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REVIEW ARTICLE

Comparison of postoperative outcomes of mini percutaneous nephrolithotomy and standard percutaneous nephrolithotomy: a meta-analysis

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Abstract

Our study was aimed to evaluate the postoperative outcomes of Mini Percutaneous Nephrolithotomy (Mini-PCNL) and Standard Percutaneous Nephrolithotomy (Standard-PCNL) to determine the optimum option for patients with renal calculi. For publications published between January 2010 and April 2021, a comprehensive search of the PubMed, Cochrane Library, Web of Science, and EMBASE databases was done. The literatures were chosen based on the criteria for inclusion and exclusion. After the data were retrieved and the quality was assessed, the meta-analysis was performed using Review Manager Software (RevMan 5.4.1, Cochrane Collaboration, Oxford, UK). We selected 20 trials with a total of 4953 people out of 322 studies. There were 2567 patients treated with Mini-PCNL and 2386 patients treated with Standard-PCNL. Meta-analysis results showed no difference in stone-free rates (SFR, $P=0.93$), fever ($P=0.83$), and postoperative pain (VAS score) ($P=0.21$) between Mini-PCNL and Standard-PCNL. Patients in the Mini-PCNL group experienced shorter hospital stay ($P<0.0001$), less hemoglobin drop ($P<0.00001$), less blood transfusion ($P<0.00001$), higher postoperative tubeless ($P=0.0002$), and fewer complications including bleeding ($P=0.01$), perforation ($P=0.03$), and leakage ($P=0.01$). Compared with Standard-PCNL, operative time was longer in the Mini-PCNL group ($P=0.0005$). Mini-PCNL had a shorter hospital stay, less hemoglobin drop, less blood transfusion, greater postoperative tubeless, fewer complications, and a longer operational time when compared to Standard-PCNL. SFR, fever, and postoperative pain were similar in both of them. Mini-PCNL may be a superior option for patients with proper size renal calculi.

Keywords Kidney stones · Mini-PCNL · Standard-PCNL · Tract size · Stone-free rate · Complications

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Introduction

The surgical standard for treating large or difficult kidney stones is percutaneous nephrolithotomy (PCNL) [1]. With the maturation of technology and the advancement of medical expertise, smaller sheaths have become increasingly used for PCNL during the last two decades. Despite the lack of a globally accepted word for PCNL tract size, procedures with an outer sheath greater than 24 Fr are considered standard PCNL procedures [2]. Mini-PCNL is defined by the European Association of Urology (EAU) as a tract size of less than 22 Fr. [3]. At present, there are many comparisons between Mini-PCNL and Standard-PCNL, but there are some controversies, so we compared the SFR, operation time, hospital stay, hemoglobin drop, blood transfusion, postoperative pain (VAS score), postoperative tubeless, and complications of Mini-PCNL and Standard-PCNL over the last decade in the hopes of obtaining an evidence-based basis that would assist clinicians in choosing surgical options.

Materials and methods

Search strategy

The meta-analysis was carried out by looking for publications published between January 2010 and April 2021 in the PubMed, Cochrane Library, Web of Science, and EMBASE databases. The search details were: ((("Kidney Calculi"[Mesh]) OR ((((((((((((Calculi, Kidney) OR (Calculus, Kidney)) OR (Kidney Calculus)) OR (Nephrolith)) OR (Renal Calculus)) OR (Kidney Stones)) OR (Kidney Stone)) OR (Stone, Kidney)) OR (Stones, Kidney)) OR (Renal Calculi)) OR (Calculi, Renal)) OR (Calculus, Renal))) AND (("Nephrolithotomy, Percutaneous"[Mesh]) OR (((Nephrolithotomies, Percutaneous) OR (Percutaneous Nephrolithotomies)) OR (Percutaneous Nephrolithotomy)))) AND (mini). The search was limited to publications in English.

Inclusion and exclusion criteria

Before beginning the literature search, inclusion and exclusion criteria were established. The studies mentioned met the following criteria: (a) comparison of Mini-PCNL and Standard-PCNL; (b) at least one of our interesting data (including basic characteristics (Table1), surgical procedures, SFR, operation time, length of hospital stay, hemoglobin drop, blood transfusions, postoperative pain, tubeless PCNL rate, and complications) is found in the literature. Exclusion criteria included: (a) Incomplete analytical data; (b) Pediatric patients under 18 years of age; (c) Super Mini-PCNL (12-14F), Ultra mini-PCNL (10-13F), Micro-PCNL (4F)[3]; (c) Data cannot be extracted.

Data extraction

In this paper, the primary outcomes studied were SFR, operative time, length of hospital stay, hemoglobin drop, blood transfusion, postoperative pain (VAS score), postoperative tubeless and related complications. We collected the author's name, publication period, study type, sample size, average age of patients, gender ratio, stone location, stone size, SFR, operation time, hospital stay, hemoglobin drop, blood transfusion, postoperative pain (VAS Score), postoperative tubeless and related complications from the final included literature. The complications include: fever, bleeding, renal pelvis perforation, urine leakage. For identifying purposes, the first author's name and the year the piece was published were utilized. Two reviewers separately extracted data and came to an agreement on all issues.

Assessment of study quality

The Oxford Centre for Evidence-Based Medicine provides criteria for grading the level of evidence (LE) for each included study. The Jadad scale [4] for randomized controlled trials (RCTs) (Supplementary Table 1) and the Newcastle–Ottawa Scale (NOS) for non-randomized controlled trials (Non-RCTs) (Supplementary Table 2,3) were used to assess the methodological quality of the investigations. The full texts of the included literatures were read and independently assessed by two researchers. If the assessment results of two researchers were inconsistent, the third person performed re-assessment.

Statistical analysis

For statistical analysis, we utilized RevMan 5.4.1 software from the Cochrane Collaboration. The summary statistic for dichotomous variables was the Pooled Risk Ratio (RR). For continuous variables, the mean difference (MD) was determined. The 95% confidence interval (CI) for both RR and MD was provided, and $P < 0.05$ was considered statistically significant. I^2 statistics were used to assess the studies' heterogeneity [5]. The fixed-effect model was used if the heterogeneity was less than 50%, else the random-effects model was used [6]. If there is heterogeneity among the study results ($I^2 \geq 50\%$), the causes of heterogeneity were analyzed one by one study until gaining the best homogeneity.

