Review Article

Safety and efficacy of percutaneous nephrolithotomy, retrograde intrarenal surgery, and extracorporeal shock wave lithotripsy for lower-pole renal stones: A systematic review and meta-analysis

Abdullah Barghash Alanazi, Rawan Marzooq Alsolami[1], Abdulaziz Albalawi, Abdullah Almousa, Abdullatif Alhassan[2], Mutlaq Alotaibi, Hossam S. El-Tholoth, Ahmed Alzahrani, Abdulrahman F. Alruwaily

Department of Urology, Prince Sultan Medical Military City, [2]Department of Urology, Security Forces Hospital, [1]Department of Urology, Ministry of Health, Riyadh, Saudi Arabia

Abstract

Background: Numerous therapeutic strategies have been developed as a result of the rise in the prevalence of renal stones. Extracorporeal shock wave lithotripsy (ESWL) retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) are currently available treatments for lower-pole renal stones (LPRSs). This systematic review and meta-main analysis's primary objective were to assess the requisite studies that examined the effectiveness of ESWL, RIRS, and PCNL for treating LPRS.

Materials and Methods: This study adhered to PRISMA guidelines' guiding principles. In two stages, the desired studies were extracted. In the initial screening, we identified 850 related articles from the years 2004 to 2022 using the keywords. Unfortunately, 350 studies were disqualified because they failed to meet our inclusion requirements; the remaining studies underwent additional screening. In the second stage, two authors went through the entire text of the articles and found duplicates and missing data. Ten articles were eventually selected for the research's conclusion.

Results: PCNL and RIRS had higher stone-free rates than ESWL and needed fewer treatment sessions out of the total of 10 clinical trials that were considered to be eligible. While ESWL required more ESWL sessions, operative time and complications seemed to benefit ESWL over PCNL. RIRS looked to be the most efficient technique for treating stones in the lower pole that were up to 1 cm in diameter.

Conclusion: To achieve stone-free status over a brief period of time and with the fewest number of sessions, the management of LPRS should probably be PCNL or RIRS, according to the pooled meta-analysis of the eligible trials in our systematic review. RIRS was more effective than ESWL for stones <10 mm in size. The choice between the two methods (PCNL or RIRS) should be made specifically for each patient depending on their anatomical characteristics, comorbidities, and preferences as deemed appropriate by the attending clinician.

Keywords: Extracorporeal shock wave lithotripsy, lower-pole renal stones, percutaneous nephrolithotomy, retrograde intrarenal surgery, urolithiasis

Address for correspondence: Dr. Rawan Marzooq Alsolami, Department of Urology, Ministry of Health, Riyadh, Saudi Arabia.
E-mail: rawanalsolami1@gmail.com

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INTRODUCTION

Urolithiasis, commonly known as kidney stones, is a condition characterized by the formation of hard deposits of minerals and salts in the urinary tract.[1] These stones can vary in size, shape, and composition, ranging from tiny grains to large stones that can block the urinary tract. There are several types of kidney stones, each with its own distinct composition. The most common type is calcium oxalate stones, which account for about 80% of all kidney stones. Other types include uric acid stones, struvite stones, and cystine stones.[2] The causes of urolithiasis can vary depending on the type of stone. Calcium oxalate stones are typically caused by an excess of calcium and oxalate in the urine. Uric acid stones are often caused by a diet high in purines, which can lead to an accumulation of uric acid in the urine. Struvite stones are caused by a bacterial infection in the urinary tract, whereas cystine stones are caused by a genetic disorder that affects the metabolism of amino acids. The symptoms of urolithiasis can vary depending on the size and location of the stone. Small stones may pass through the urinary tract without causing any symptoms, whereas larger stones can cause severe pain, nausea, vomiting, and difficulty urinating. In some cases, urolithiasis can lead to complications such as kidney damage, urinary tract infections, and sepsis.[3]

There are several treatment modalities available for urolithiasis, depending on the size and location of the stone. In some cases, small stones may pass through the urinary tract with the help of pain relievers and increased fluid intake.[4,5] For larger stones, however, more invasive treatments may be necessary. Extracorporeal shock wave lithotripsy (ESWL) is a noninvasive treatment that uses shock waves to break up kidney stones into smaller pieces, which can then be passed through the urinary tract. This procedure is typically done under sedation and takes about an hour to complete.[6] Another minimally invasive treatment option is ureteroscopy, which involves inserting a thin tube with a camera into the urethra and up into the urinary tract to locate and remove the stone. This procedure can also be used to break up larger stones using laser technology.[7] For larger stones that cannot be treated with ESWL or ureteroscopy, percutaneous nephrolithotomy (PCNL) may be necessary. This procedure involves making a small incision in the back and using a scope to locate and remove the stone. This procedure is typically done under general anesthesia and requires a short hospital stay.[8]

