Systematic Review

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Systematic Review

Repositioning lower pole stones prior to lithotripsy in retrograde intrarenal surgery as a strategy to enhance stone free rate: A systematic review, meta-analysis, and meta-regression

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Abstract

Lower pole stones (LPS) are associated with the difficulty to achieve a total stone-free rate (SFR) of any location in the urinary tract. Several studies have suggested that the repositioning of LPS in Retrograde Intrarenal Surgery (RIRS) could improve the SFR. Thus, the aim of this systematic review was to assess the efficacy of the LPS repositioning prior to lithotripsy in retrograde intrarenal surgery. A systematic search was conducted across five databases (PubMed, Scopus, Embase, Web of Science, and Scilit) to identify studies available up to August 1, 2023. Studies were included if they reported the repositioning of LPS before lithotripsy versus in-situ lithotripsy. Quality assessment was carried out using 'Cochrane Risk of Bias 2.0' and 'Newcastle Ottawa Scale' depending on the study design. Meta-analyses and meta-regression analyses were performed using random-effects models to account for between-study heterogeneity. Pooled effect estimates were expressed as odds ratios (ORs) or standardized mean differences (SMDs), together with their corresponding 95% confidence intervals (95% CIs). Pooled analysis of seven studies (n=496 patients) suggested that the repositioning LPS significantly improved SFR (7 studies; OR: 3.40; 95%CI: 1.86–6.22; p<0.001). The SFR increased from 79% (95%CI: 72–86%) to 95% (95%CI: 92–98%) when the repositioning was performed. The incidence of complications did not differ significantly between the experimental and control groups (4 studies; OR: 1.87; 95%CI: 0.90–3.30; p=0.11). Nonetheless, patients in the experimental group received longer operative time (3 studies; SMD=1.36; 95%CI: 0.3–2.42; p<0.001). Meta-regression suggested that SFR was not dependent on age, gender, stone size, and follow-up duration (all p>0.05). In conclusion, repositioning the lower pole stone before lithotripsy during RIRS yields better results than in-situ lithotripsy, despite the extended duration of the operative procedure.

Keywords: Lower pole stones, ureteroscopy, retrograde intrarenal surgery, stone-free rate, lithotripsy

Introduction

Kidney stones may present with renal colic, flank pain, hematuria, urinary tract infection, urinary obstruction, urinary retention, or hydronephrosis [1]. Individuals with this condition face an increased risk of developing chronic kidney diseases [2], end-stage renal disease [3], diabetes, hypertension, and cardiovascular diseases [4], all of which can significantly and negatively affect their quality of life. Over the past four decades, there has been a significant rise in the global

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prevalence of kidney stones, particularly in regions like Asia, Europe, and North America [5,6]. 6 This pathologic condition has been recognized as a serious challenge to global health by imposing a significant financial burden on healthcare systems [7,8].

This challenge becomes more evident when dealing with lower pole stones (LPS), which occupy for 35% of all kidney cases [9]. Kidney stones can be classified according to their anatomical location as upper-, middle-, or lower-pole stones. Among these, lower-pole stones are associated with the lowest stone-free rate (SFR). Consequently, patients may require multiple interventions and prolonged hospitalization, resulting in an increased financial burden [9]. The reduced SFR is primarily attributed to the difficulty in accessing the inferior renal calyx, which, in turn, makes it challenging to eliminate stone fragments even after stone fragmentation procedures have been performed [10].

Several treatment modalities are available for LPS, including minimally invasive retrograde intrarenal surgery (RIRS), non-invasive extracorporeal shock wave lithotripsy (ESWL), and percutaneous nephrolithotomy (PCNL), which can be performed using several variants, including mini-, ultra-mini-, micro-, and super-mini PCNL. Owing to the limited spontaneous clearance of stone fragments from the lower pole, ESWL is generally not recommended for lower pole stones, particularly when stone size exceeds 20 mm [11]. Compared with PCNL, RIRS is often preferred because it is less invasive, requires a shorter hospital stay, and is associated with fewer complications [12]. However, its SFR may be lower than that achieved with PCNL, and its overall efficacy may therefore be inferior in some cases [12].

To improve the SFR following RIRS, stones may be relocated from the lower pole to the upper or interpolar calyx before fragmentation [13,14]. This technique has been reported to increase the SFR from 74% to 95% [13,14]. However, one study reported no significant improvement in the SFR following stone relocation [15]. Given these conflicting findings, this systematic review and meta-analysis aimed to comprehensively evaluate the effectiveness of repositioning LPS during RIRS in improving the SFR.

Methods

Literature searching and selection

The literature search was conducted in PubMed, Scopus, Embase, Web of Science, and Scilit to identify studies published and indexed up to August 1, 2023. The combination of keywords is presented in **Table 1**. Eligibility criteria were defined using the PICOS framework: population (P), patients with LPS; intervention (I), stone repositioning before lithotripsy; comparator (C), in-situ lithotripsy; outcome (O), SFR; and study design (S), interventional or observational studies. Only studies published in English or Indonesian were included. Study identification, screening, and selection were reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. Records were managed and screened using Mendeley. Two reviewers (R.N. and M.A.N.) independently screened and selected the studies. Any disagreements were resolved through discussion and reassessment of the relevant articles until consensus was reached.