Table 1 Characteristics of included studies

study	Design	Procedures	Sample size	Age (year)	Sex (M/F)	side (R/L)	BMI, kg/m2	Stone Size, mm
Bozzini, G. 2020	RCT	Mini-PCNL	47	55.8	20/27	22/25		16.82
		Standard-PCNL	44	53.3	23/21	25/19		16.38
Cheng,F. 2010	RCT	Mini-PCNL	72	37.2	39/33	43/29		
		Standard-PCNL	115	39.6	63/52	67/48		
Du, C. 2018	RCT	Mini-PCNL	304	41.2 ± 16.9	181/123	147/157		
		Standard-PCNL	297	44.5 ± 18.7	179/118	151/146		
Guler,A. 2019	RCT	Mini-PCNL	51	46.9 ± 13.7	29/22	29/22	28.5 ± 5.6	38.7 ± 13.1
		Standard-PCNL	46	47.4 ± 13.9	23/23	25/21	29.6 ± 5.9	42.8 ± 22.5
Kandemir,E. 2020	RCT	Mini-PCNL	76	47.0 ± 13.9	50/26	40/36	28.6 ± 5.4	32.6 ± 8.1
		Standard-PCNL	72	46.7 ± 14.2	48/24	35/47	28.4 ± 5.6	33.1 ± 10.9
Kukreja,R. A. 2018	RCT	Mini-PCNL	61	41.95 ± 13.53		33/28	27.1 ± 5.87	20.6 ± 3.47
		Standard-PCNL	62	40.3 ± 14.2		30/32	25.54 ± 3.58	21.5 ± 3.53
Sakr, A. 2017	RCT	Mini-PCNL	75	43.8	40/35	51/36	28.4	27
		Standard-PCNL	75	40.2	52/23	33/48	27.8	26
Tepeler, A. 2014	RCT	Mini-PCNL	10	47.2	4/6		27.5	19.9
		Standard-PCNL	10	44.3	6/4		27.8	21.9
Thakur, A. 2021	RCT	Mini-PCNL	30	34.5 ± 16.32	21/9		26.32 ± 5.10	17.9 ± 5
		Standard-PCNL	30	32.4 ± 12.6	17/13		25 ± 5.16	19.4 ± 5.3
Zeng, G. 2021	RCT	Mini-PCNL	992	51	526/466	500/492	24.4	29
		Standard-PCNL	988	51	531/457	487/501	24.7	29
Zhong,W. 2011	RCT	Mini-PCNL	29	41	14/15			
		Standard-PCNL	25	38	11/14			
Abdelhafez, M. F. 2016	Non-RCT	Mini-PCNL	71	52	37/34	29/42	26.2	38.6
		Standard-PCNL	62	58	31/31	21/41	26.4	38.2
ElSheemy,M.S. 2019	Non-RCT	Mini-PCNL	378	37.08 ± 12.62	137/241	206/172	27.2 ± 2.22	
		Standard-PCNL	151	43.42 ± 13.21	58/93	75/76	27.03 ± 2.16	
Hamamoto, S. 2014	Non-RCT	Mini-PCNL	19	48.9	12/7	5/14	24.8	
		Standard-PCNL	82	53.2	66/16	22/60	24.6	
Khadgi, S. 2021	Non-RCT	Mini-PCNL	83	43.7 ± 13.9	44/39	36/47	29 ± 3.3	
		Standard-PCNL	70	51.9 ± 9.7	32/38	21/41	34 ± 6	
Knoll,T. 2010	Non-RCT	Mini-PCNL	25	52 ± 11.6	16/9		27 ± 3.5	18 ± 3.3
		Standard-PCNL	25	48 ± 15.5	17/8		29 ± 5.6	22 ± 4.25
Li,L.Y. 2010	Non-RCT	Mini-PCNL	93	51.5	56/37	48/45		28.6
		Standard-PCNL	72	49.2	43/29	31/41		30.4
Mishra,S. 2011	Non-RCT	Mini-PCNL	26	42.2 ± 19.8	18/8	8/19	23.8 ± 2.6	
		Standard-PCNL	26	48.2 ± 16.8	18/8	10/18	22.6 ± 2.7	
Sabnis, R. B. 2020	Non-RCT	Mini-PCNL	11	40.2 ± 15.1	5/6			
		Standard-PCNL	20	49.2 ± 11.5	16/4			
Wu, C. 2017	Non-RCT	Mini-PCNL	114	47.6 ± 8.2	69/45	59/55	23.0 ± 2.7	34 ± 10
		Standard-PCNL	114	48.1 ± 7.9	68/46	55/59	22.8 ± 2.8	33 ± 11

Results

Study selection and characteristics

The literature search resulted in the discovery of 322 potentially relevant publications. After removing 231 irrelevant articles, 91 items were further evaluated. Finally, our meta-analysis included 20 publications. (Fig. 1)[7–26]. A total of 4953 participants were included in the study, with 2567 receiving Mini-PCNL and 2386 receiving Standard-PCNL. This research includes 11 RCTs [8–10, 12, 14, 17, 21–23, 25, 26] and 9 non-RCTs [7, 11, 13, 15, 16, 18–20, 24]. Table 1 shows the main characteristics of the studies that were considered.

SFR and subgroup analysis

15 studies reported SFR, with good homogeneity among the studies (P=0.15, I^2=29%). SFR was 85.1% (1910 of 2244 patients) of Mini-PCNL and 83.9% (1702 of 2029 patients) of Standard-PCNL with no significant difference (Risk Ratio (RR) =1.00, 95%Confidence Interval (CI) 0.97–1.02, P=0.93; Fig.2). For 7 RCT studies, SFR was 84.5% (1300 of 1538 patients) of Mini-PCNL and 83.8% (1275 of 1521 patients) of Standard-PCNL with no significant difference (RR=1.01, 95% CI 0.98–1.04, P=0.56; Fig.2). For 8 Non-RCT studies, SFR was 86.4% (610 of 706 patients) of Mini-PCNL and 84.1% (427 of 508 patients) of Standard-PCNL with no significant difference (RR=0.97, 95% CI 0.93–1.02, P=0.19; Fig.2).