In some cases, surgical intervention may be necessary to remove the stone.[9] This may involve open surgery, in which an incision is made in the back or side to access the kidney, or laparoscopic surgery, in which small incisions are made and a camera and surgical instruments are used to remove the stone. Prevention is key when it comes to urolithiasis.[10-13] Lifestyle changes such as increasing fluid intake, reducing salt and animal protein intake, and maintaining a healthy weight can help prevent the formation of kidney stones. Certain medications can also be used to prevent the formation of stones in individuals who are at high risk.[11-14]

Urolithiasis is a common condition that can cause significant pain and discomfort. There are several treatment modalities available, ranging from noninvasive procedures such as ESWL and ureteroscopy to more invasive procedures such as PCNL and surgery. Prevention through lifestyle changes and medication can also help reduce the risk of developing kidney stones. Treatments for kidney stones have been compared in few systematic reviews. By addressing the most thorough and up-to-date data, our work builds upon the previous systematic reviews. While some research[15-17] only examined two different types of treatments, others[9,17] compared all three without taking stone size into account. To determine which approach is best for the management of lower-pole renal stone (LPRS), the current study chose studies that assessed the effectiveness of ESWL, retrograde intrarenal surgery (RIRS), and PCNL.

MATERIALS AND METHODS

Working hypotheses for the review

There were multiple working hypotheses that we devised for our review. There is no significant difference in the stone-free rates between ESWL, RIRS, and PCNL for treating LPRS. There is no significant difference in the operative time and complications between ESWL, RIRS, and PCNL for treating LPRS. There is no significant difference in the effectiveness of ESWL and RIRS for stones < 10 mm in size. There is no significant difference in the choice of treatment method (PCNL or RIRS) based on anatomical characteristics, comorbidities, and preferences of the patient.

Search strategy for review

- PubMed: (((“Percutaneous Nephrolithotomy”[Mesh]) OR (“Retrograde Intrarenal Surgery”[Mesh])) OR (“Extracorporeal Shockwave Lithotripsy”[Mesh])) AND ((“Renal Calculi”[Mesh]) OR (“Kidney Calculi”[Mesh])) AND (“Lower Pole”[Mesh] OR “Inferior Pole”[Mesh]) AND (“Safety”[Mesh] OR “Adverse Effects”[Mesh] OR “Complications”[Mesh] OR “Outcome Assessment (Health Care)”[Mesh] OR “Treatment Outcome”[Mesh] OR “Therapeutic

Effectiveness"[Mesh] OR "Efficacy"[Mesh] OR "Meta-Analysis"[Publication Type] OR "Systematic Review"[Publication Type])

- Web of Science: (TS=("percutaneous nephrolithotomy" OR "retrograde intrarenal surgery" OR "extracorporeal shock wave lithotripsy") AND TS=("renal stones" OR "renal calculi" OR "kidney stones" OR "kidney calculi") AND TS=("lower pole" OR "inferior pole") AND TS=("safety" OR "adverse effects" OR "complications" OR "outcome assessment" OR "treatment outcome" OR "therapeutic effectiveness" OR "efficacy" OR "meta-analysis" OR "systematic review"))
- Scopus: TITLE-ABS-KEY(("percutaneous nephrolithotomy" OR "retrograde intrarenal surgery" OR "extracorporeal shock wave lithotripsy") AND ("renal stones" OR "renal calculi" OR "kidney stones" OR "kidney calculi") AND ("lower pole" OR "inferior pole") AND ("safety" OR "adverse effects" OR "complications" OR "outcome assessment" OR "treatment outcome" OR "therapeutic effectiveness" OR "efficacy" OR "meta-analysis" OR "systematic review"))
- Cochrane: ("percutaneous nephrolithotomy" OR "retrograde intrarenal surgery" OR "extracorporeal shock wave lithotripsy") AND ("renal stones" OR "renal calculi" OR "kidney stones" OR "kidney calculi") AND ("lower pole" OR "inferior pole") AND ("safety" OR "adverse effects" OR "complications" OR "outcome assessment" OR "treatment outcome" OR "therapeutic effectiveness" OR "efficacy" OR "meta-analysis" OR "systematic review").

Study and data selection framework

The study selection process for our review followed the PRISMA guidelines[18] as outlined below [Figure 1], where, using the MeSH keywords, a search was conducted in PubMed, Web of Science, Scopus, and Cochrane databases for articles published between 2015 and 2022 that examined the effectiveness of ESWL, RIRS, and PCNL for treating lower-pole renal stones. In the initial screening, the titles and abstracts of the identified articles were screened to determine their relevance to the study's objective. Articles that did not meet the inclusion criteria were excluded from the study. In the second stage, two reviewers independently read the full text of the remaining articles to ensure they met the inclusion criteria. Data from the eligible studies were extracted using a standardized form, which included information on study design, patient characteristics, intervention details, outcome measures, and adverse events. A meta-analysis was conducted to pool the results of the eligible studies. The findings were visualized using forest plots, and the sources of heterogeneity were investigated using subgroup analyses. To guarantee the accuracy and validity of the study's results, several reviewers participated in the data selection process. The titles and abstracts of the identified articles were separately reviewed by two reviewers, and those that met the criteria for inclusion underwent additional review in the second stage. Discussion was used to settle any disagreements between the reviewers, and a third reviewer was contacted when no agreement could be reached. Two reviewers separately extracted the data, and any discrepancies were settled by consensus or with the assistance of a third reviewer. The study selection process and data extraction were conducted independently by two reviewers to minimize bias and improve the accuracy of the study's findings.