Table 1. Search strategy uniquely designed for each database

Database	Keywords
PubMed	(“retrograde intrarenal surgery” OR RIRS OR ureteroscopy OR ureterorenoscopy) AND ("kidney stone" OR "renal calculi" OR nephrolithiasis)
Scopus	TITLE-ABS (("retrograde intrarenal surgery" OR rirs OR ureteroscopy OR ureterorenoscopy) AND ("kidney stone" OR "renal calculi" OR nephrolithiasis))
Embase	('retrograde intrarenal surgery':ti,ab OR rirs:ti,ab OR ureteroscopy:ti,ab OR ureterorenoscopy:ti,ab) AND ('kidney stone':ti,ab OR 'renal calculi':ti,ab OR nephrolithiasis:ti,ab)
Web of science	(TI=(("retrograde intrarenal surgery" OR rirs OR ureteroscopy OR ureterorenoscopy) AND ("kidney stone" OR "renal calculi" OR nephrolithiasis))) OR AB=(("retrograde intrarenal surgery" OR rirs OR ureteroscopy OR ureterorenoscopy) AND ("kidney stone" OR "renal calculi" OR nephrolithiasis))
Scilit	[Title, Abstract, Keywords]: (“retrograde intrarenal surgery” OR RIRS OR ureteroscopy OR ureterorenoscopy) AND ("kidney stone" OR "renal calculi" OR nephrolithiasis)

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Data extraction

Two reviewers (R.N. and M.A.N.) independently extracted data from the included studies using a standardized data-extraction form. The extracted information included the first author, year of publication, country, study design, sample size, participant demographics (age and sex), stone characteristics (stone size and stone density), duration of follow-up, and risk-of-bias assessment. Outcome data extracted comprised the SFR, operative time, and postoperative complications. For dichotomous outcomes, the numbers of events and total participants in each group were extracted, whereas for continuous outcomes, the mean and standard deviation (SD) were recorded. When continuous data were reported as medians with ranges or interquartile ranges, they were converted to estimated means and SDs using a previously published method [17]. Any discrepancies between the reviewers were resolved through discussion and re-examination of the original articles until consensus was reached.

Quality appraisal

The risk of bias in randomized controlled trials (RCTs) was assessed using the revised Cochrane Risk of Bias tool (RoB 2), which evaluates five domains: bias arising from the randomization process, bias due to deviations from the intended interventions, bias due to missing outcome data, bias in outcome measurement, and bias in the selection of the reported result [18]. Each domain and the overall risk of bias were classified as low risk, some concerns, or high risk.

Observational studies were assessed using the Newcastle–Ottawa Scale (NOS) or an appropriately modified version, as applicable to the study design. The NOS evaluates study quality across three domains: selection of participants, comparability of study groups, and ascertainment of the outcome. Three reviewers (T.F.D., M.A., and R.N.) independently performed the assessments. Any disagreements were resolved through discussion and reassessment of the relevant study until consensus was reached.

Quantitative data analysis

Statistical analyses were performed using Review Manager version 5.4.1 (The Cochrane Collaboration, Copenhagen, Denmark), jamovi version 2.3.21 (The jamovi project, Sydney, Australia), and Comprehensive Meta-Analysis version 3 (Biostat, Inc., Englewood, NJ, USA). Dichotomous outcomes were summarized as pooled odds ratios (ORs), whereas continuous outcomes were summarized as standardized mean differences (SMDs), with corresponding 95% confidence intervals (CIs). Random-effects models were used for the primary meta-analyses to account for anticipated between-study heterogeneity, with the DerSimonian–Laird method used to estimate the between-study variance. For pooled proportions of stone-free outcomes, the Freeman–Tukey double-arcsine transformation was applied, and the resulting estimates were back-transformed to the original proportion scale. A two-sided p-value of <0.05 was considered statistically significant for pooled effect estimates and meta-regression analyses.

Statistical heterogeneity was assessed using Cochran's Q test and quantified using the I^2 statistic. Heterogeneity was considered substantial when I^2 was ≥50%, whereas a Q-test p-value of <0.10 was considered indicative of statistically significant heterogeneity [18]. Sensitivity analysis was performed by excluding studies judged to have a high risk of bias. Random-effects meta-regression analyses were conducted to examine whether age, male-to-female ratio, stone size, and follow-up duration moderated the treatment effect. Publication bias was assessed visually using funnel plots when at least 10 studies were available for an outcome.

