywords and Medical Subject Headings (MeSH) terms (Appendix 1).

Selection criteria

Two researchers independently input the results from the listed databases into EndNote software. Duplicates were identified and removed using EndNote. Subsequently, both researchers screened the remaining articles to determine eligible studies, and a third researcher resolved any disagreements. Based on the PICO framework, the inclusion criteria were defined as follows: Population (P): Patients undergoing FURS to treat kidney stones. Eligible studies included pediatric or adult patients, provided that they focused on interventions involving flexible ureteral access sheaths (FUAS). Intervention (I): The intervention group consisted of patients treated with FANS-UAS during FURS. Comparison (C): The control group included patients treated with S-UAS during FURS. Outcome (O): Treatment outcomes included the Stone-Free Rate (SFR) measured on the first postoperative day and during follow-up (1–3 months), stone location, the duration of lithotripsy (in minutes), postoperative hospitalization (in days), and the incidence of complications such as overall complications (non-specified), fever, and sepsis.

The inclusion criteria required published studies with full-text articles that included control and intervention groups. Exclusion criteria were reviews, book chapters, conference abstracts, in vivo and in vitro studies. Studies without control groups or those reporting data from other types of urinary stone surgeries (other than flexible ureteroscopy) were also excluded. Reported outcomes, including SFR and complications such as fever and sepsis, were analyzed using relative risk (RR), while continuous outcome variables such as duration of lithotripsy and postoperative hospitalization were calculated using the Standardized Mean Difference (SMD) as the effect size. Also, given that terms such as"flexible,""tip-flexible,"and"bendable"are often used interchangeably in the literature, we have standardized the terminology throughout this manuscript to align with the current consensus, referring to FANS-UAS as the preferred designation for flexible tip UAS.

Data extraction

The results included the outcomes and complications in the groups under study. The following information was extracted from each study: name of the first author, publication date, start date of data collection, country, age, gender, body mass index, type of intervention, study design, follow-up period, sample size, and types of outcomes and complications.

Quality appraisal

A systematic bias evaluation was carried out for the included randomized controlled trials (RCTs) using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool, which examines six primary domains: selection, performance, detection, attrition, reporting, and other possible bias sources. This tool offers a structured framework for researchers to identify and assess the risk of bias at different trial stages. Ultimately, the assessment is classified into three risk levels: low, some concerns, and high [15]. Additionally, a systematic evaluation of bias in non-randomized intervention studies, including uncontrolled clinical trials, was conducted using the ROBINS-I tool. This tool assesses bias across seven domains: confounding, participant selection, intervention classification, deviations from planned interventions, missing data, outcome measurement, and result reporting. The final bias risk is low, moderate, or high [16].

Two independent researchers carried out screening, selection of studies, validation, data extraction, and evaluation of methodological quality. A third reviewer resolved any disagreements between them, and consensus was achieved in all instances.

Publication bias

Publication bias was evaluated using funnel plots and Egger's weighted regression [17]. A *p*-value greater than 0.05 indicated the absence of publication bias.

Sensitivity analysis

Sensitivity analysis was conducted using the leave-one-out method to evaluate the influence of individual studies on the overall effect size for the primary outcome.

Statistical analyses

The data were input into statistical software, and analyses were conducted using STATA 17.0 (Stata Corporation, College Station, TX). A random effects model was applied to address the heterogeneity across studies. Cochran's Q test and Higgins I^2 test were utilized To evaluate heterogeneity, alongside a qualitative review of the differences between studies by the researchers. Forest plots were generated to illustrate the effect size for each study and the pooled estimates. Statistical significance was defined as a *p*-value below 0.05.

Results

Study selection

Following a comprehensive search of international databases, 1,412 articles were identified. After eliminating duplicates, 1,261 articles were screened by title and abstract. Based on this screening, 32 articles were moved to the next stage. At this stage, full-text articles were evaluated, resulting in 8 articles being included in the final analysis. Additionally, the references of the selected articles were reviewed to incorporate relevant studies. The process of study selection is illustrated in Fig. 1.

Characteristics of studies

The included studies were up to the end of October 2024. Eight studies were eligible during this period, and they examined the outcomes and complications of interest. The data collection period for all studies ranged from 2019 to 2024. Patients across the studies had a mean age exceeding 50 years and a BMI higher than 25 kg/m^2. Additionally, the patients were similar in terms of both age and BMI. Furthermore, five studies specifically