Inclusion criteria

Types of studies that were considered for inclusion in our study included the following:

- Studies that were reporting on PCNL, RIRS, and/or ESWL for lower-pole renal stones
- Studies that were reporting on safety and/or efficacy outcomes such as stone clearance rate, complication rate, or length of hospital stay
- Studies published in the English language.

Exclusion criteria

Following articles were considered to be unsuitable for further consideration with respect to our study:

- Case reports, letters, and editorials
- Studies reporting on upper-pole or mid-pole renal stones
- Studies reporting on other treatments for lower-pole renal stones such as ureteroscopy or open surgery
- Studies with abysmally low sample size
- Studies with follow-up duration < 3 months
- Studies with inadequate reporting of outcomes or methodology.

Risk of bias assessment

The Cochrane Collaboration tool [Figure 2] for assessing the risk of bias was used in our systematic review, which aims to make the process clearer and more accurate when it comes to assessing the risk of bias in systematic reviews that include randomized/nonrandomized control trials.[19]

RESULTS

All of the recruited articles were randomized controlled trials (RCTs) either being prospective or being retrospective. The region of these recruited studies was Korea, Turkey,

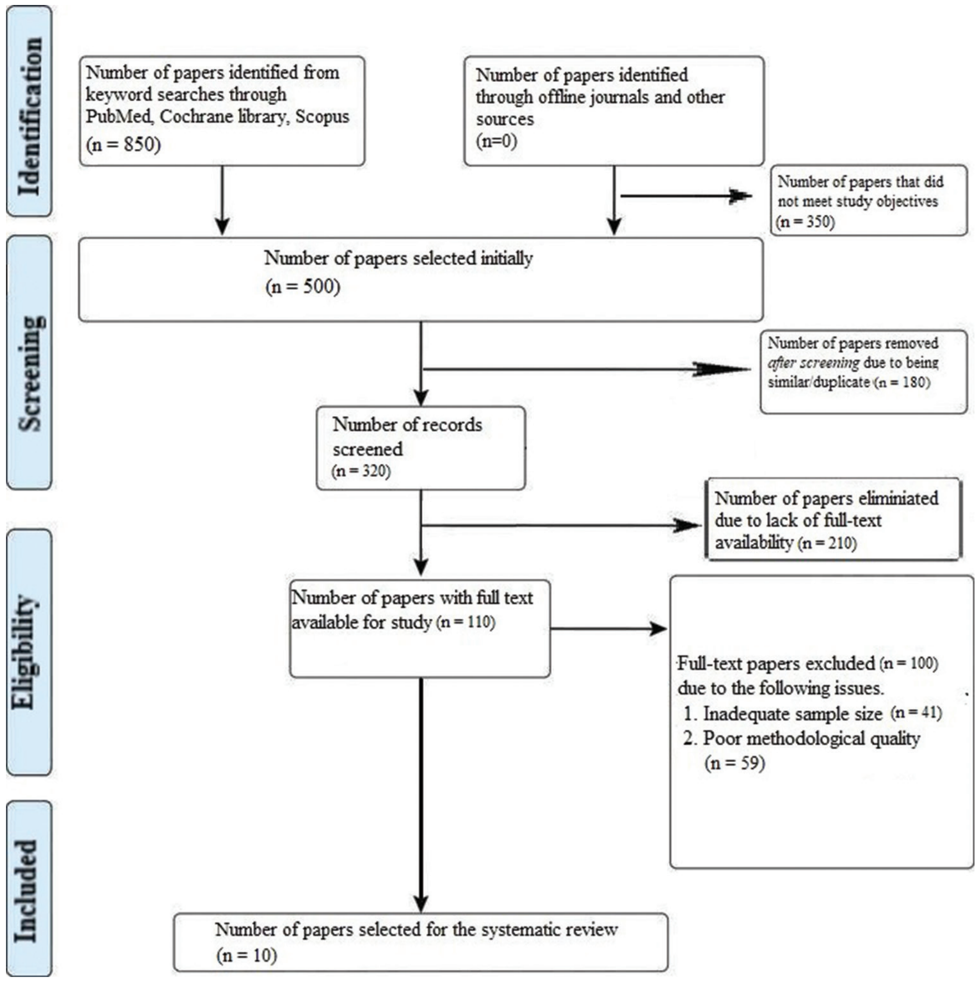

Figure 1: PRISMA checklist representing selection of articles for this systematic review

Iran, Egypt, and China. Two RCTs compared ESWL and RIRS, whereas two compared ESWL with PNCL. For the meta-analysis, the standardized mean difference was the medium for comparing the surgical time, pain score, and length of hospital stay. The size of the stone ranges from 10 mm to 2 cm. Only one study recruited a pediatric population, whereas all studies chose an adult population for comparison. The mean age of patients ranges from 13.85 to 60.02 years. The follow-up duration ranges from 6 weeks to 3 months. We mentioned all demographic details including region, study type, follow-up duration, population size, patient age, inclusion criteria, stone-free rate, and complications are shown in Table 1. Meta-analysis was drawn using the Hedge's test, whereas the heterogeneity test was performed using I^2.