Results

Selected studies and their characteristics

A total of 7,412 records were identified through the database searches, of which 3,090 duplicates were removed. After title and abstract screening, 4,293 records were excluded, leaving 29 reports for full-text assessment. Of these, 18 were excluded because they were irrelevant to the review question, two lacked a control group, and two were review articles. Consequently, seven studies were included in both the qualitative and quantitative syntheses. The study-selection process is presented in the PRISMA flow diagram (**Figure 1**).

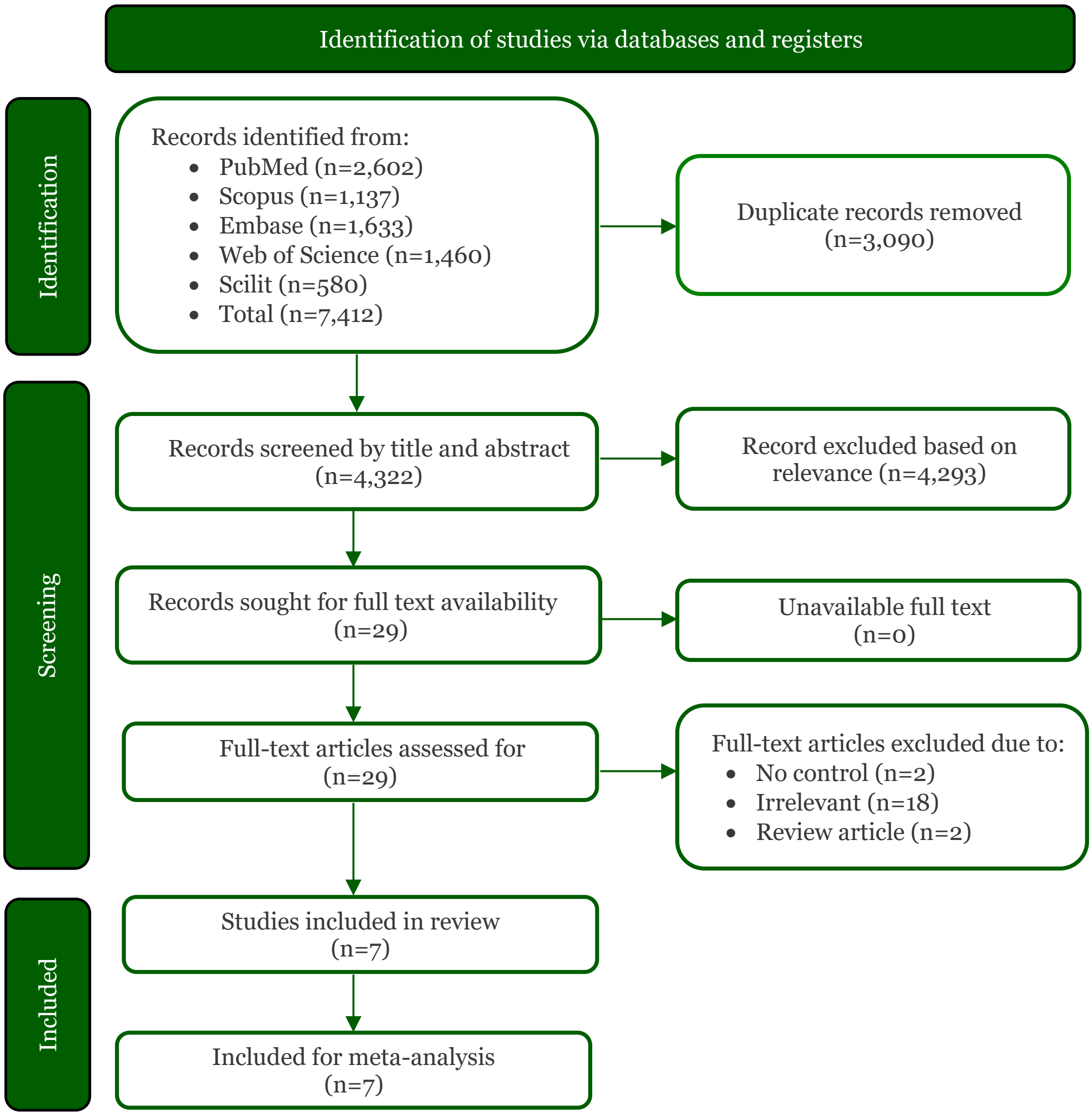

Figure 1. PRISMA flow diagram for the screening and selection process.

Characteristics of included studies

Characteristics of the seven included studies are presented in **Table 2**. The studies were reported from the USA [14,19-22], Nepal [15], and Turkey [23]. Five studies were randomized control trials [14,21-24] and two studies were cohort [19,20]. The total number of participants was 496, with 224 in the displacement group and 272 in the control group. Among these studies, the average age of participants ranged from 32.88 to 62.2 years and had stone size <20 mm located in the lower pole. Three studies followed up the SFR in the one-month post-operative [14,21,22], one study in two months [19], two studies in three months [20,24], and one study did not report the follow-up time [23].