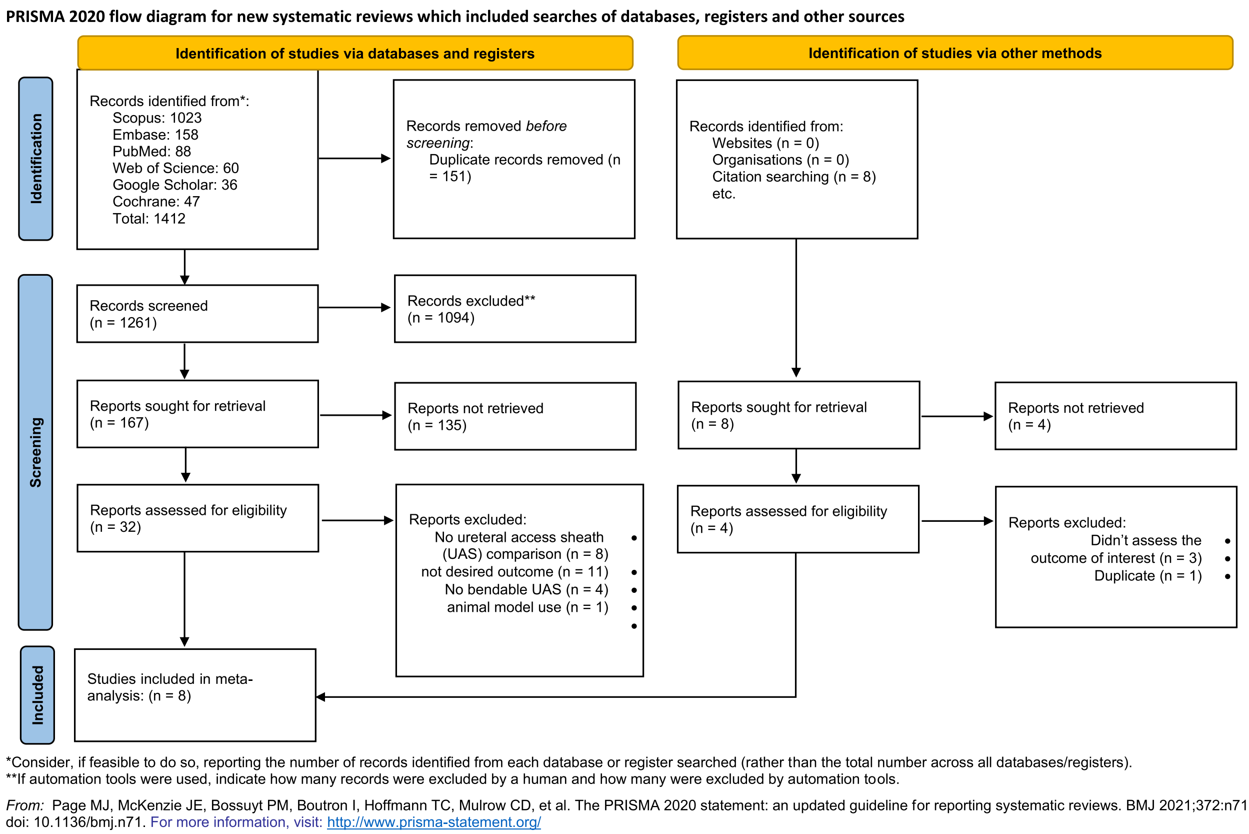

Fig. 1 Preferred Reporting Items for a Systematic Review and Meta-Analysis (PRISMA) 2020 flow diagram for new systematic reviews, including database, registers, and other source searches

reported working on anatomically normal kidneys and two studies reported the use of postoperative stenting. Moreover, the majority of the included studies focused on kidney stones larger than 1.5 to 2 cm. The other findings from the studies are summarized in Table 1.

Quality appraisal

Appendix 2 presents the quality assessment results for the articles. Using the provided checklist to evaluate seven non-randomized trials, five studies were identified as having moderate risk, while two were classified as having serious risk. Furthermore, one randomized study was assessed as having moderate quality.

Heterogeneity

There was heterogeneity among the studies for the primary outcomes of the study based on the chi-squared test and I2 index. The heterogeneity analysis for the primary outcomes revealed the following: Day 1 SFR (I2 =98.58%, $P<$ 0.001), Follow-up SFR (I2 =77.63%, $P=$ 0.0002), Duration of Lithotripsy (I2 =82.48%, $P<$ 0.001), and Postoperative Hospitalization (I2 =0.00%, $P=$ 0.584). In some cases, where the heterogeneity analysis between studies was not significant, the random effects model was used for the analyses due to the inherent qualitative differences between the studies. Further details are provided in Table 2.

Results of the meta-analysis

Comparison of outcomes between the intervention and control groups

According to the random effects model, the SFR outcomes on the first day and at follow-up were more significant in the intervention group than in the control group. Based on seven studies, the intervention group's first-day SFR outcome was more than twice as high as the control group's (RR =2.12, 95% CI: 1.13–3.98, $P=$ 0.019). Additionally, the follow-up SFR at 1–3 months, based on seven studies, remained 15% higher in the intervention group (RR =1.15, 95% CI: 1.06–1.25, $P=$ 0.0008), which were all statistically significant (Fig. 2 and Table 2).

Removing any of the studies did not significantly change SFR outcomes, and the outcomes remained consistent when sensitivity analysis was performed (Fig. 3).