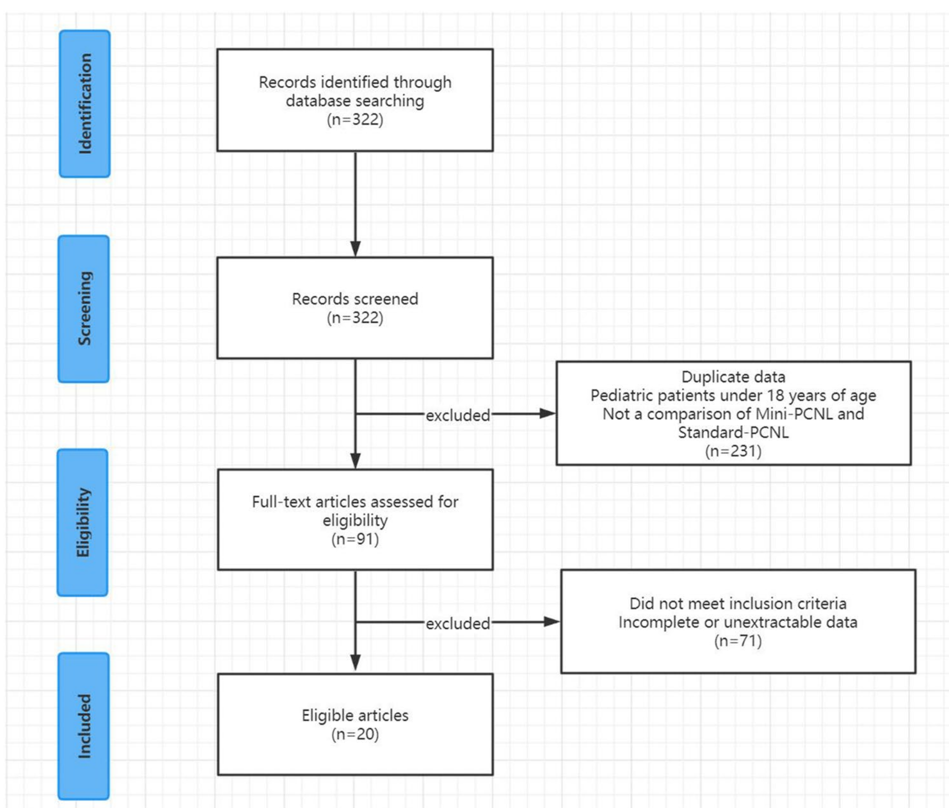
Operation time and subgroup analysis

Operative time was reported in 16 studies with high heterogeneity across studies (P<0.00001, I^2=94%), clinical consistency across studies after sensitivity analysis, and shorter operative time of Standard-PCNL using a random-effects model analysis (Mean Difference (MD) = 12.05, 95% CI 5.28–18.82, P=0.0005). In 8 RCT studies, Standard-PCNL was associated with shorter operative times using a random-effects model analysis (MD = 10.22, 95% CI 1.26–19.18, P=0.03; Fig.3); and there was the same conclusion reached in 8 Non-RCT studies (MD=13.76, 95% CI 1.12–26.41, P=0.03; Fig.3).

Hospital stays and subgroup analysis

12 studies reported hospital stays, which was heterogeneous across studies (P<0.00001, I^2=96%), clinical consistency across studies after sensitivity analysis, and shorter length of hospital stays with

Fig.1 Study details flow chart



Study or Subgroup	Mini-PCNL Events	Mini-PCNL Total	Standard-PCNL Events	Standard-PCNL Total	Weight	Risk Ratio M-H, Fixed, 95% CI
1.1.1 RCT						
Bozzini, G. 2020	39	47	38	44	2.2%	0.96 [0.81, 1.14]
Du, C. 2018	225	304	217	297	12.5%	1.01 [0.92, 1.11]
Kukreja,R.A. 2018	57	61	57	62	3.2%	1.02 [0.92, 1.12]
Sakr, A. 2017	68	75	70	75	4.0%	0.97 [0.88, 1.07]
Thakur, A. 2021	29	30	30	30	1.7%	0.97 [0.88, 1.06]
Zeng, G. 2021	856	992	848	988	48.5%	1.01 [0.97, 1.04]
Zhong,W. 2011	26	29	15	25	0.9%	1.49 [1.06, 2.11]
Subtotal (95% CI)		**1538**		**1521**	**73.2%**	**1.01 [0.98, 1.04]**
Total events	1300		1275			
Heterogeneity: Chi² = 6.86, df = 6 (P = 0.33); I² = 12%						
Test for overall effect: Z = 0.59 (P = 0.56)						
1.1.2 Non-RCT						
Abdelhafez, M. F. 2016	53	71	38	62	2.3%	1.22 [0.96, 1.55]
ElSheemy,M.S. 2019	340	378	145	151	11.8%	0.94 [0.89, 0.98]
Hamamoto, S. 2014	11	19	50	82	1.1%	0.95 [0.62, 1.45]
Khadgi, S. 2021	69	83	62	70	3.8%	0.94 [0.83, 1.07]
Knoll,T. 2010	24	25	23	25	1.3%	1.04 [0.91, 1.20]
Li,L.Y. 2010	78	93	63	72	4.1%	0.96 [0.85, 1.09]
Mishra,S. 2011	25	26	26	26	1.5%	0.96 [0.87, 1.07]
Sabnis, R. B. 2020	10	11	20	20	0.9%	0.90 [0.72, 1.12]
Subtotal (95% CI)		**706**		**508**	**26.8%**	**0.97 [0.93, 1.02]**
Total events	610		427			
Heterogeneity: Chi² = 7.49, df = 7 (P = 0.38); I² = 7%						
Test for overall effect: Z = 1.30 (P = 0.19)						
Total (95% CI)		**2244**		**2029**	**100.0%**	**1.00 [0.97, 1.02]**
Total events	1910		1702			
Heterogeneity: Chi² = 19.62, df = 14 (P = 0.14); I² = 29%						
Test for overall effect: Z = 0.09 (P = 0.93)						
Test for subgroup differences: Chi² = 1.98, df = 1 (P = 0.16), I² = 49.4%						