Quality of included studies

The quality assessment indicated that the majority of both RCTs and cohort studies had a low risk of bias, with the exception of two studies [22,23]. According to the RoB 2.0 criteria, three studies were deemed to have a low risk of bias across all domains [14,21,24]. However, two studies were identified as having a high risk of bias, mainly due to concerns in various domains, such as deviations from the intended intervention, missing outcome data, and selective reporting [22,23]. The NOS quality assessment also confirmed the high quality of the two cohort studies that were included in the analysis [19,20]. The detail version of the quality assessment has been presented in **Figure 2** and **Table 3**.

Table 2. Characteristics of the included study

Author, years	Country	Study design	Study characteristics			Risk of bias
			Variables	Experimental	Control	
Yaghoubian *et al.*, 2023 [14]	USA	RCT	n	62	62	Low risk
			Age (y.o)	57.07±2.79	58±4.73	
			M/F	39/30	30/39	
			Stone size (mm)	5.82±0.49	5.5±0.42	
			Stone density (HU)	928.58± 126.02	869.71± 131.94	
			Follow up	1 Month	1 Month	
Shrestha *et al.*, 2023 [24]	Nepal	RCT	n	33	35	Low risk
			Age (y.o)	42±13.3	32.88±12.03	
			M/F	26/7	22/13	
			Stone size (mm)	11.98±3.18	11.74±3.12	
			Stone density (HU)	1102.97± 279.04	966.42±326.23	
			Follow up	3 Months	3 Months	
Schuster *et al.*, 2002 [19]	USA	Cohort	n	19	59	Low risk
			Age (y.o)	53.2	46.6	
			M/F	12/7	32/27	
			Stone size (mm)	10.3	8	
			Stone density (HU)	NR	NR	
			Follow up	2 Months	2 Months	
Kourambas *et al.*, 2000 [20]	USA	Cohort	n	10	26	Low risk
			Age	43.6	43.6	
			M/F	24/12	24/12	
			Stone size (mm)	7	7	
			Stone density (HU)	NR	NR	
			Follow up	3 Months	3 Months	
Gallante *et al.*, 2020 [21]	USA	RCT	n	39	29	Low risk
			Age (y.o)	62.2± 3.26	57± 5.92	
			M/F	17/22	8/21	
			Stone size (mm)	13.4± 2.32	10.36± 1.23	
			Stone density (HU)	NR	NR	
			Follow up	1 Month	1 Month	
Gallante *et al.*, 2019 [22]	USA	RCT	n	32	28	High risk
			Age (y.o)	59.06±11.7	54.54±18.3	
			M/F	17/15	8/20	
			Stone size (mm)	14.2	14.61	
			Stone density (HU)	NR	NR	
			Follow up	1 Month	1 Month	
Sarica *et al.*, 2011 [23]	Turkey	RCT	n	29	33	High risk
			Age (y.o)	NR	NR	
			M/F	NR	NR	
			Stone size (mm)	NR	NR	
			Stone density (HU)	NR	NR	
			Follow up	NR	NR	

HU: hounsfield unit; M/F: male/female; NR: not reported; RCT: randomized controlled trials

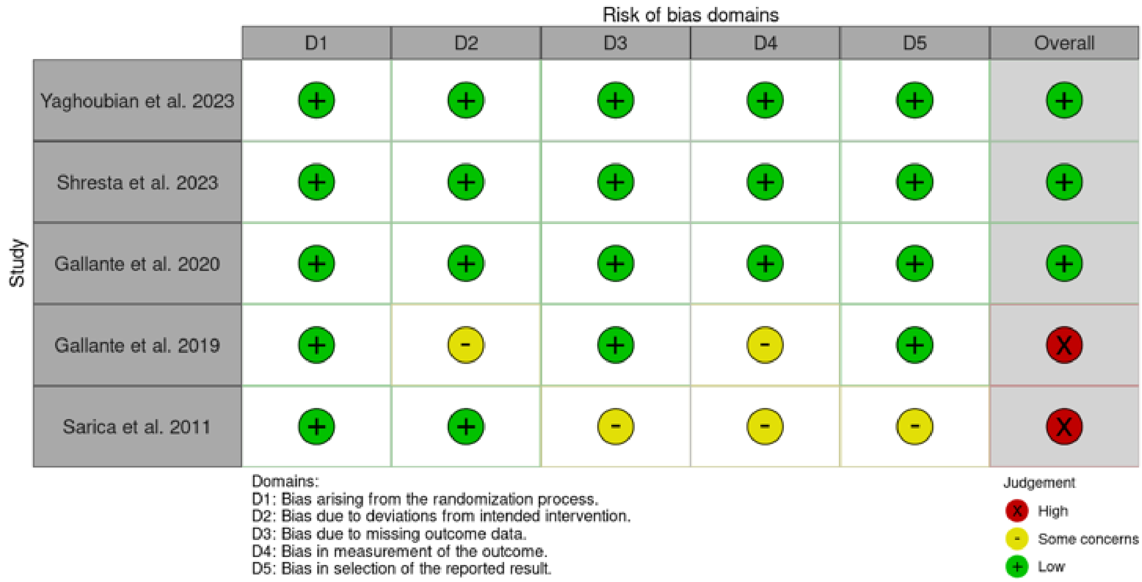

Figure 2. Traffic plot risk of bias of included RCT.