For quantitative outcomes, the results showed that the mean Duration of Lithotripsy (in minutes) for eight

Table 1 Basic information of included studies

ID	Authour	Data collection duration	Country	Intervention	Control	Kidney Anatomy	Findings on stone size	Postoperative Stenting use	Age Intervention (mean ± SD)	BMI Intervention (mean ± SD)	Age Control (mean ± SD)	BMI Control (mean ± SD)	Intervention sample size
1	Huang (2023) [18]	2022–2023	China	vacuum-assisted dedusting lithotripsy (VADL) using flexible vacuumassisted ureteral access sheath (FV-UAS)	traditional flexible ureteroscopic lithotripsy (fURL)	Only normal kidneys	FV-UAS improved SFR for both ≤ 2 cm and 2–3 cm stones	No mention; FV-UAS may reduce the need for stenting	54.7 ± 10.70	26.5 ± 4.9	54.5 ± 11.0	26.3 ± 4.2	206
2	Chen (2024) [19]	2019–2023	China	tip-flexible suctioning ureteral access sheath (TFS-UAS) plus disposable flexible ureteroscope (DFU)	traditional ureteral access sheath (T-UAS) plus disposable flexibleureteroscope (DFU)	Only normal kidneys	Compared TFS-UAS vs. T-UAS for stones ranging from 1 to 3 cm in size but no analysis on stone size	F5 double-J stent placed postoperatively in all patients	45.62 ± 12.93	25.21 ± 3.77	46.35 ± 14.88	25.66 ± 4.35	238
3	Cui (2024) [20]	2022–2023	China	bendable flexible ureteral access sheath (FUAS) combined with retrograde intrarenal surgery (RIRS)	intelligent intrarenal pressure control platforms (IPCP)	Only normal kidneys	FANS-UAS had higher SFR for stones ≥ 15 mm	Stenting not explicitly mentioned; pre-op stenting was an exclusion criterion	55.0 ± 13.34	24.29 ± 2.88	53.5 ± 13.6	23.45 ± 3.03	99
4	Ding (2023) [21]	2022–2023	China	omnidirectional (OD) ureteral access sheath (UAS)	conventional Cook UAS	Not specified	OD-UAS had better SFR for larger stones (> 15 mm) but no direct volume analysis	Stent removal was required for follow-up, implying stenting was performed	57.6 ± 13.7	24.6 ± 3.2	55.7 ± 13.1	24.0 ± 2.6	199

Table 1 (continued)

ID	Authour	Data collection duration	Country	Intervention	Control	Kidney Anatomy	Findings on stone size	Postoperative Stenting use	Age Intervention (mean ± SD)	BMI Intervention (mean ± SD)	Age Control (mean ± SD)	BMI Control (mean ± SD)	Intervention sample size
5	Ong (2024) [22]	2022–2023	Multi-center (Singapore, United Kingdom, Canada, Saudi Arabia, India, Indonesia, Russia, Hong Kong, Italy, France)	flexible and navigable suction UAS (FANS)	traditional suction ureteral access sheath (SUAS)	Not specified	FANS-UAS showed higher SFR, particularly for larger stones	No mention of stenting in outcome measures	52.0 ± 20.01	-	54.7 ± 10.70	26.5 ± 4.9	90
6	Yu (2024) [23]	2022–2022	China	Flexible UAS	Traditional UAS	Only normal kidneys	f-UAS had better outcomes for stones > 15 mm but no volume-based analysis	No mention of postoperative stenting	51.1 ± 12.2	24.3 ± 2.8	54.7 ± 10.70	26.5 ± 4.9	304
7	Zhang (2023) [24]	2021–2022	China	tip-flexible suctioning ureteral access sheath (NTFS-UAS)	traditional ureteral access sheath (T-UAS)	Only normal kidneys	NTFS-UAS had higher SFR for stones > 20 mm	No specific mention of stenting post-surgery	47.69 ± 9.18	24.25 ± 2.97	54.7 ± 10.70	26.5 ± 4.9	214
8	Zhu (2024) [25]	2023–2024	multi-center (china, turkey, Malaysia, Philippines)	S-UAS, tip bendable suction ureteral access sheath	Traditional UAS	Only normal kidneys	S-UAS had higher SFR for all stone sizes, especially ≥ 20 mm	No explicit mention of stenting	53.0 ± 14.08	24.8 ± 3.04	54.7 ± 10.70	26.5 ± 4.9	320

Table 2 Result of meta-analysis and heterogeneity of the comparison between FANS-UAS and S-UAS for studied outcome

Variable		**Number of studies**	**Effect estimate (Risk Ratio)**	**95% CI**	***p*.value**	**Heterogeneity**		
						Q-Value	***p*.value**	**I^2**
Outcomes	Immediate SFR[a] (day 1)	7	2.12	1.13 to 3.98	0.019	80.87	< 0.001	98.58
	Follow-up SFR [a](1–3 month)	7	1.15	1.06 to 1.25	0.0008	26.07	0.0002	77.63
	-	-	Effect estimate (SMD[a])	-	-	-	-	-
	Duration of lithotripsy	8	0.08	−0.15 to 0.32	0.486	40.46	< 0.001	82.48
	Postoperative hospitalization	4	−0.08	−0.20 to 0.04	0.199	1.94	0.584	0.00
-	-	-	Effect estimate (Risk Ratio)	-	-	-	-	-
Complications	Fever	8	0.33	0.22 to 0.48	< 0.001	5.76	0.567	0.00
	Sepsis	4	0.57	0.23 to 1.39	0.215	1.22	0.747	0.00
	Overal[b]	3	0.41	0.27 to 0.61	< 0.001	3.30	0.192	0.00