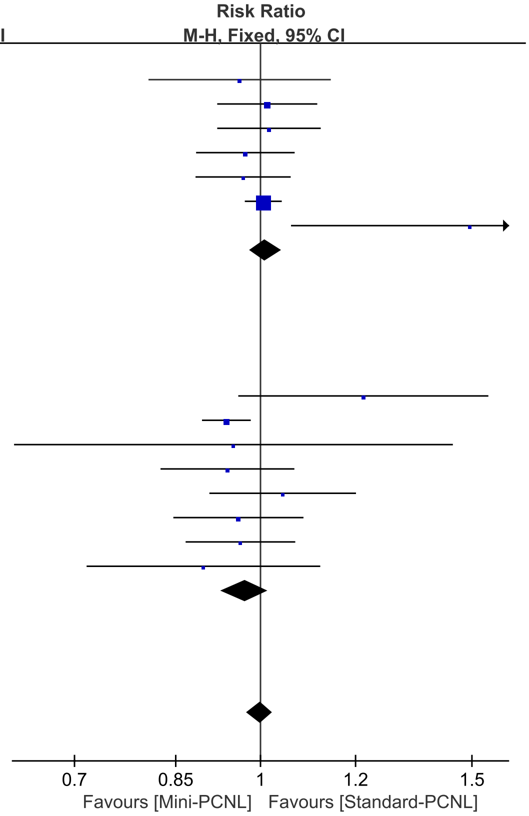


Fig.2 Forest plot for SFR

Study or Subgroup	Mini-PCNL Mean	Mini-PCNL SD	Mini-PCNL Total	Standard-PCNL Mean	Standard-PCNL SD	Standard-PCNL Total	Weight	Mean Difference IV, Random, 95% CI
2.1.1 RCT								
Bozzini, G. 2020	55.8	11.4	47	45.9	7.7	44	6.9%	9.90 [5.93, 13.87]
Du, C. 2018	81	41	304	53	27	297	6.8%	28.00 [22.46, 33.54]
Guler,A. 2019	81	41	304	53	27	297	6.8%	28.00 [22.46, 33.54]
Kandemir,E. 2020	106.9	38.8	76	91.2	33.2	72	5.9%	15.70 [4.09, 27.31]
Kukreja,R.A. 2018	25.46	11.9	61	24.68	12.45	62	6.9%	0.78 [-3.52, 5.08]
Sakr, A. 2017	83.2	17.3	75	78.6	24.4	75	6.6%	4.60 [-2.17, 11.37]
Tepeler, A. 2014	36.5	14.2	10	49	9.8	10	6.0%	-12.50 [-23.19, -1.81]
Thakur, A. 2021	49.17	15.46	30	44.17	20.55	30	6.3%	5.00 [-4.20, 14.20]
Subtotal (95% CI)			**907**			**887**	**52.1%**	**10.22 [1.26, 19.18]**
Heterogeneity: Tau² = 152.55; Chi² = 118.41, df = 7 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 2.23 (P = 0.03)								
2.1.2 Non-RCT								
Abdelhafez, M. F. 2016	113.2	44.1	71	89.1	43.5	62	5.3%	24.10 [9.18, 39.02]
ElSheemy,M.S. 2019	68.6	20.09	378	60.49	11.384	151	7.0%	8.11 [5.39, 10.83]
Hamamoto, S. 2014	181.9	15.5	19	134.1	7.8	82	6.6%	47.80 [40.63, 54.97]
Khadgi, S. 2021	90	32.4	83	99.6	32.9	70	6.1%	-9.60 [-19.99, 0.79]
Knoll,T. 2010	59	29.1	25	49	21.7	25	5.4%	10.00 [-4.23, 24.23]
Li,L.Y. 2010	87.6	31.6	93	64.5	25.7	72	6.3%	23.10 [14.35, 31.85]
Mishra,S. 2011	45.2	12.6	26	31	16.6	26	6.4%	14.20 [6.19, 22.21]
Sabnis, R. B. 2020	53.4	23.8	11	65.2	23.5	20	4.8%	-11.80 [-29.23, 5.63]
Subtotal (95% CI)			**706**			**508**	**47.9%**	**13.76 [1.12, 26.41]**
Heterogeneity: Tau² = 301.07; Chi² = 136.18, df = 7 (P < 0.00001); I² = 95%								
Test for overall effect: Z = 2.13 (P = 0.03)								
Total (95% CI)			**1613**			**1395**	**100.0%**	**12.05 [5.28, 18.82]**
Heterogeneity: Tau² = 168.36; Chi² = 255.11, df = 15 (P < 0.00001); I² = 94%								
Test for overall effect: Z = 3.49 (P = 0.0005)								
Test for subgroup differences: Chi² = 0.20, df = 1 (P = 0.65), I² = 0%								

