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Evidence of the outcome and safety of upper pole *vs.* other pole access single puncture PCNL for kidney stones: which is better?

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Abstract. – OBJECTIVE: The purpose of this study was to retrospectively assess the efficacy and safety of percutaneous nephrolithotomy (PCNL) for upper urinary stones using upper pole access (UPA) and other (low or middle) pole access (OPA).

MATERIALS AND METHODS: A comprehensive literature review of articles investigating the clinical efficacy and safety of UPA and OPA was performed. The relevant literature was obtained from PubMed, EMBASE, Science Direct, Google Scholar and the Cochrane Library. The primary outcomes, including the stone-free rate, were evaluated using Review Manager 5.4 software. The secondary outcomes (peri- and postoperative complications and operative date) were also compared and analyzed.

RESULTS: Ten comparative studies involving 5,290 patients were included in the analysis. The pooled data showed that the UPA group had a stone-free rate (SFR) similar to that of the OPA group [odds ratio (OR) 1.38, 95% confidence interval (CI): 0.94 to 2.03; *p*=0.22] but a higher incidence of blood transfusion [OR: 1.50; 95% CI: (1.03, 2.19), *p*=0.04]. There was no statistically significant difference in operative time [mean difference (MD): -7.27; 95% CI: (-25.18, 10.65), *p*=0.43] or hospital stay [MD: -0.13; 95% CI: (-0.64, 0.37), *p*=0.60] between the two groups. In addition, the results support that UPA causes fewer complications than OPA.

CONCLUSIONS: Our findings suggest that UPA and OPA are both effective treatments for the management of upper urinary stones. Compared to OPA, UPA is associated with less need for blood transfusion and fewer complications. Nevertheless, the findings should be further confirmed by well-designed prospective randomized controlled trials (RCTs) with large samples and strict standards.

Key Words:
Percutaneous nephrolithotomy, Single access, Upper pole, Middle pole, Lower pole, Kidney stone.

Introduction

Urolithiasis is a common disease affecting 5-15% of the population worldwide[1,2]. With an increasing incidence and prevalence, kidney stones impose a heavy burden on healthcare systems[3,4]. The current main treatment modalities for kidney stones consist of extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), rigid ureterorenoscopy (URS), retrograde intrarenal surgery (RIRS), and laparoscopic or open surgery. According to the European Association of Urology (EAU) guidelines, PCNL is recommended as the standard treatment modality for large or complex kidney stones (>2 cm) and as a consideration for stones larger than 1.5 cm located in the lower pole[5]. PCNL is also used as a treatment for stones obstructing the kidney and for hard stones and residual stones that remain after failed shock wave lithotripsy[6,7]. When undergoing the PCNL procedure, the most important step is choosing a suitable access to the appropriate calyx. PCNL can be performed through access to the upper, middle, or lower pole (LP) of the kidney. In general, access *via* the upper pole has

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been advocated in previous literature, as it allows for a tract to be placed in line with the long axis of the kidney, thereby facilitating entry into the pelvicalyceal system and leading to satisfactory stone-free rates (SFRs), fewer punctures and less manipulative trauma than LP access[8,9].

In recent years, urologists have gained more clinical experience and have paid attention to the miniaturization of instruments with the aim of minimizing harm to achieve the best benefit. There has been no consensus on which access is the best for PCNL and few studies[5,6] have discussed the influence of access position. Therefore, we collected previously published studies on the use of UPA and other (low or middle) pole access (OPA) in treating renal stones to investigate the efficacy and safety of these access positions for PCNL. We believe that new findings will provide more reliable evidence that can be used as a reference.

Materials and Methods

Search Strategy

A comprehensive literature search of PubMed, EMBASE, Science Direct, Google Scholar and the Cochrane Library was conducted in March 2021. The following key words were used: "percutaneous nephrolithotomy", "PCNL," "access," "upper pole," "middle pole," "lower pole," and "stones". Additionally, manual searches of the references and citation lists of all relevant reviews were performed. Literature was selected in accordance with the search strategy promoted by the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.

Inclusion and Exclusion Criteria

Studies were included based on the following criteria: (a) the study was a prospective study or retrospective study; (b) the study compared the efficacy and safety of UPA with those of OPA; (c) there was no statistically significant difference in the basic characteristics of the participants; and (d) at least one of the following outcomes was reported: stone-free rate, surgery-related data, or postoperative complications.

Studies were excluded based on the following criteria: (a) studies that did not meet the inclusion criteria; (b) studies reporting outcomes that could not be analyzed; (c) studies not published in English; and (d) conference articles, letters, commentaries, or reviews.

Data Extraction and Quality Assessment

After screening the studies based on the inclusion and exclusion criteria, two reviewers (T. Huang and B.-B. Jiao) independently extracted the data and appraised both the quality and content. Data were extracted from each study and summarized in a standardized data collection form. The following items were extracted: first author, year of publication, country, study design, intervention, sample size, stone-free rate (SFR), operative time, hospital stay and overall complications. Any differences at this stage were resolved through discussion, and the senior reviewer (G. Zhang) made a majority decision if necessary.