[a] *SMD* Standardized Mean Difference, *SFR* Stone Free Rate

[b] Without mentioning the exact type of complication

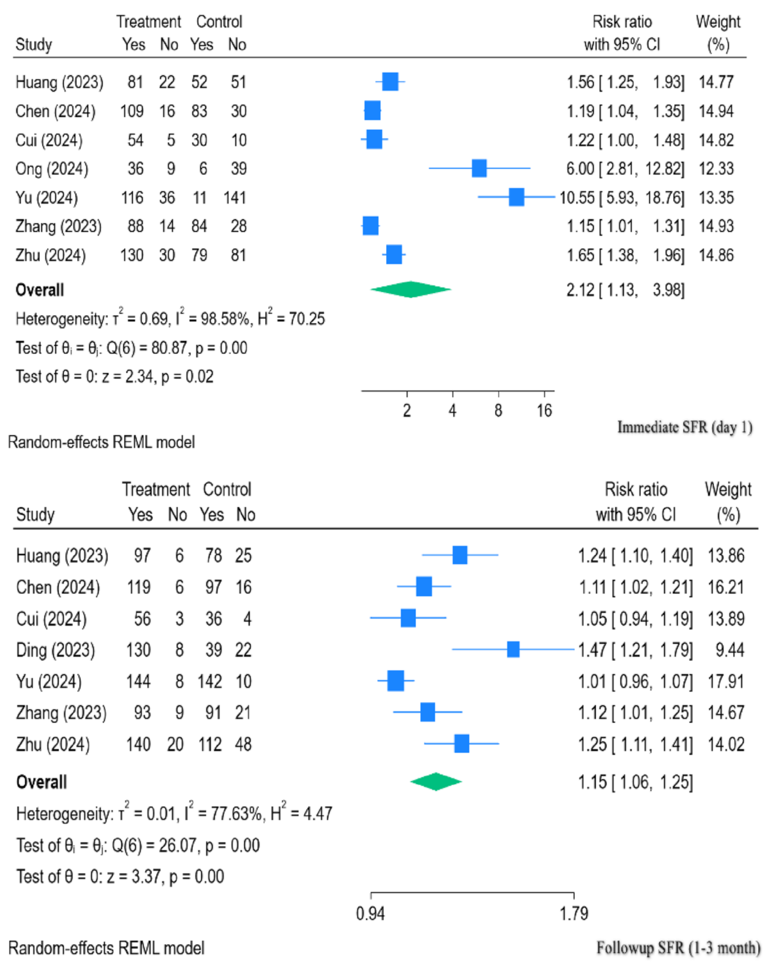

Fig. 2 Meta-analysis of the comparison between FANS-UAS and S-UAS for outcome of Immediate SFR (day 1) and Follow-up SFR (1–3 month)

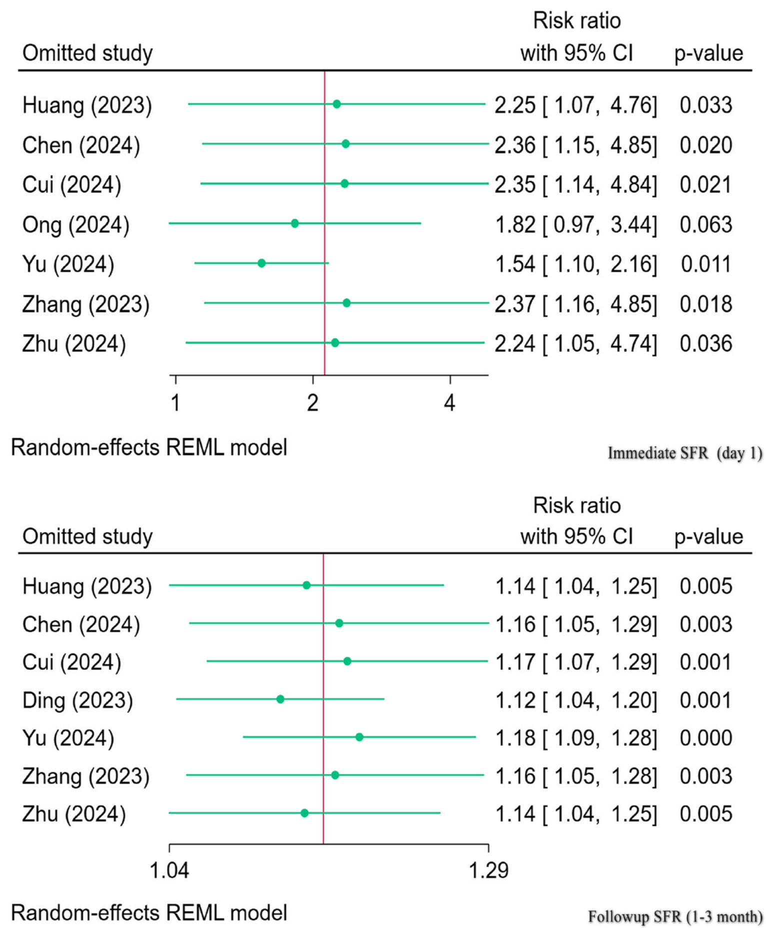

Fig. 3 Sensitivity analysis results of the studies included in the meta-analysis with the exclusion of one study for Immediate SFR and Follow-up SFR