Table 3. The result of the Newcastle-Ottawa Scale in cohort studies

Author, year	Selection of cohorts				Comparability of cohorts	Outcome			Total score
	A	B	C	D	E	F	G	H	
Kourambas *et al.*, 2002 [20]	☆	☆	☆	☆	☆	☆	☆	☆	8
Schuster *et al.*, 2002 [19]	☆	☆	☆	☆	☆	☆	☆	☆	8

A: representativeness of the exposed cohort; B: selection of the non-exposed cohort; C: ascertainment of exposure; D: demonstration that outcome of interest was not present at start of study; E: comparability of cohorts on the basis of the design or analysis; F: assessment of outcome; G: was follow up long enough for outcomes to occur; H: adequacy of follow up of cohort.

Effects of stone repositioning on stone-free rate

The pooled analysis showed that stone repositioning before fragmentation was associated with a significantly higher SFR than in situ lithotripsy (OR: 3.40; 95%CI: 1.86–6.22; p<0.001). No statistical heterogeneity was observed across the included studies (I^2=0%; Cochran's Q p=0.74) (**Figure 3**). After excluding two studies judged to have a high risk of bias, the association remained statistically significant and the pooled effect estimate increased slightly to OR:3.87 (95%CI: 1.99–7.53) (**Figure 4**). The pooled stone-free proportions were 95% (95%CI: 92–98%) in the stone-repositioning group and 79% (95%CI: 72–86%) in the in-situ lithotripsy group (**Figure 5**).

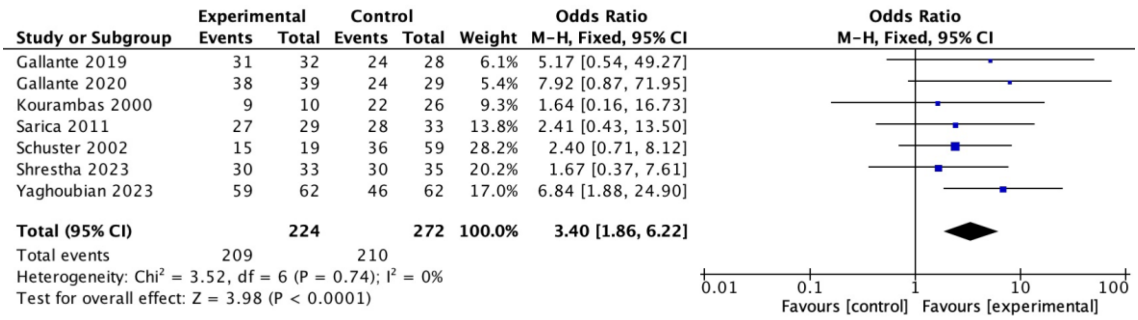

Figure 3. Forest plot comparing the stone-free rate between stone repositioning before fragmentation and in situ lithotripsy across all included studies.

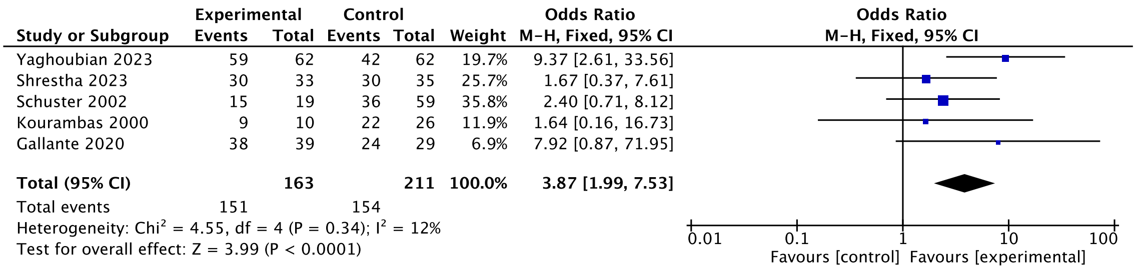

Figure 4. Forest plot comparing the stone-free rate after excluding studies judged to have a high risk of bias.