The level of evidence of each included study was evaluated by the Oxford Centre for Evidence-based Medicine[10]. The Newcastle-Ottawa scale[11] was used to assess the quality of case-control trials. Studies with scores of 7-9 were defined as high-quality, while those with scores of 0-6 were defined as low-quality. The decision to pool studies in the meta-analysis was not influenced by the studies' quality.

Statistical Analysis

All meta-analyses were performed using Review Manager [RevMan, version 5.4; Nordic Cochrane Centre (Cochrane Collaboration), Copenhagen, Denmark; 2020]. We chose the mean difference (MD) or standardized MD (SMD) to evaluate the continuous outcome. Some continuous data were expressed as medians and range values, and we counted their means and standard deviations by using the statistical formula provided by Luo et al[12,13]. The results were expressed as odds ratios (ORs) with 95% confidence intervals (CIs) for dichotomous variables. χ^2 and I^2 tests (I^2>50% was regarded as substantial heterogeneity) were used to assess the data heterogeneity. Fixed-effects models were applied for the meta-analyses when the heterogeneity was low. Otherwise, a random-effects model was used to reduce the effect of statistical heterogeneity. The pooled effects were determined by the z-test, and a p-value <0.05 was considered statistically significant for several comparisons. All the results of the meta-analysis were presented by using forest plots.

Results

Characteristics of Selected Studies

Initially, a total of 554 articles were identified based on the search strategy. After screening the abstract and full text and applying the inclusion and exclusion criteria, ten studies[14-23] were includ-

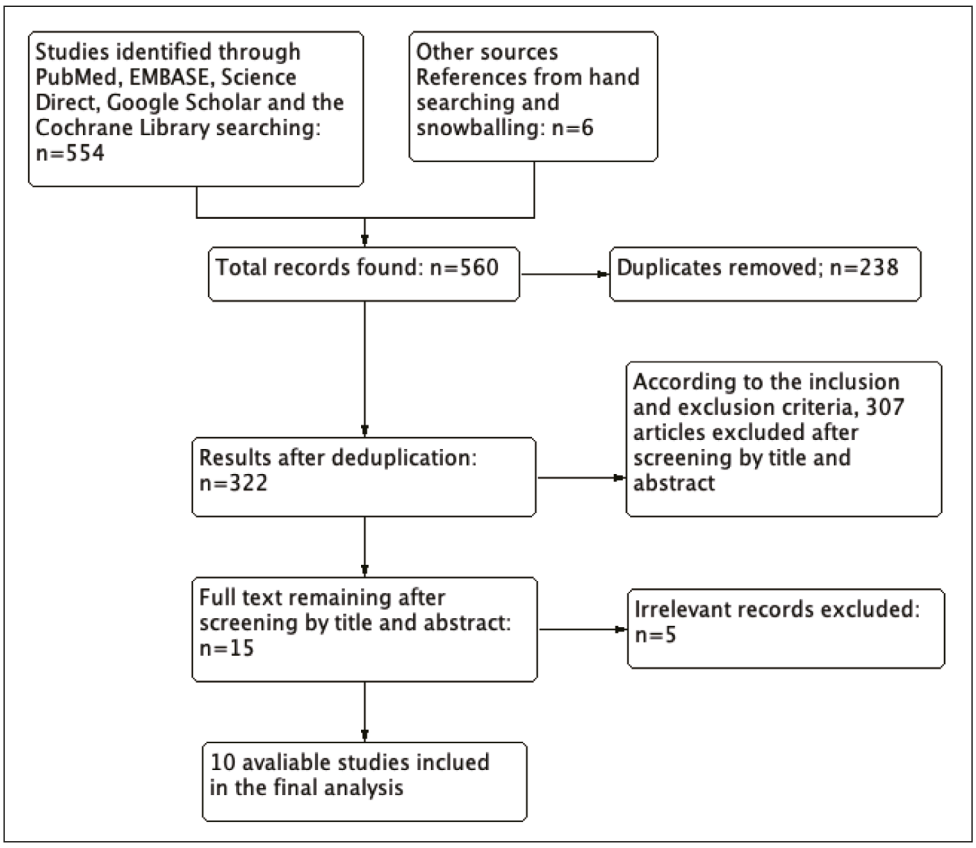

Figure 1. PRISMA flowchart.

ed. A detailed flowchart of the literature selection process is presented in Figure 1. The patient and study characteristics are summarized in Table I. No differences were found in basic physical conditions between the UPA group and OPA group. The outcome parameters for UPA and OPA are shown in Table II.

Stone-Free Rate

A total of ten studies[14-23] involving 5,290 patients were included to compare the SFRs of UPA and OPA. Due to significant heterogeneity among these trials, the random-effects model was chosen to analyze these trials (I^2=57%). No significant difference was observed between the two groups in the pooled analysis [OR: 1.38; 95% CI: (0.94, 2.03), p=0.10] (Figure 2A). In addition, we performed a sensitivity analysis. The results demonstrated that UPA led to higher stone clearance than OPA [OR: 1.52; 95% CI: (1.16, 2.01), p=0.003] (Figure 2B).