studies (SMD =0.08, 95% CI: −0.15 to 0.32, P= 0.486) and the mean postoperative hospitalization (in days) for four studies (SMD =−0.08, 95% CI: −0.20 to 0.04, P= 0.199) indicated that the SMD between the intervention group and control group were almost identical with no statistically significant differences (Appendix 3 and Table 2).

Comparison of SFR between the intervention and control groups based on stone location

The subgroup analysis reveals differences in immediate and follow-up SFR based on stone location. In the first-day SFR analysis, FANS-UAS showed a greater benefit when both renal and ureteral stones were included (RR =2.33, 95% CI: 0.91 to 5.94, P= 0.08), whereas its effect was lower for renal stones alone (RR =1.89, 95% CI: 0.70 to 5.15, P= 0.21). For follow-up SFR, FANS-UAS demonstrated a higher effect in renal-only cases (RR =1.20, 95% CI: 1.02 to 1.41, P= 0.03) compared to mixed-location stones (RR =1.13, 95% CI: 1.01 to 1.26, P= 0.03). (Fig. 4).

Complications between the intervention and control groups

Complications included the most significant complication, fever, with eight studies. There was a 67% reduction in fever incidence among the intervention group versus the control group (RR =0.33, 95% CI: 0.22 to 0.48, P= 0.001). Also, four studies assessed sepsis in the intervention versus control groups and found it to be 43% lower in the intervention group (RR =0.57, 95% CI: 0.23–1.39, P= 0.215) (Fig. 5 and Table 2). Additionally, three studies reported complications generally without specifying the exact nature of the complication. In these studies, compared to the control group, the overall complication rate for the intervention group was 59% lower (RR =0.41, 95% CI: 0.27–0.61, P< 0.001) (Appendix 4 and Table 2).

Publication bias

Finally, funnel plots were used to visualize publication bias for the study's primary outcome, SFR. Egger's test for SFR on the first day (bias: 7.01, SE =0.99, P= 0.001) and

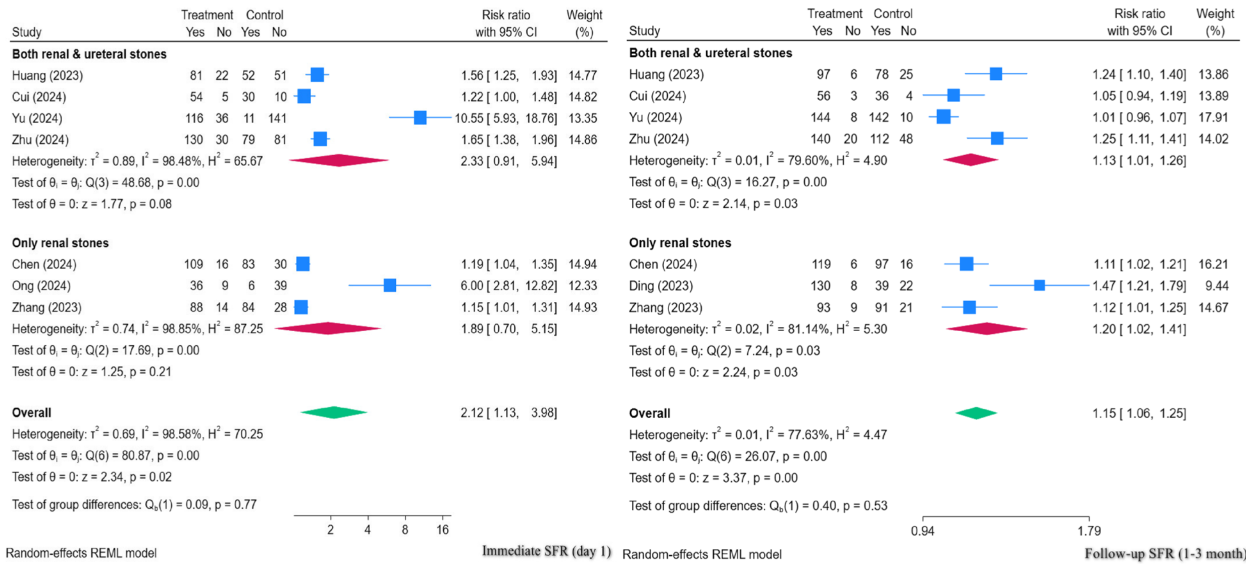

Fig. 4 Subgroup meta-analysis of the comparison between FANS-UAS and S-UAS based on stone location