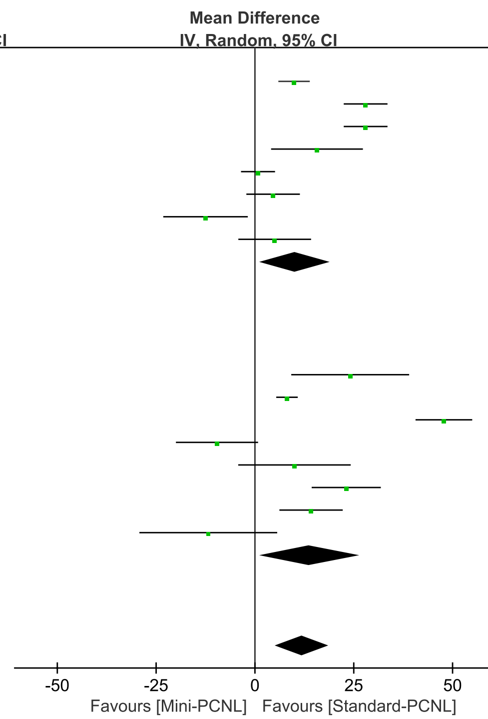


Fig.3 Forest plot for operative time

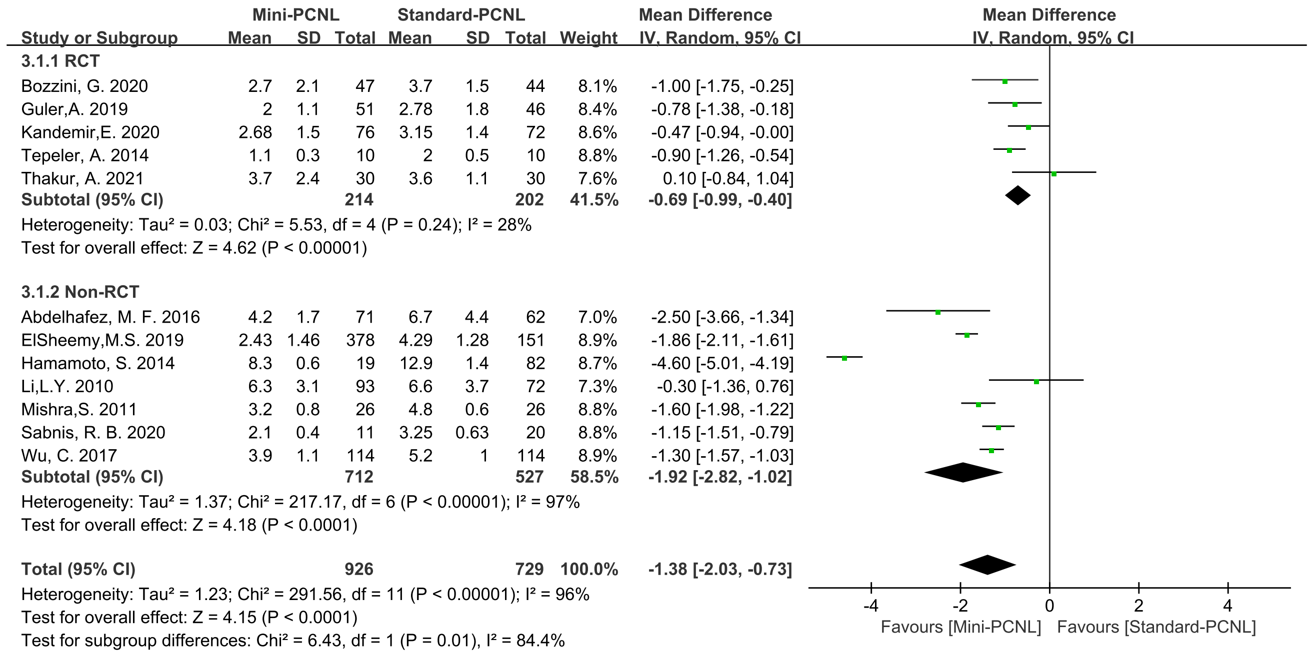


Fig.4 Forest plot for hospital stays

Mini-PCNL using random-effects model analysis (MD=–1.38, 95% CI –2.03 to –0.73, P<0.0001; Fig.4). In 5 RCT studies, Mini-PCNL had shorter hospital stay using random-effect model analysis (MD=–0.69, 95% CI –0.99 to –0.40, P<0.00001; Fig.4); and there was same conclusion in 7 Non-RCT studies (MD =–1.92, 95% CI –2.82 to –1.02, P<0.0001 Fig.4).

Hemoglobin drop and subgroup analysis

10 studies reported hemoglobin drop, and less hemoglobin drop was found in Mini-PCNL using random-effects model (MD = –0.65, 95%CI –0.92 to –0.37; P < 0.00001; Fig. 5). Mini-PCNL showed less hemoglobin drop in 6 RCT studies analyzed with random-effects model (MD = –0.67, 95% CI –1.03 to –0.31, P = 0.0003; Fig. 5); and there was same

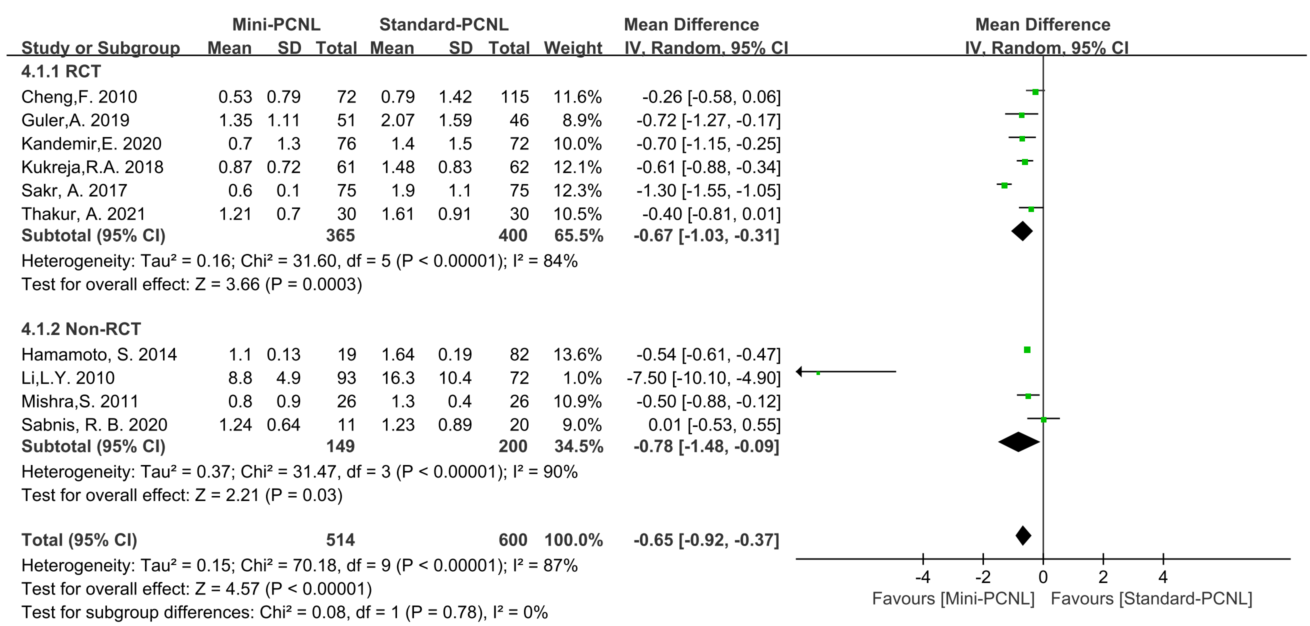


Fig.5 Forest plot for hemoglobin drop

conclusion in 4 Non-RCT studies (MD = –0.78, 95% CI –1.48 to –0.09, P = 0.03; Fig. 5).

Blood transfusions and subgroup analysis

12 studies reported blood transfusions, with good homogeneity among the studies (P = 0.34, I^2 = 11%). Using the fixed-effect model analysis, meta-analysis results showed fewer blood transfusions in Mini-PCNL (RR = 0.44, 95% CI 0.31–0.62, P < 0.00001; Fig. 6). In 8 RCT studies, Mini-PCNL had fewer blood transfusions using a fixed-effects model analysis (RR = 0.50, 95% CI 0.33–0.77, P = 0.001; Fig. 6); and there was the same conclusion was reached in 4 Non-RCT studies (RR = 0.33, 95% CI 0.18–0.61, P = 0.0004; Fig. 6).

Postoperative pain (VAS score) analysis

3 studies reported postoperative pain (VAS score), which was heterogeneous across studies (P < 0.03, I^2 = 72%), and there was clinical consistency across studies after sensitivity analysis, which was analyzed using a random-effects model, and there was no significant difference between the two groups (MD = –0.29, 95% CI –0.74 to 0.16, P = 0.21; Fig. 7).

Tubeless PCNL rate analysis

6 studies reported tubeless PCNL, which was heterogeneous across studies (P < 0.00001, I^2 = 96%), and there was clinical consistency across studies after sensitivity analysis, which was analyzed using a random-effects model. The