The study by Lee revealed similar outcomes of surgery time, hemoglobin decline, and hospital stay. However, they observed that RIRS cases required more analgesia and reported high pain scores than the PNCL group. In a study by Javanmard *et al.*, the single-session stone-free rate was higher in the RIRS group than in shock wave lithotripsy (SWL) (90% vs. 75%). They also revealed fewer pain scores in the RIRS group than in SWL with a statistically significant difference of 0.001 (5.2 ± 2.8 vs. 3.1 ± 2.7). However, the SWL group reported fewer postoperative hospital stays than RIRS (6.7 ± 1.3 vs. 18.9 ± 4.3 h). Atis's study reported a mean stone size of 28.39 ± 4.67 in the PCNL group and 25.08 ± 6.07 mm in the RIRS group. Prolonged surgery time was reported in the RIRS group, wheras the PCNL group reported high fluoroscopy times, hospitalization times, and pain scores. Therefore, their study was in favor of the RIRS method. In the study of Demirbas *et al.*, the pain score was observed as 4.73 ± 1.25 in the PNCL group higher than the studies of Lee *et al.*, Zeng *et al.,* and Gucuk *et al.* All these studies used visual analog pain scale, whereas the study of Oktay *et al.* used SF-36 scale for measuring the pain.

Stone-free rate

All studies reported the stone-free rate (SFR). We observed that studies comparing mini PCNL and

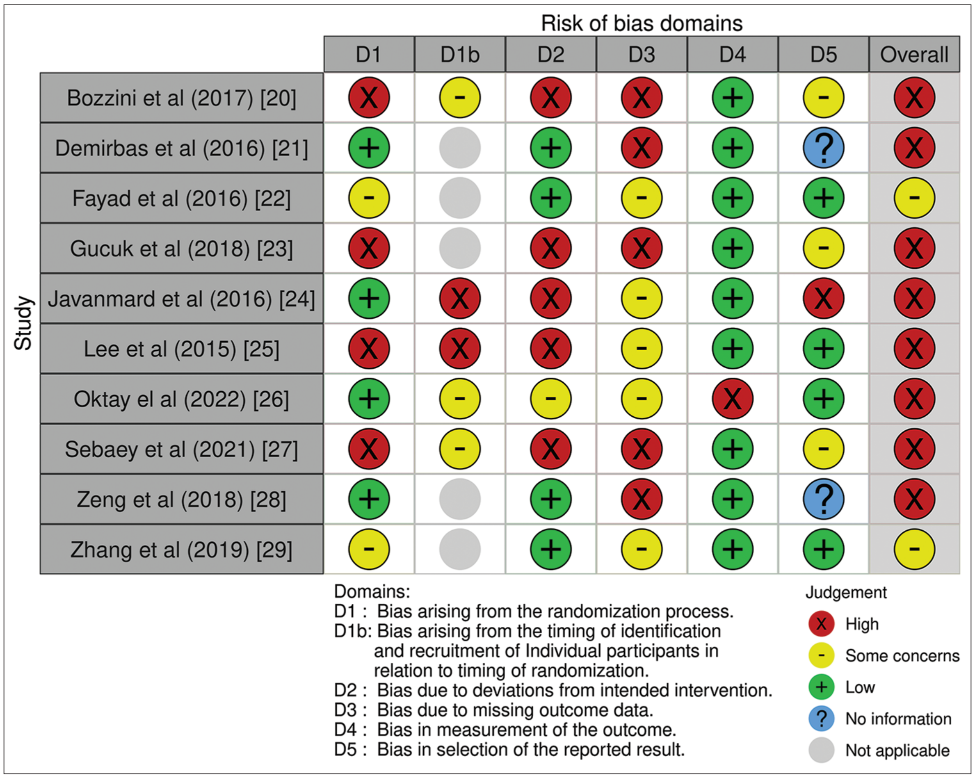

Figure 2: Cochrane's risk of bias tool

RIRS (odd ratio [OR] =0.19; 95% 0.12; 0.27) technique has better outcomes in terms of SFR than PCNL versus RIRS (OR = 0.14, 95% 0.08; 0.20) and ESWL versus RIRS had better results than other subgroups (OR = 0.22, 95% 0.05; 0.08). Egger regression test was performed for publication bias. We observed P value of linear regression test >0.05 (P = 0.6921) (test result: t = 0.40, df = 19, P = 0.6921).

Complications rate

Meanwhile, seven studies reported the complications according to the Clavien classification. We observed that studies comparing mini PCNL and RIRS (OR = 0.30; 95% 0.04; 0.52) technique reported more complications than PCNL versus RIRS (OR = 0.29, 95% 0.09; 0.47).