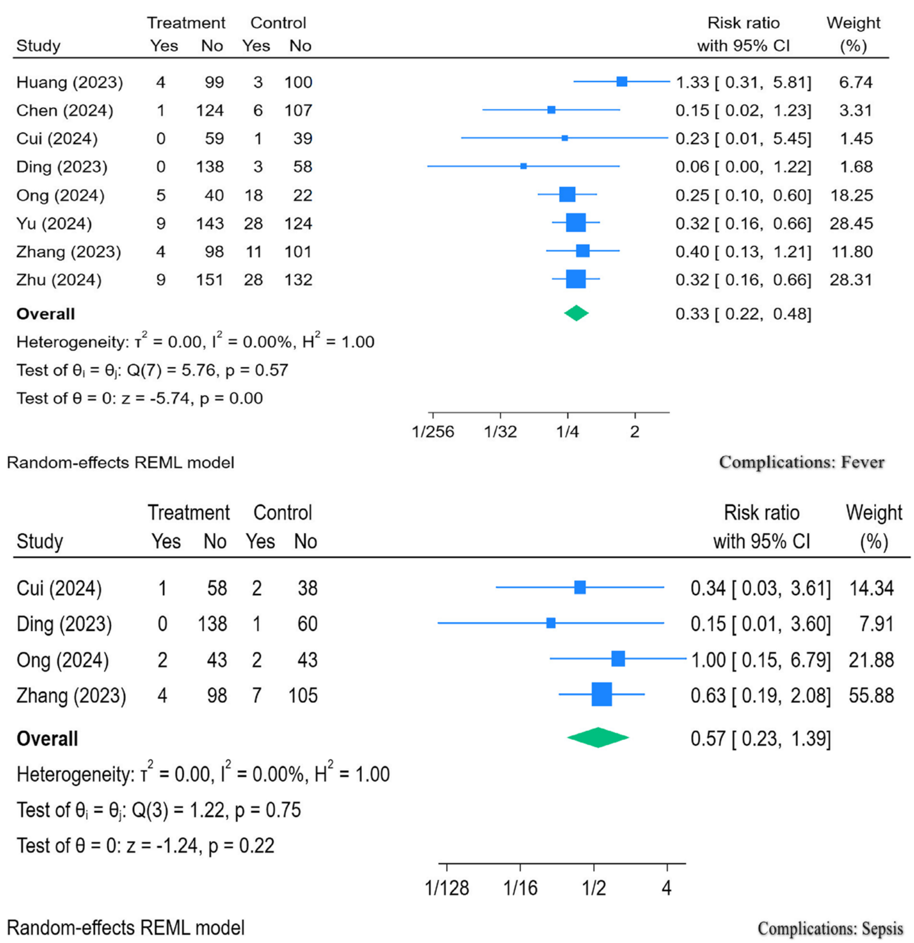

Fig. 5 Meta-analysis of the comparison between FANS-UAS and S-UAS for adverse events of fever and sepsis

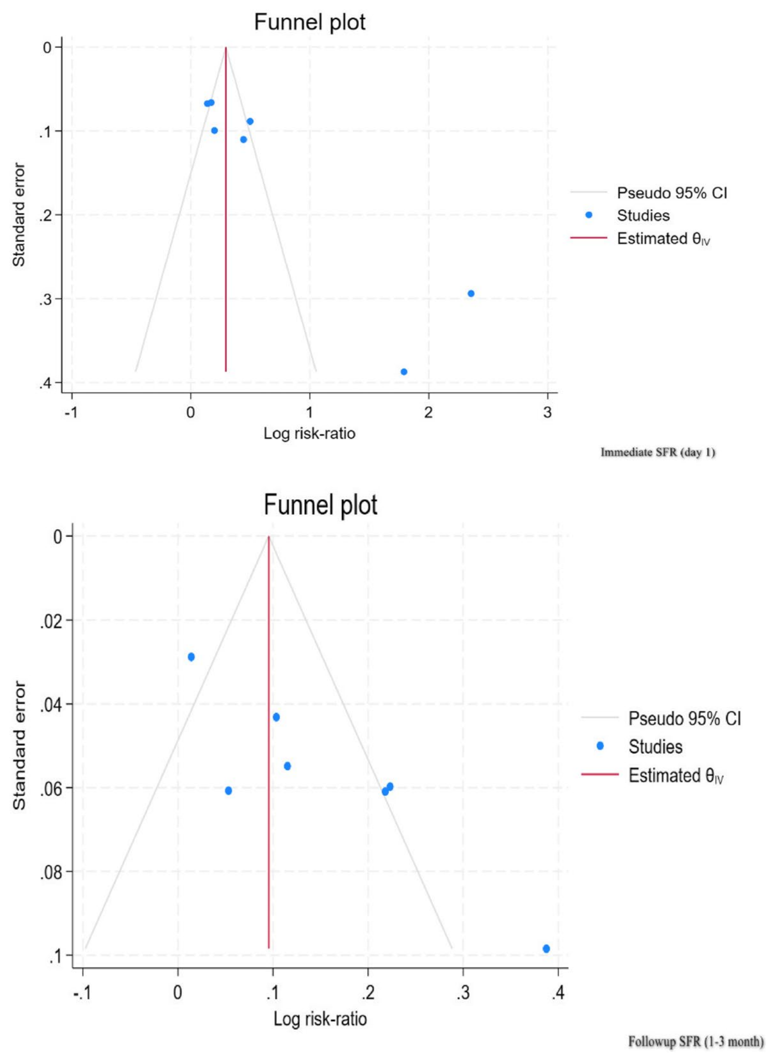

Fig. 6 Funnel plot for the publication bias assessing of the studies in meta-analysis

SFR follow-up (bias: 4.91, SE = 1.09, P = 0.001) confirmed this bias (Fig. 6).