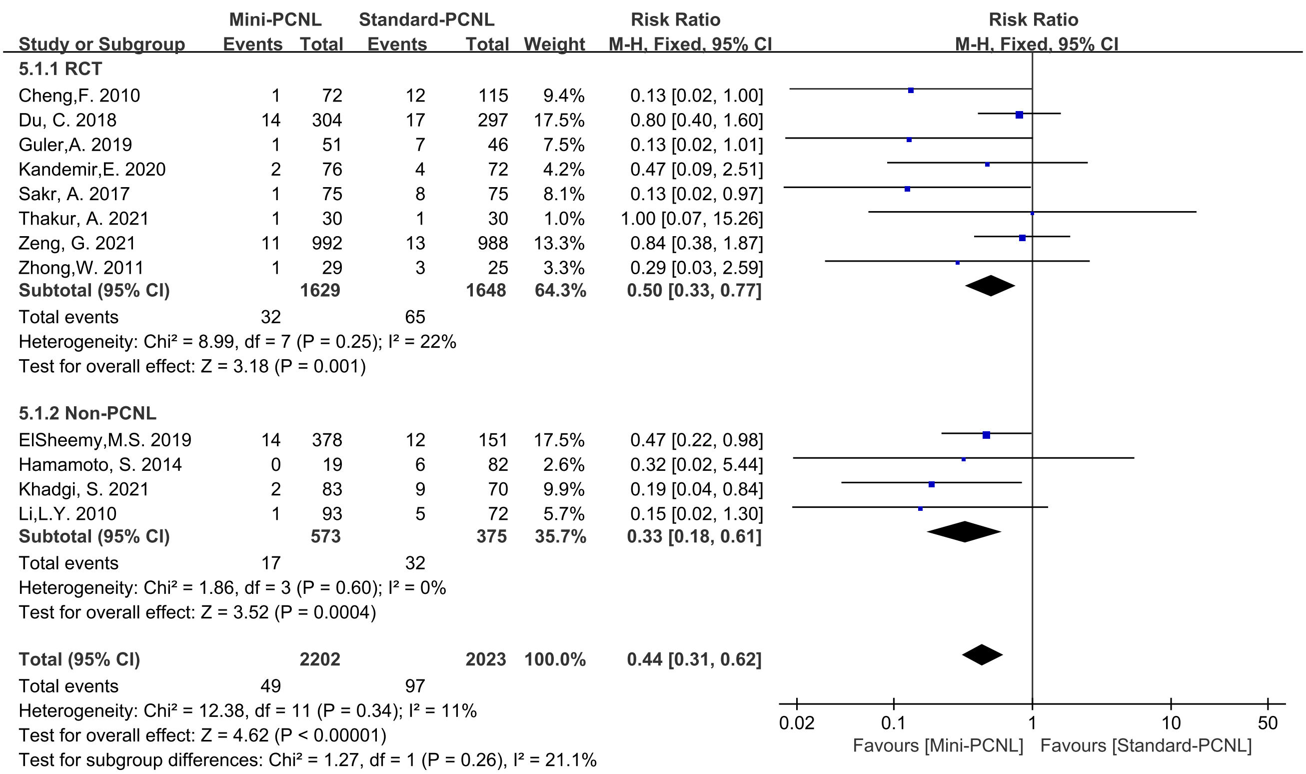


Fig.6 Forest plot for blood transfusions

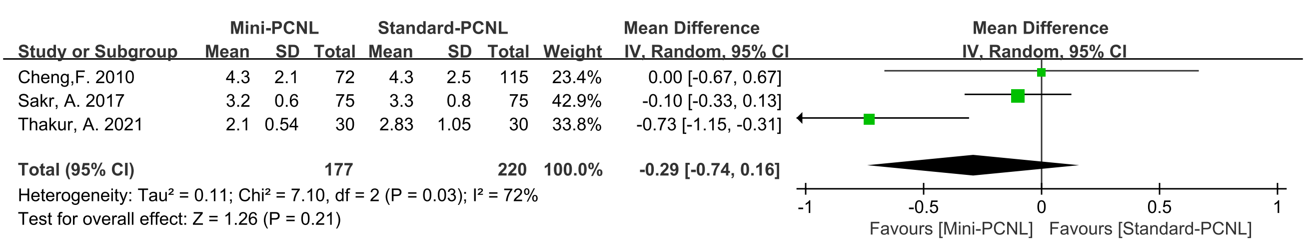


Fig.7 Forest plot for postoperative pain (VAS score)

report showed that Mini-PCNL has a higher tubeless rate (RR = 4.24, 95% CI 1.99–9.00, $P = 0.0002$; Fig. 8).

Complications and subgroup analysis

Complications analyzed in this paper included: fever, bleeding, renal pelvis perforation, and urine leakage. Mini-PCNL is less likely to cause bleeding (RR = 0.47, 95%CI 0.26–0.85, $P = 0.01$; Fig. 9), renal pelvis perforation (RR = 0.37, 95%CI 0.15–0.90, $P = 0.03$; Fig. 10), and urine leakage (RR = 0.24, 95% CI 0.08–0.73, $P = 0.01$; Fig. 11). Standard-PCNL was clinically consistent across studies after a sensitivity analysis. However, there was no significant difference between Mini-PCNL and Standard-PCNL on fever (RR = 0.96, 95% CI 0.68–1.36, $P = 0.83$; Fig. 12).

Publication bias

In this study, funnel plots were employed to assess publication bias. (Supplementary Table 4–14). The results were as follows: the funnel plot was symmetrical for blood transfusion, bleeding, and renal pelvis perforation; the funnel plot was basically symmetrical for SFR, operation