Surgical time

Figure 2 presents the forest plot of surgical duration obtained through the meta-analysis. The pooled P value of surgical duration was observed as <0.01 when comparing the PNCL versus RIRS, while the pooled P value in ESWL versus RIRS was observed as < 0.01. These pooled P values were greater than the significant P = 0.05 showing significant differences between subgroups; however, ingroup pooled prevalence shows nonsignificant differences when comparing PNCL versus RIRS and RIRS versus ESWL (0.34 vs. 0.27). The 95% CI and the pooled surgical duration of Lee *et al.*, Fayad *et al.*, Gucuk *et al.*, and Oktay *et al.* overlaps with the line of null effect, therefore, favoring the PCNL treatment, whereas the overall results favor the RIRS treatment. Furthermore, while comparing ESWL versus RIRS and PNCL versus ESWL both favors the ESWL treatment; however, we cannot conclude from this result due to limited RCT studies were conducted on the ESWL method. The study of Bozzini *et al.* and Zeng *et al.* carried the most weight (19.4% vs. 19%) in a subgroup of PNCL versus RIRS. The heterogeneity of this category was observed to be 99% showing many variations (OR; 0.65 at 95% confidence interval [CI] 0.51–0.79). No significant bias was reported among studies (Egger linear regression test P = 0.244.

Postoperative pain

Figure 3 presents the forest plot of pooled pain score through the fixed effect model. Overall 6 studies compared the postoperative pain. The pooled P value of surgical duration was observed as 0.001 when comparing the PNCL versus RIRS, whereas the pooled P value in ESWL versus RIRS was observed as 0.0004. These pooled P values were greater than the significant P value of 0.05 showing significant differences between subgroups, however, ingroup pooled prevalence shows nonsignificant differences when comparing PNCL versus RIRS and RIRS versus ESWL (0.33 vs. 0.29) The 95% CI and the pooled

Table 1: Demographic characteristics, study descriptions, and design of the investigations selected for our systematic review

Author (year)	Study design	Region	Intervention	Follow-up	Number of patients	Mean age (years)	Inclusion criteria	Definition of stone-free	SFR	Complications	
										Clavien I–II	Clavien III–IV
Bozzini *et al.* (2017)[20]	Prospective randomized controlled trial	Italy	SWL versus RIRS versus PCNL	3 months	194 SWL, 207 RIRS, 181 PCNL	SWL: 13.8±3.1, RIRS: 14.8±2.7, PCNL: 15.2±2.3	Lower pole stone ≤20 mm	No residual stone Asymptomatic stone fragments ≤3 mm	SWL: 119 (61.8%), RIRS: 170 (82.1%), PCNL: 159 (87.3%)	SWL: 6, RIRS: 25, PCNL: 31	0
Demirbas *et al.* (2016)[21]	Randomized controlled trial	Turkey	PCNL versus RIRS	Not mentioned	30 PCNL, 43 RIRS	PCNL: 43.7±14.6, RIRS: 48.7±16.8	Renal stones 10–25 mm	Complete removal or ≤3 mm in low-dose noncontrast CT after 1 month	PCNL: 28 (93.3%), RIRS: 18 (42.9%)	PCNL: 2, RIRS: 3	PCNL: 5, RIRS: 3
Fayad *et al.* (2016)[22]	Prospective randomized controlled trial	Egypt	PCNL versus RIRS	3 months	60 RIRS, 60 mPCNL (16-Fr)	RIRS: 37.7±9.8, mPCNL: 37.2±9.2	Lower pole stone ≤20 mm	Stone fragments ≤2 mm	RIRS: 50 (84.3%), mPCNL: 58 (97.7%)	PCNL: 2, RIRS: 3	0
Gucuk *et al.* (2019)[23]	Prospective randomized controlled trial	Turkey	PNL versus RIRS	3 months	30 PNL, 30 RIRS	PNL: 46.1±17.5, RIRS: 46.6±13.5	Renal stone up to 2 cm	No stone	PNL: 86.7%, RIRS: 83.3%	PCNL: 12, RIRS: 7	0 RIRS: 1
Javanmard *et al.* (2016)[24]	Prospective randomized controlled trial	Iran	RIRS versus ESWL	3 months	60 RIRS, 60 ESWL	RIRS: 32.4±7.8, ESWL: 31.3±6.5	0.6–2 cm	Residual stone fragments ≤3 mm	RIRS: 52 (86.7%), ESWL: 45 (75%)	ESWL: 13, RIRS: 5	ESWL: 5, RIRS: 0
Lee *et al.* (2015)[25]	Prospective randomized controlled trial	Korea	mPCNL versus RIRS	3 months	35 mPCNL, 33 RIRS	Not mentioned	>1-cm renal stone	Removal upto <2 mm	mPCNL: 30 (85.7%), RIRS: 32 (97%)	Not mentioned	Not mentioned
Ucer *et al.* (2022)[26]	Prospective controlled trial	Turkey	PCNL versus RIRS	3 months	52 RIRS, 50 PNCL	PNL: 46.23±14.19, RIRS: 50.35±14.56	Renal pelvis stone (2–4 cm)	Evidence of stone fragments or the presence of nonsymptomatic residual fragments <3 mm on CT	PNL: 95.5%, RIRS: 80.6%	NR	NR
Sebaey *et al.* (2022)[27]	Prospective randomized controlled trial	Egypt	mPCNL versus RIRS	Not mentioned	35 mPCNL, 35 RIRS	mPCNL: 36.11±11.91, RIRS: 34.0±10.69	Renal stone 20–30 mm	Stone-free or clinically insignificant residual fragments <4 mm on CT	mPCNL: 31 (88.6%), RIRS: 29 (82.9%)	NR	NR
Zeng *et al.* (2018)[28]	Prospective randomized controlled trial	China	RIRS versus mPCNL (14 Fr)	3 months	76 RIRS 77 mPCNL (14 Fr)	RIRS: 47.1±13.9, mPCNL (14 Fr): 49.4±12.8	10≤ lower pole stone ≤20 mm	Stone fragment <3 mm	RIRS: 64 (80%), mPCNL (14 Fr): 64 (80%)	PCNL: 11, RIRS: 13	0
Zhang *et al.* (2019)[29]	Prospective randomized controlled trial	China	Ultra-mPCNL (13 Fr) versus SWL	Not mentioned	72 PCNL, 66 SWL	PCNL: 48.9±11.1, RIRS: 50.1±11.9, SWL: 50.5±12.6	LPRS 10–20 mm	Complete removal or ≤3 mm in low-dose noncontrast CT after 1 month	PCNL: 69 (95.5%), RIRS: 80.6%, SWL: 48 (73%)	PCNL: 7, RIRS: 5, SWL: 3	PCNL: 3, RIRS: 1, SWL: 1