Discussion

In this study, patients with kidney stones who underwent FURS using a FANS-UAS were compared with those who received the S-UAS. Among the patients who used the FANS-UAS, the likelihood of SFR on the first-day post-surgery was more than twice as high as that of the group using the S-UAS. Moreover, the SFR at follow-ups between one and three months was 15% higher in the FANS-UAS group compared to the S-UAS group. There was no significant difference in the duration of the surgery (lithotripsy) or the length of hospital stay between the two groups. Overall, post-operative complications were 59% less frequent in the group that used the FANS-UAS, with specific reductions in the incidence of fever and sepsis, which were 67% and 43%, respectively, compared to the S-UAS group.

Most of the previous studies conducted on FANS-UAS have demonstrated its effectiveness and relative advantages over S-UAS types. After treatment with the FANS-UAS, Chen et al. reported a mean SFR of 83% on the first day and 85% at one-month post-treatment for 206 kidney stone patients with a diameter greater than 3 cm [26]. A retrospective study published in 2024 by Ying et al. compared the treatment of 103 patients with unilateral upper urinary tract stones treated with FANS-UAS with the treatment of 138 patients with S-UAS. There was a significant difference between groups on the first day, with the FANS-UAS group having 76.7% SFR and the S-UAS group having 63.77% SFR [27]. Likewise, Ding et al. compared 199 patients with kidney stones treated with FANS-UAS and S-UAS, reporting that the

FANS-UAS group achieved an SFR of 94.2% within one month, while the control group had a significantly lower rate of 63.9% [21]. Beyond adult cases, studies have also explored the efficacy of FANS-UAS in pediatric patients. A study by Gauhar et al. 2024 examined a type of flexible and steerable UAS in 50 pediatric patients and reported a 100% final SFR. Additionally, fever occurred in only four patients, lasting less than 24 h, without any findings of sepsis [28]. Another study by Peng et al. evaluated the effect of FANS-UAS in 21 children aged 5 to 18 years with kidney stones under 3 cm and reported SFRs of 81% on the first day and 85.7% one month later [29]. The higher success rate of the FANS-UAS compared to S-UAS is attributed to its ability to more easily navigate the ureteropelvic junction, get closer to the stone, apply more potent suction on the fragmented stone pieces, and facilitate easier removal of these fragments, leading to a better SFR [30]. Additionally, recent studies confirm that FANS-UAS is particularly beneficial for managing large stones (≥ 2 cm). Huang et al. compared intelligent pressure-controlled (IPC) and FANS-UAS for 2–4 cm renal stones and found that immediate SFR was higher in the FANS-UAS group (82.5% vs. 69.8%), though long-term outcomes were comparable, suggesting sustained efficacy [31]. Wang et al. compared FURS and PCNL for stones > 2 cm and found that FURS with FANS-UAS resulted in higher stone clearance, reduced complications, and faster recovery, reinforcing its role in minimally invasive stone management [32]. Furthermore, Erkoç et al. evaluated aspiration-assisted UAS (ClearPETRA) in RIRS and demonstrated that for stones between 2–3 cm, FANS-UAS significantly increased SFR and reduced postoperative sepsis rates, confirming its safety and efficacy in complex cases [33]. While most findings suggest a greater advantage for FANS-UAS in larger stones, some reports indicate that it remains highly effective for stones < 2 cm [18], likely due to its enhanced suction-assisted fragment removal and reduced intrarenal pressure fluctuations. These attributes enable FANS-UAS to achieve superior performance across various stone sizes, making it a recommended approach for both small and large kidney stones. Given its enhanced navigability, superior suction, and improved fragment clearance, FANS-UAS should be considered a preferred option for kidney stone management, especially in cases requiring high SFR and minimized complications.

This study suggests that FANS-UAS may offer advantages over S-UAS in improving SFR, with its effectiveness influenced by stone location. Prior studies have shown mixed findings regarding UAS effectiveness. Lima et al. compared outcomes between renal stone treatments with and without UAS over a 7-year period, reporting that UAS-assisted procedures achieved good stone-free rates in large and multiple renal stones but did not show a significant advantage in smaller calculi [34]. Similarly, Traxer et al. conducted a large-scale analysis of renal stones treated with FURS with and without UAS and found no significant difference in SFR between groups, but a reduction in postoperative complications was noted with UAS use [35]. In contrast, L'esperance et al. evaluated the effect of UAS on stone-free rates in renal calculi and observed significantly improved outcomes in procedures involving UAS, particularly for upper ureteral stones, supporting our finding that FANS-UAS may be more beneficial when treating stones at multiple locations [36]. The variation in results may be due to differences in surgical techniques, patient selection, and stone burden. FANS-UAS maximizes its advantages in cases with ureteral stones, where its suction capabilities aid in fragment evacuation. However, in renal-only cases, factors such as stone density and calyceal anatomy may limit its effectiveness. The high heterogeneity among studies highlights the need for standardized protocols to improve comparability. Clinically, FANS-UAS is most beneficial in complex stone cases requiring enhanced maneuverability and suction, particularly in upper urinary tract stones or larger stone burdens. Future research should focus on randomized trials with standardized patient selection, uniform follow-up durations, and stone-specific analyses to better define FANS-UAS's role compared to S-UAS [37].