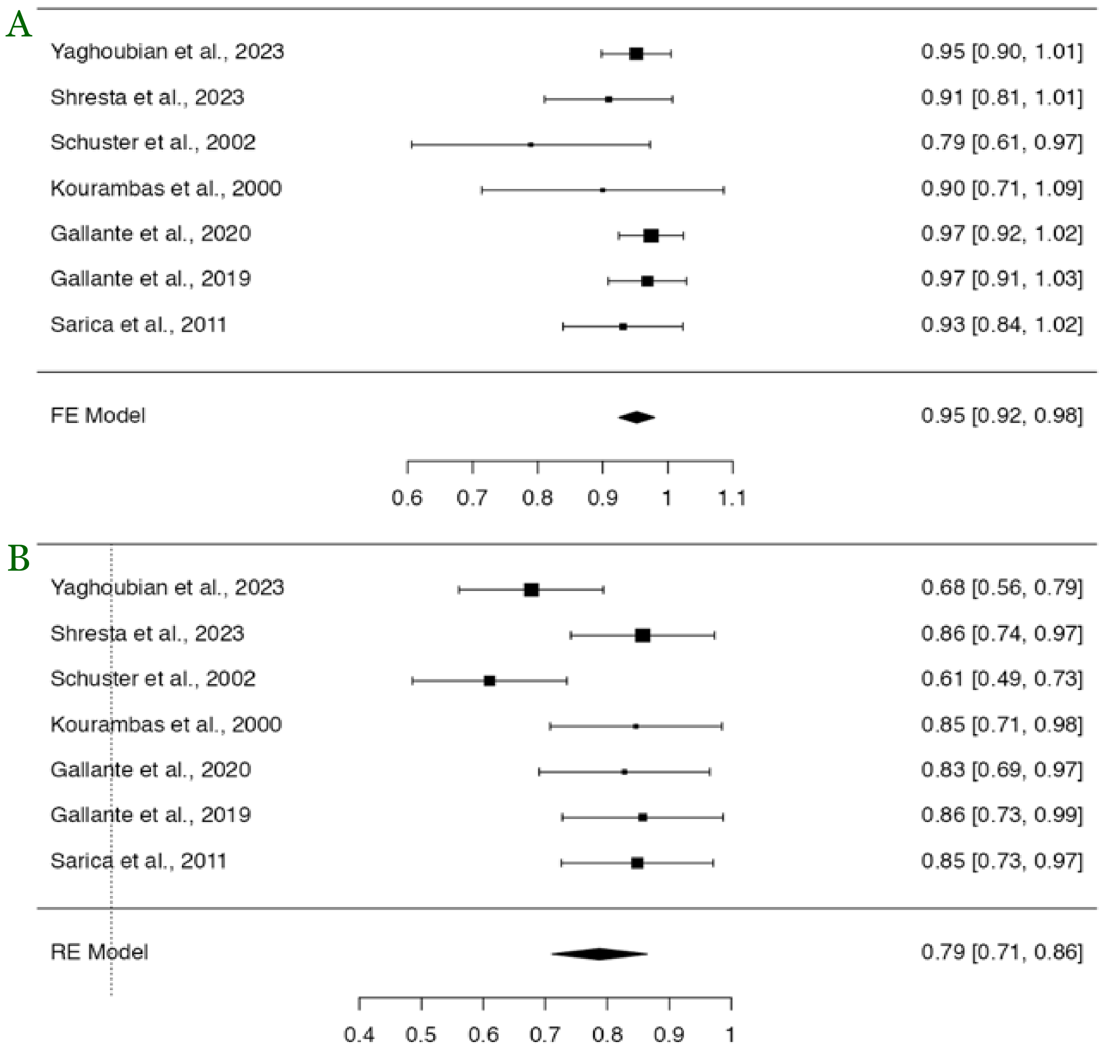

Figure 5. Forest plot proportion of stone free rate in experimental group (A) and control group (B).

Effects of stone repositioning on operative time

The pooled comparison of operative time between lithotripsy with prior stone repositioning and in situ lithotripsy is presented in **Figure 6**. Stone repositioning before fragmentation was associated with a significantly longer operative time than in situ lithotripsy (SMD=1.36; 95%CI: 0.30–2.42; p=0.01). However, the heterogeneity was high (I^2=93%, p<0.001), indicating the operative time was different in each study. The two remaining studies, which could not be included in the meta-analysis because of incomplete outcome data, also reported longer operative times in the stone-repositioning group than in the in-situ lithotripsy group.

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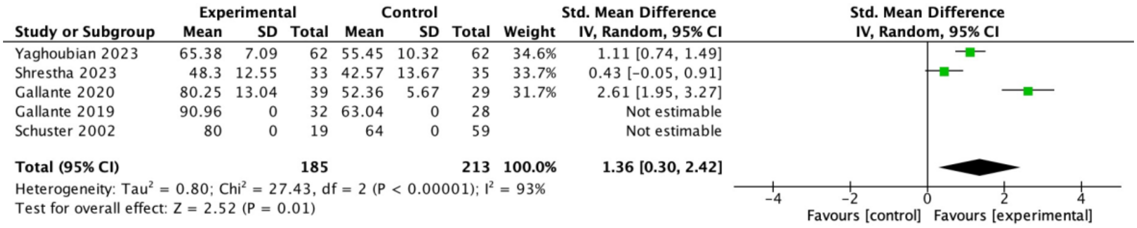

Figure 6. Forest plot comparing operative time between stone repositioning before fragmentation and in situ lithotripsy.