SWL: Shock wave lithotripsy, RIRS: Retrograde intrarenal surgery, PCNL: Percutaneous nephrolithotomy, CT: Computed tomography, ESWL: Extracorporeal SWL, mPCNL: Mini PCNL, LPRS: Lower-pole renal stones, SFR: Stone-free rate, NR: Not Reported, PNL: Percutaneous Nephrolithotomy postoperative pain of Lee *et al*. overlaps with the line of null effect, therefore, favoring the PCNL treatment, whereas the overall results favor the RIRS treatment. The study of Oktay *et al*. and Zeng *et al*. carried the most weight (21.1% vs. 31.3%) in a subgroup of PNCL versus RIRS. The heterogeneity of this category was observed to be 91% showing many variations (OR; 0.19 at 95% CI 0.01–0.37). No significant bias was reported among studies (Egger linear regression test $P = 0.77$.

Hospital stay

Figure 4 presents the forest plot of length of hospital stay obtained through the meta-analysis. The pooled P value of surgical duration was observed as 0.0002 when comparing the PNCL versus RIRS, whereas the pooled P value in ESWL versus RIRS was observed as 0.003. These pooled P values were greater than the significant $P = 0.05$ showing significant differences between subgroups. We also observed significant difference in length of hospital stay in intragroup comparison of PNCL versus RIRS and RIRS versus ESWL (0.02 vs. 0.06). The 95% CI and the pooled surgical duration of all studies show less hospital stay after RIRS treatment by not crossing the line of null hypothesis. Less duration of hospital stay was also reported when comparing the ESWL with RIRS but our meta-analysis failed to conclude the results of ESWL due to limited RCTs. We observed 98% heterogeneity in this category with insignificant publication bias (0.822) [Figure 5].

DISCUSSION

The significance of this study is that it provides a comprehensive and evidence-based analysis of the effectiveness of three different methods for treating lower-pole renal stones. By conducting a systematic review and meta-analysis of RCTs, the study was able to identify which treatment methods were most effective at achieving stone-free status over a brief period of time and with the fewest number of sessions. The study's findings have important implications for clinical practice, as they suggest that PCNL and RIRS are superior to ESWL in terms of stone-free rates and the need for re-treatment sessions, whereas ESWL may be preferable in terms of operative time and complications. The study also highlights the importance of considering individual patient characteristics and preferences when making treatment decisions, which can help improve patient outcomes and satisfaction. Overall, this study provides valuable insights into the optimal management of lower-pole renal stones