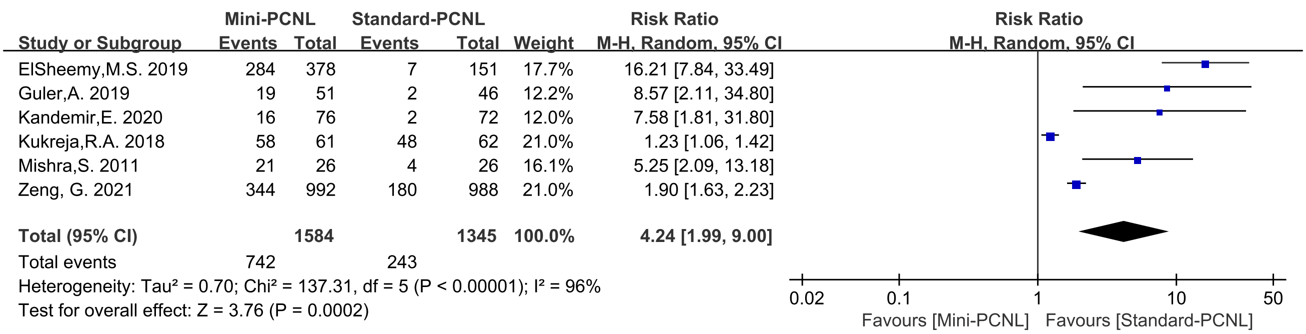


Fig. 8 Forest plot for tubeless PCNL

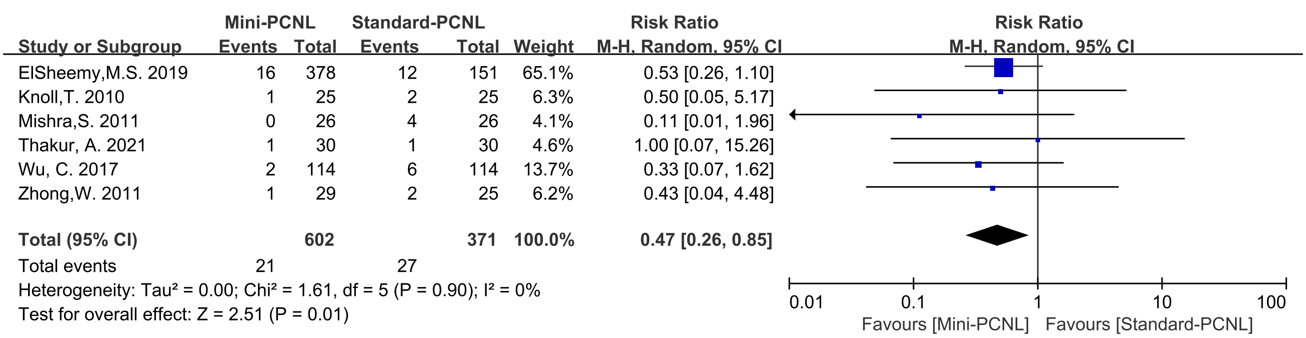


Fig. 9 Forest plot for bleeding

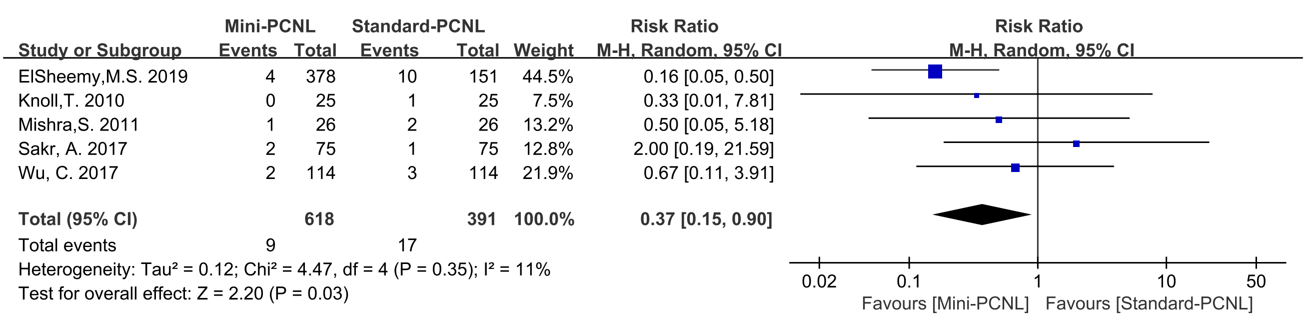


Fig. 10 Forest plot for renal pelvis perforation

Study or Subgroup	Mini-PCNL Events	Mini-PCNL Total	Standard-PCNL Events	Standard-PCNL Total	Weight	Risk Ratio M-H, Random, 95% CI
Cheng,F. 2010	0	72	2	115	13.4%	0.32 [0.02, 6.53]
ElSheemy,M.S. 2019	0	378	7	151	15.0%	0.03 [0.00, 0.47]
Sakr, A. 2017	1	75	3	75	24.3%	0.33 [0.04, 3.13]
Tepeler, A. 2014	0	10	1	10	12.8%	0.33 [0.02, 7.32]
Thakur, A. 2021	0	30	1	30	12.2%	0.33 [0.01, 7.87]
Zhong,W. 2011	1	29	2	25	22.3%	0.43 [0.04, 4.48]
Total (95% CI)		**594**		**406**	**100.0%**	**0.24 [0.08, 0.73]**
Total events	2		16			

Heterogeneity: Tau² = 0.00; Chi² = 2.93, df = 5 (P = 0.71); I² = 0%
Test for overall effect: Z = 2.53 (P = 0.01)

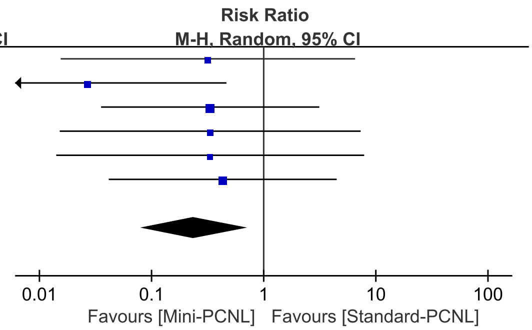


Fig. 11 Forest plot for urine leakage

Study or Subgroup	Mini-PCNL Events	Mini-PCNL Total	Standard-PCNL Events	Standard-PCNL Total	Weight	Risk Ratio M-H, Random, 95% CI
8.1.1 RCT						
Cheng,F. 2010	15	72	27	115	11.5%	0.89 [0.51, 1.55]
Du, C. 2018	45	304	28	297	13.0%	1.57 [1.01, 2.45]
Guler,A. 2019	1	51	0	46	1.1%	2.71 [0.11, 64.96]
Kandemir,E. 2020	0	76	2	72	1.2%	0.19 [0.01, 3.88]
Sakr, A. 2017	8	75	5	75	6.3%	1.60 [0.55, 4.67]
Tepeler, A. 2014	1	10	0	10	1.1%	3.00 [0.14, 65.90]
Thakur, A. 2021	7	30	5	30	6.6%	1.40 [0.50, 3.92]
Zeng, G. 2021	97	992	81	988	14.9%	1.19 [0.90, 1.58]
Zhong,W. 2011	3	29	3	25	3.9%	0.86 [0.19, 3.90]
Subtotal (95% CI)		**1639**		**1658**	**59.8%**	**1.23 [1.00, 1.51]**
Total events	177		151			
Heterogeneity: Tau² = 0.00; Chi² = 5.06, df = 8 (P = 0.75); I² = 0%						
Test for overall effect: Z = 1.95 (P = 0.05)						
8.1.2 Non-RCT						
ElSheemy,M.S. 2019	15	378	22	151	10.6%	0.27 [0.15, 0.51]
Hamamoto, S. 2014	1	19	12	82	2.5%	0.36 [0.05, 2.60]
Knoll,T. 2010	3	25	5	25	4.8%	0.60 [0.16, 2.25]
Li,L.Y. 2010	5	93	6	72	5.8%	0.65 [0.21, 2.03]
Mishra,S. 2011	2	26	4	26	3.6%	0.50 [0.10, 2.50]
Sabnis, R. B. 2020	1	11	1	20	1.5%	1.82 [0.13, 26.32]
Wu, C. 2017	28	114	15	114	11.4%	1.87 [1.05, 3.30]
Subtotal (95% CI)		**666**		**490**	**40.2%**	**0.66 [0.29, 1.46]**
Total events	55		65			
Heterogeneity: Tau² = 0.71; Chi² = 21.12, df = 6 (P = 0.002); I² = 72%						
Test for overall effect: Z = 1.03 (P = 0.30)						
Total (95% CI)		**2305**		**2148**	**100.0%**	**0.96 [0.68, 1.36]**
Total events	232		216			