Regarding postoperative complications, various studies have reported that the use of FANS-UAS is associated with fewer complications compared to S-UAS. Different studies have yielded varying results regarding the duration of surgery. Some indicated reduced surgical time, while others found no difference. Hu et al., comparing two groups of patients with kidney stones treated with FANS-UAS and S-UAS, found that the surgical and lithotripsy times were shorter with the FANS-UAS method. Additionally, this study reported significantly fewer complications, including postoperative fever, septicemia, and the need for analgesics, in the FANS-UAS group compared to the S-UAS group [38]. However, the study by Ying et al. found no differences between the FANS-UAS and S-UAS groups regarding hospital stay duration, surgical time, or the incidence of systemic inflammatory response syndrome [27]. Gauhar et al. conducted a study involving 394 patients from 25 different centers worldwide, who underwent surgery using FANS-UAS and S-UAS. Among these patients, only 12 developed mild fever within the first 24 h, and none experienced sepsis [39]. In another study, Gauhar et al. compared 10 French and 12 French FANS-UAS and S-UAS in 31 patients and found that none developed fever or sepsis in either group [40]. FANS-UAS allows for better intrarenal pressure (IRP) management by avoiding the obstruction caused by the ureteropelvic junction. This and the reduced stone residue after surgery with the FANS-UAS method contribute to fewer postoperative complications and infections [6].

This is the first meta-analysis that specifically examines FANS-UAS compared to S-UAS during FURS in patients with kidney stones. Moreover, this study utilized subgroup analyses to investigate the relationship between variables further. This study has several limitations. A major limitation is the variability in suction settings across included studies, as some trials lacked clear documentation of suction parameters, potentially affecting the comparability of results. Additionally, differences in laser lithotripsy setting used in the included studies were not accounted for, which could influence stone fragmentation and SFR outcomes. Another consideration is the heterogeneity in postoperative management strategies, such as stenting protocols and adjunctive therapies, which may have impacted post-treatment SFR and complication rates. Moreover, zero residual fragments (ZRF) were only reported in studies involving FANS, while non-FANS studies did not achieve complete clearance. This discrepancy needs to be acknowledged as a potential source of bias. Alternatively, the lack of ZRF in non-FANS studies should be highlighted as a limitation, emphasizing that FANS-UAS may not universally achieve complete clearance and that more standardized comparisons are necessary. Many studies were excluded due to non-randomized designs and the absence of control groups, limiting the overall generalizability of findings. Additionally, variability in follow-up durations (one-month vs. three-month follow-ups) across studies may have influenced the long-term SFR assessment. Furthermore, certain demographic and clinical factors, such as gender, underlying conditions, and previous surgeries, were not consistently reported, which may have contributed to confounding effects. Another key limitation is the potential presence of publication bias, particularly in SFR outcomes. To mitigate this, a sensitivity analysis was performed by systematically excluding individual studies, confirming the stability of the overall effect estimates. While the possibility of bias remains, the consistency of results across multiple analyses strengthens the reliability of our conclusions. However, the qualitative assessment of included studies indicated that many had moderate or severe methodological limitations, reinforcing the need for future high-quality, randomized studies with standardized methodologies to further validate these findings.

Conclusion

The findings of this study indicate that the use of FANS-UAS compared to S-UAS during FURS for patients with kidney stones is associated with a higher SFR on the first day and at one to three months. Furthermore, using FANS-UAS is linked to reduced surgical complications, including fever and sepsis. Urologists should consider that FANS-UAS facilitates more straightforward access to kidney stones in the calyces and enables more efficient removal through suction, thereby leading to better overall outcomes.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
I.A., O.Ab., and O.Al. conceptualized the study framework. A.A. and A.S. were responsible for conducting the database searches and applying the inclusion and exclusion criteria. Data extraction and validation were performed by I.A. and A.A. M.S., O.Al., and I.A. handled the data analysis, interpreted the results, and created the related tables and figures. The initial draft of the manuscript was prepared by I.A., O.Ab., and O.Al. A comprehensive review and revisions to the final draft were undertaken by I.A.. All authors provided input, contributed to revisions, and gave their approval for the final version to be submitted.

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Data availability
The corresponding author's dataset during the current study are available upon reasonable request.

Declarations

Ethics approval and consent to participate
There is no ethical statement for this study due to the nature of the secondary studies like systematic reviews and meta-analysis.

Competing interests
The authors declare no competing interests.

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