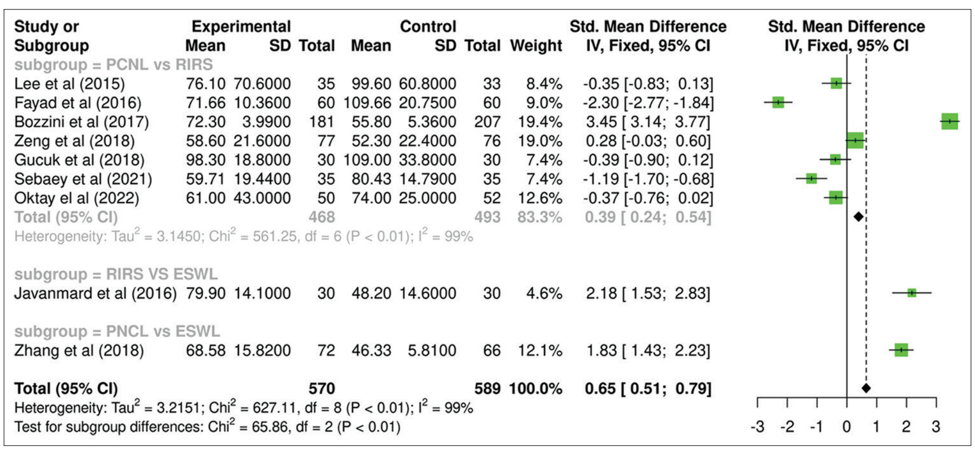

Figure 3: Forest plot of surgical duration in the clinical trials selected for our investigation

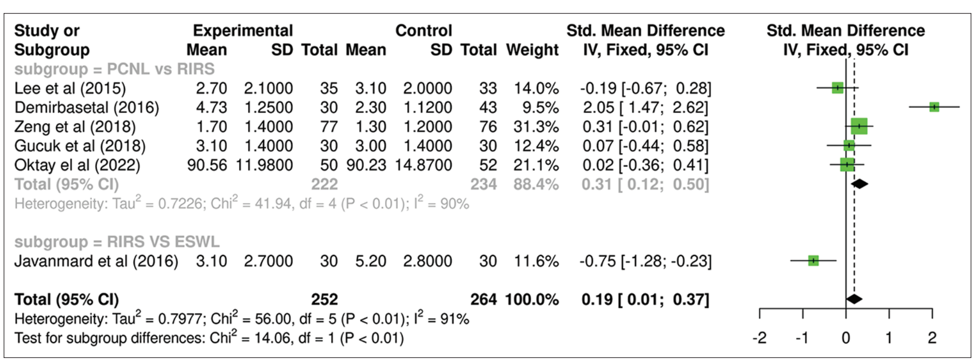

Figure 4: Forest plot of postoperative pain as observed in the clinical trials selected for our investigation

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Fixed, 95% CI
subgroup = PCNL vs RIRS								
Lee et al (2015)	1.60	1.1000	35	1.50	0.9000	33	10.4%	0.10 [-0.38; 0.57]
Demirbasetal (2016)	2.46	3.0200	30	1.37	1.4800	43	10.5%	0.48 [0.01; 0.95]
Bozzini et al (2017)	3.70	1.1000	181	1.30	0.3300	207	27.5%	3.04 [2.74; 3.33]
Zeng et al (2018)	2.50	1.1000	77	2.20	1.1000	76	23.3%	0.27 [-0.05; 0.59]
Gucuk et al (2018)	2.10	2.0300	30	1.60	1.3400	30	9.1%	0.29 [-0.22; 0.80]
Sebaey et al (2021)	1.41	0.4600	35	1.29	0.4400	35	10.6%	0.26 [-0.21; 0.73]
Total (95% CI)			388			424	91.4%	1.11 [0.95; 1.27]
Heterogeneity: $Tau^2 = 1.2730$; $Chi^2 = 239.28$, df = 5 ($P < 0.01$); $I^2 = 98\%$								
subgroup = RIRS VS ESWL								
Javanmard et al (2016)	18.90	4.3000	30	6.70	1.3000	30	3.2%	3.79 [2.93; 4.65]
subgroup = PNCL vs ESWL								
Zhang et al (2018)	5.32	1.2000	72	1.08	0.2800	66	5.4%	4.75 [4.09; 5.40]
Total (95% CI)			**490**			**520**	**100.0%**	**1.39 [1.24; 1.54]**
Heterogeneity: $Tau^2 = 3.5247$; $Chi^2 = 380.60$, df = 7 ($P < 0.01$); $I^2 = 98\%$								
Test for subgroup differences: $Chi^2 = 141.32$, df = 2 ($P < 0.01$)								

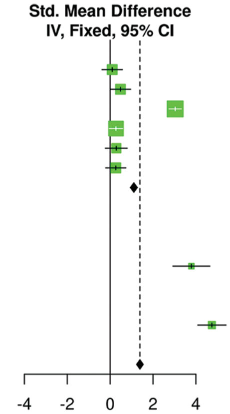

Figure 5: Forest plot of length of hospital stay as observed in the clinical trials selected for our investigation

and can help guide clinical practice and future research in this area.