Complications

Four studies reported complications; however, one study (Kourambas *et al.* [20]) reported no complications in either group and was therefore not included in the pooled analysis because the treatment effect was not estimable. The pooled analysis showed no statistically significant difference in complication rates between stone repositioning and in situ lithotripsy (OR: 1.87; 95%CI: 0.87–3.98) (**Figure 7**). The complications reported in the remaining studies were predominantly Clavien–Dindo grade I–II events, including fever, flank pain, and urinary retention, with no significant between-group differences.

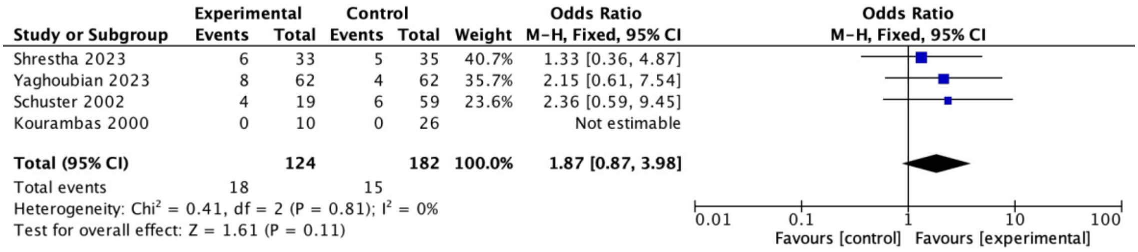

Figure 7. Forest plot comparing complication rates between stone repositioning before fragmentation and in situ lithotripsy. Kourambas *et al.* [20] reported zero complications in both groups; therefore, the study-specific effect estimate was not estimable and was excluded from the pooled odds ratio.

Meta-regression

The results of meta-regression analyses performed to examine the moderator effect of age, male-to-female ratio, stone size, and follow-up duration are presented in **Figure 8**. None of these study-level characteristics was significantly associated with the treatment effect (all $p>0.05$).

Publication bias

Publication bias was not assessed because fewer than 10 studies were available for the primary outcome. Visual inspection of funnel plots and formal statistical tests for publication bias are considered unreliable when the number of included studies is small; therefore, no publication bias analysis was performed.

Discussion

This is the first meta-analysis comparing stone repositioning before fragmentation with in-situ lithotripsy for lower-pole stones. The findings demonstrate that stone repositioning during retrograde intrarenal surgery significantly improves the stone-free rate compared with in-situ lithotripsy. The pooled stone-free proportion in the stone-repositioning group was 95% (95% CI: 92–98%), indicating a high likelihood of complete stone clearance following the procedure. This improvement could be attributed to the potential return of residual fragments to the lower pole during in-situ procedures, leading to reduced stone-free rates [14]. Moreover, repositioning offers advantages such as enhanced visualization and stone residue retrieval, contributing to comprehensive treatment [24].