Heterogeneity: Tau² = 0.19; Chi² = 32.29, df = 15 (P = 0.006); I² = 54%
Test for overall effect: Z = 0.22 (P = 0.83)
Test for subgroup differences: Chi² = 2.21, df = 1 (P = 0.14), I² = 54.7%

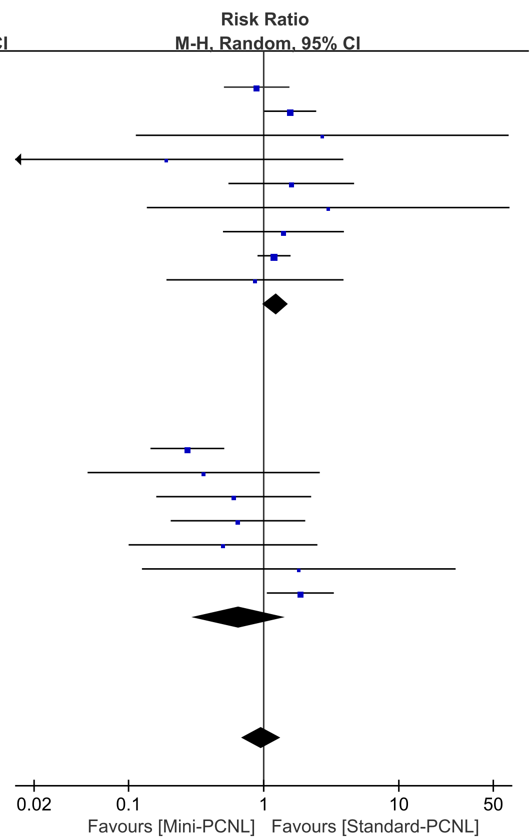


Fig. 12 Forest plot for fever

time, hospital stay, hemoglobin drop, postoperative pain (VAS score), fever, urine leakage, and tubeless PCNL.

Sensitivity analysis

The studies were removed in turn to investigate the effect of each study on the summary results. The pooled results did not show alterations when individual studies were excluded.

Discussion

PCNL-based procedures, with the exception of a few patients with particularly big and/or intricate staghorn stones, are recommended preferred open surgery because to lower morbidity [27]. In recent years, Mini-PCNL has grown in popularity, and we analyzed the literature and discovered that it has a similar SFR to Standard-PCNL, but with shorter hospital stays, less hemoglobin drop, less blood transfusions, higher tubeless PCNL, and fewer complications, increased operative time.

SFR is one of the main indicators for surgeons to choose surgical approach. Lahme, S. et al. suggested that Standard-PCNL has a high stone-free rate, but it also has a high treatment morbidity rate [28]. However, in our study, we found that Mini-PCNL may have a similar SFR to Standard-PCNL in recent years. RCT literature study of subgroup analysis revealed two primary causes for the increased SFR of Mini-PCNL: 1. In terms of surface area, the nephroscope utilized in Standard-PCNL (20.8F) has a 150 percent increase over Mini-PCNL (12F). As a result, the distance between the tract and the nephroscope was larger with Mini-PCNL, allowing for improved visualization and fragment evacuation during the treatment [25]. 2. The presence of a large number of calculi (10.8 cm^2) in the PCNL group in this series, as well as a lack of experience with flexible nephroscopy, may have contributed to a lower clearance rate than in other series [26]. For Non-RCT studies, we discovered that patients with many stones and a substantial stone burden > 2 cm^2 had a significant difference in SFR, but patients with a single stone or a stone burden ≤ 2 cm^2 had no significant difference in SFR [11]. We believe that, with the advancement of technology and equipment, Mini-PCNL might have a similar SFR to Standard-PCNL.

The analysis concluded that operating time was shorter in Standard-PCNL than in Mini-PCNL, whether in RCT or non-RCT studies. Because of the bigger sheath of Standard-PCNL and the clearance between the nephroscope and the channel, it is not necessary to break the stone into smaller fragments like Mini-PCNL, resulting in a shorter operative time.

We reviewed the literature in recent years and discovered that Mini-PCNL has a greater tubeless rate, which demonstrated superiority of Mini-PCNL. Mini-PCNL has a smaller wound bed, less bleeding, and less hemoglobin drop than Standard-PCNL, resulting in a higher tubeless rate, and potentially shorter hospital stays and less postoperative pain. Because the VAS score was used as the postoperative pain inclusion criterion in this study, there were only a few literatures eventually included, and the analysis results may be skewed as a result of the limited data extraction and quantity of literatures. Corroboration will require more high-quality literature items.

Finally, in the analysis of postoperative complications, Mini-PCNL was superior in terms of bleeding, perforation, and leakage due to its smaller sheath. In the analysis of fever, there was no significant difference between the two groups (Fig. 12). The main cause of postoperative fever in patients was believed to be bacterial endotoxin absorption produced by higher renal pelvis pressure in Mini-PCNL. However, some studies have shown that the Mini-PCNL nephroscope was at least 6.5 Fr smaller than the sheath (8.5/11.5 Fr ureteroscope in an 18 Fr sheath) [11]. The incidence of fever after Mini-PCNL was reduced as a result of this. The higher rate of fever after Standard-PCNL, on the other hand, could be due to the presence of infection calculi or a higher rate of complications: Perforation, leakage, hematoma, and obstruction of the pelvic–calyceal canal [11].

A number of enhancements should be made in the future. First, some articles have tiny sample sizes, which may necessitate larger sample sizes to confirm the articles' credibility. Second, different conclusions appear to be reached in RCT and non-RCT investigations; further research may be required for confirmation. Finally, despite applying the random-effects model to these elements, the study discovered considerable heterogeneity for some parameters, which may have an impact on the outcomes of our investigation. Despite these limitations, our meta-analysis offered high-quality evidence by updating the most recent data.

Conclusion

According to our meta-analysis, Mini-PCNL is at least as effective and safe for the removal of renal calculi as Standard-PCNL with similar SFR. Furthermore, Mini-PCNL had a shorter hospital stay, less hemoglobin drop, less transfusion, greater postoperative tubeless, and fewer complications than Standard-PCNL.

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Author contributions Chuanping Wan, Writing - original, Writing - review & editingDaoqi Wang, Writing - review & editingJiajia Xiang, Data curationBin Yang, Data curationJinming Xu, ResourcesGuiming Zhou, SoftwareYuan Zhou, SoftwareYuan Zhao, InvestigationJiao Zhong, InvestigationJianhe Liu, Project administration

Declarations

Competing interests In relation to this article, none of the authors have any conflicts of interest to disclose.

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