Pooled analysis of the SFRs of the ESWL, RIRS, and PCNL was provided by a previous well-conducted meta-analysis on the same subject. Recent high-quality studies added to the body of knowledge and provided the context for a current meta-analysis that clarifies various facets of the effectiveness of the aforementioned treatments for LPRS.[20-29]

The present study found that RIRS and PCNL had higher SFRs than ESWL. Despite PCNL having higher SFRs in three of the four studies, there was no obvious distinction between PCNL and RIRS's SFRs at the same period. Care should be taken when interpreting the SFR results. A precise definition of SFR was offered by each of the 10 studies. In 7 of the 10 studies that we chose for our review, the follow-up period was 3 months.[20,22-26,28] To achieve stone-free status during this follow-up period, additional sessions of each procedure may be conducted. The re-treatment rates illustrated these occurrences.

Several trials[20,21,23] chose and enrolled patients who met the favorable anatomical criteria for the different approaches and ESWL. Based on the evidence that is presently available regarding the influence of anatomy on the outcome of SWL, cases with various variations of abnormalities as shown by contrast-enhanced computerized tomography were also excluded from a study on a similar topic.[20] This comprehensive research provided comparison data for all three methods, but the conclusions were drawn based on a small sample of circumstances where ESWL and RIRS might function most effectively. In another study, a lower calyceal architecture that was unfavorable was used as an exclusion factor.[30] In their two trials, Sener *et al*.[31] eliminated patients who had a steep infundibulopelvic angle. Similar to this, Naguib *et al*.[32] only considered ESWL instances with favorable calyceal morphology. The results given for ESWL and RIRS may have been impacted by the selection of instances with advantageous anatomy. The application of the aforementioned exclusion criteria for both treatment modalities did most likely not have an impact on the reported comparison results when ESWL is compared to RIRS.[30,31,33] However, Naguib *et al*.[32] only applied this standard to the ESWL group, which undoubtedly skewed their findings. As a result, it was determined that there was a considerable danger of selection bias in the study.

After PCNL or RIRS, ESWL seems to be used more frequently to treat any remaining lithiasis. Additional ESWL sessions were frequently scheduled after the first one, with PCNL and RIRS serving as common backup strategies. The sole study that provided data on re-treatment rates to help patients become stone-free found rates similar for PCNL and RIRS with outcomes that tended to favor PCNL. Compared to PCNL and RIRS, re-treatment rates for ESWL were noticeably greater. The intricate anatomical relationships of the lower calyceal group and the requirement for numerous ESWL sessions to reach stone-free status are practically reflected by these results.[34-36]

The pooled study demonstrated that the operating period was longer for PCNL than RIRS. ESWL required less time during surgery than PCNL and RIRS, but the mean difference of 7 min between ESWL and RIRS is likely not clinically significant. The included studies came from endoscopy and ESWL-experienced centers, so the experience of the surgeon may not have an impact on the length of the operation. However, there are variations in the nephroscope and access sheath sizes that could have affected the length of the PCNL procedure. Over time, the visual clarity and flexibility of flexible ureteroscopes have significantly increased, whereas the PCNL instruments have experienced downsizing.[37] In addition, laser lithotripters are now more effective.[38,39] Unfortunately, a meta-analysis cannot determine how the technical inconsistencies affect the operative time.

According to the pooled analysis's findings, PCNL required more time in the hospital than ESWL and RIRS did. The shorter hospital stays for ESWL were anticipated, but they should be offset by two or three factors such as the retreatment rate, urgent readmissions, and cost-effectiveness. However, it is important to interpret the combined results on the complications with caution. The studies used different definitions of a bleeding complication. Three trials supplied data that could be combined for the comparison of PCNL to RIRS. Only bleeding that need for blood transfusion was observed in one trial.[22] The other trial found that despite PCNL's increased transfusion rate, blood loss was comparable between it and RIRS.[40] It seems that the distinction established between a drop in hemoglobin and bleeding that is clinically severe more accurately reflects the realities of clinical practice. Not all cases of postoperative macroscopic hematuria are clinically significant. However, Bozzini *et al.*'s study[20] had the greatest number of participants and included cases of extensive hematuria that required blood transfusions or a Double-J stent as treatment. The number of patients who received treatment utilizing each technique remained unknown. Moreover, none of the included trials offered a comprehensive justification for the requirement of selective embolization of any hemorrhage.

The extensive time span in which the included studies were conducted (>12 years) was one of the noticeable flaws of our systematic review and meta-analysis. As a result, throughout time, equipment, materials, and experience with the approaches may have changed. The percutaneous technique is the same, so differences in instrument size, such as between standard and mini-PCNL, do not pose a restriction. Similar modifications were made to the RIRS hardware during the previously mentioned lengthy timeframe. As a result, the modern quantitative analysis has a sound conceptual foundation and trustworthy outcomes. We also think that more research on LPRS is required to develop a clear therapeutic strategy for those suffering from urolithiasis.

CONCLUSION

According to the pooled meta-analysis of the eligible trials in our systematic review, the management of LPRS should probably be PCNL or RIRS to attain stone-free state over a short period and with the fewest number of sessions. For stones smaller than 10 mm, RIRS performed better than ESWL. Each patient should receive personalized consideration when choosing between PCNL or RIRS based on their anatomical traits, comorbidities, and desires as determined by the attending clinician.

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Conflicts of interest

There are no conflicts of interest.

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