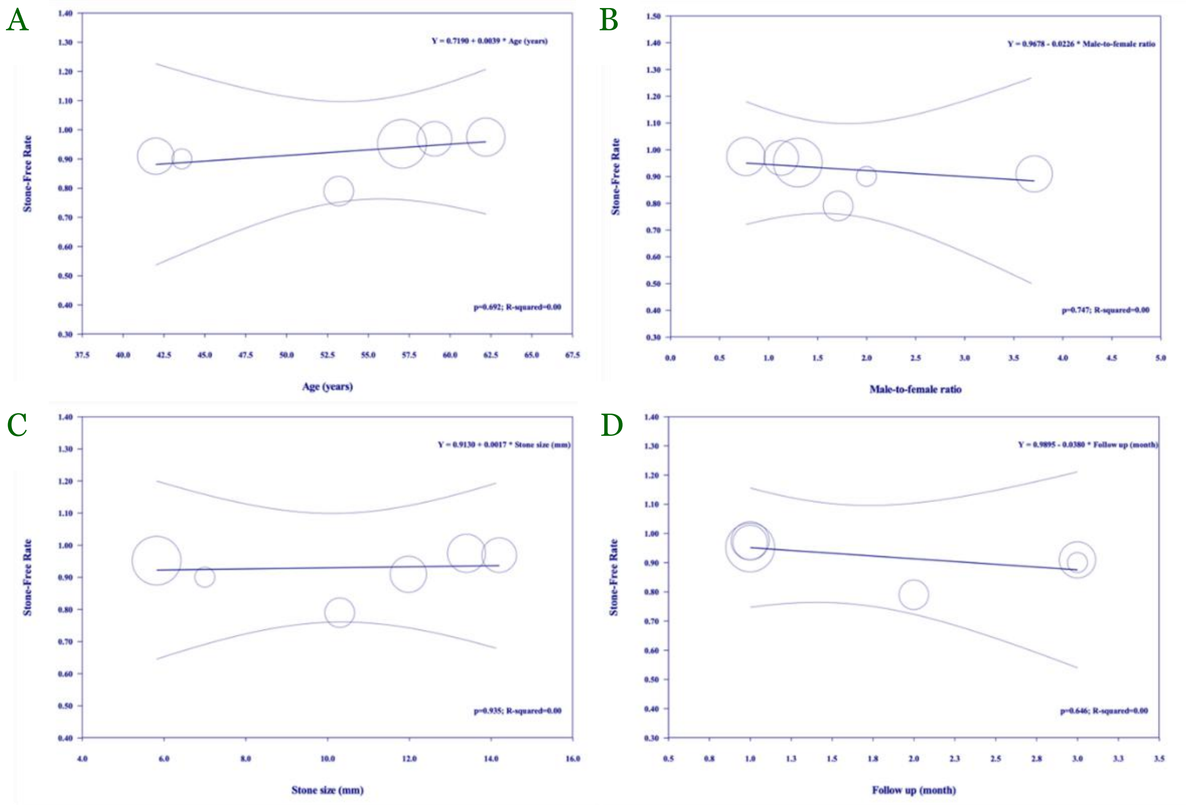

Figure 8. Bubble plot for the correlations of age (A), male-to-female ratio (B), stone size (C), follow up (D) with the efficacy of repositioning RIRS in lower pole kidney stone management, respectively.

A notable increase in operating time was observed in repositioning before lithotripsy compared to in-situ procedures. Stone size variations and the complexity of stone retrieval may influence this difference [25]. Indeed, no statistical significance in the context of complications in both groups, some complications were found during the procedures [14,19,24]. Previous reports have revealed potential complications such as fever, flank pain, urinary retention, and hospital readmission [14,19,24]. Even though the adverse event is limited to Clavien I and II which are mild and moderate complications [26], clinicians have to be careful with these possible side effects.

Previous meta-analyses have compared PCNL and RIRS as a management of lower pole stones. The result showed that PCNL has a significantly higher SFR of that than RIRS [12,27]. However, in those studies the repositioning before lithotripsy in the RIRS procedure was not performed, consequently necessitating a further investigation to evaluate and compare the efficacy and safety between RIRS with prior stone repositioning and PCNL as the most effective management of lower pole stones. With the present data on the benefits of RIRS with prior stone repositioning, the approach can be highly considered, especially when other options such as PCNL is not available due to facilities and expertise lacking. Regardless, the decision to reposition should consider stone characteristics, calyceal anatomy, surgeon experience, expected procedural complexity, and the patient's ability to tolerate a longer intervention.

Previous meta-analyses comparing PCNL and RIRS for the management of lower-pole stones have consistently shown that PCNL achieves significantly higher stone-free rates than conventional RIRS [12,27]. However, the RIRS procedures evaluated in those studies did not routinely incorporate stone repositioning before lithotripsy. Given the substantial improvement in stone-free rates observed with prior stone repositioning in the present meta-analysis, future studies should directly compare RIRS with stone repositioning and PCNL to determine their relative efficacy and safety. The current findings suggest that stone repositioning may enhance the effectiveness of RIRS and could represent a practical strategy, particularly in settings where PCNL is unavailable. Nevertheless, the decision to perform stone repositioning should be individualized, taking into account stone characteristics, calyceal anatomy, surgeon experience, procedural complexity, and the patient's ability to tolerate a longer operative time.

The main limitation of the evidence synthesis in this systematic review is the inclusion of only seven studies. The studies also varied in design, stone characteristics, operative techniques, definitions and timing of stone-free assessment, imaging methods, and follow-up duration. Two studies had a high risk of bias, although their exclusion did not materially change the primary result. Incomplete reporting restricted the operative-time and complication analyses, and publication bias could not be assessed because fewer than 10 studies were available. In addition, the meta-regression analyses were underpowered and based on study-level data, limiting conclusions about potential moderators. Future studies should adopt standardized definitions and imaging protocols for stone-free status, report operative and complication outcomes consistently, and use adequately powered prospective or randomized designs with longer follow-up. Comparative studies should also assess retreatment, recurrence, patient-reported outcomes, resource use, and cost-effectiveness to determine the broader clinical value of stone repositioning.

Conclusions

Stone repositioning before lithotripsy during RIRS was associated with a higher stone-free rate than in situ lithotripsy, with a pooled stone-free proportion of 95%. However, it is worth noting that the stone repositioning also significantly prolonged operative time. No significant difference in complication rates was observed. However, the findings should be interpreted cautiously because of the limited number of studies, methodological variability, and scarcity of real-world evidence. Further prospective and real-world studies should compare repositioning-assisted RIRS with other viable treatments for lower-pole stones, particularly PCNL and ESWL, to clarify its relative effectiveness, safety, and clinical applicability.

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None.

Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

No new data were generated in this study.

Declaration of artificial intelligence use

This study used the artificial intelligence (AI) tool ChatGPT (OpenAI, San Francisco, CA, USA) for technical writing assistance, including improvements to grammar, language, clarity, and manuscript structure. The authors read and critically reviewed all AI-assisted content to ensure the integrity and reliability of the manuscript. All final decisions, interpretations, and conclusions presented in this article were made solely by the authors.

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