Operation Duration

Six studies[14,15,17,19,20,22] reported the operative time. The random-effects model was selected due to the high heterogeneity (I^2=98%). As shown in Figure 3A, the overall results showed that the difference between the two groups was not statistically significant [MD: -7.27; 95% CI: (-25.18, 10.65), p=0.43]. To identify bias, a sensitivity analysis was performed, which suggested the same results.

Hospitalization Time

Five studies[15,17,19,20,22] were analyzed to assess the length of hospital stay. The pooled analysis using a random-effects model demonstrated that there were no statistically significant differences between the two groups. Using a random-effects model, the pooled analysis showed that there were no evident significant differences between UPA and OPA [MD: -0.13; 95% CI: (-0.64, 0.37), p=0.60] (Figure 3B).

Hemoglobin Drop

Four studies[14,15,19,20] reported these issues. When these studies were included, a random-effects model was used. The overall results showed that there were no statistically significant differences between the two groups [MD: -0.17; 95% CI: (-0.48, 0.14), p=0.28] (Figure 4).

Table I. Summary of comparative studies included in meta-analysis.

Study	Country	Study period	Study design	Intervention		Sample size		LE	Study quality
				Trial	Control	Trial	Control		
Aron et al[14]	India	1998-2003	Prospective study	UPA	OPA	69	33	2b	7#
Blum et al[15]	America	Not mentioned	Prospective study	UPA	OPA	13	44	2b	8#
Lightfoot et al[16]	America	2002-2012	Retrospective study	UPA	OPA	125	138	2b	8#
Netto et al[17]	Brazil	1995-2000	Retrospective study	UPA	OPA	16	70	2b	7v
Nottingham et al[18]	America	1999-2017	Prospective study	UPA	OPA	112	655	2b	8#
Oner et al[19]	Turkey	2004-2016	Retrospective study	UPA	OPA	10	67	2b	8#
Singh et al[20]	India	Not mentioned	Prospective study	UPA	OPA	43	51	2b	8#
Soares et al[21]	America	2005-2017	Retrospective study	UPA	OPA	188	96	2b	8#
Tefekli et al[22]	Global	2007-2009	Prospective study	UPA	OPA	403	3112	2b	8#
Wong et al[23]	America	Not mentioned	Retrospective study	UPA	OPA	35	10	2b	7#

LE = level of evidence; UPA = upper pole access percutaneous nephrolithotomy; OPA = other pole access percutaneous nephrolithotomy.
#Using Newcastle-Ottawa Scale (score from 0 to 9).

Table II. Study outcomes comparing UPA and OPA.

Outcomes	No. of studies	Sample size		Heterogeneity (total)				MD or OR (95% CI)	*p*-value (total)
		UPA	OPA	Chi^2	df	I^2 (%)	*p*-value		
Overall SFR	10	1,014	4,276	20.88	9	57	0.01	1.38 (0.94,2.03)	0.1
SFR (sensitivity analysis)	9	611	1,164	6.26	8	0	0.62	1.52 (1.16,2.01)	0.003
Operation time	6	558	3,392	237.49	5	<0.00001	98	-7.27 (-25.18,10.65)	0.43
Hospital stay	5	489	3,359	11.8	4	66	0.02	-0.13 (-0.64,0.37)	0.6
Auxiliary treatment	5	815	3,947	9.75	4	59	0.04	0.96 (0.64,1.44)	0.85
Hemoglobin drop	4	139	210	6.59	3	54	0.09	-0.17 (-0.48,0.14)	0.28
Blood transfusion	6	610	3,482	4.72	4	15	0.32	1.50 (1.03,2.19)	0.04
Pulmonary adverse events	6	301	346	1.46	4	0	0.83	2.71 (0.85,8.70)	0.09
Postoperative fever/sepsis	5	151	265	1.89	4	0	0.76	1.31 (0.60,2.85)	0.5
Urinary leakage	2	29	114	1.99	1	50	0.16	3.99 (0.18,87.22)	0.38
Overall Complications	6	851	4,112	7.17	5	30	0.21	1.67 (1.36,2.05)	<0.00001
Minor complications	6	851	4,112	3.6	5	0	0.61	1.47 (1.16,1.85)	0.001
Major complications	6	851	4,112	3.14	4	0	0.54	1.91 (1.30,2.80)	0.001
Clavien I complications	4	551	3,361	1.57	3	0	0.67	1.29 (0.95,1.75)	0.1
Clavien II complications	4	551	3,361	1.77	2	0	0.41	1.71 (1.16,2.51)	0.007
Clavien III complications	4	551	3,361	0.59	2	0	0.74	1.92 (1.21,3.05)	0.006
Clavien IV complications	4	551	3,361	0.6	1	0	0.44	1.19 (0.39,3.62)	0.76

CI = confidence interval; MD = mean difference; OR = odds ratio.

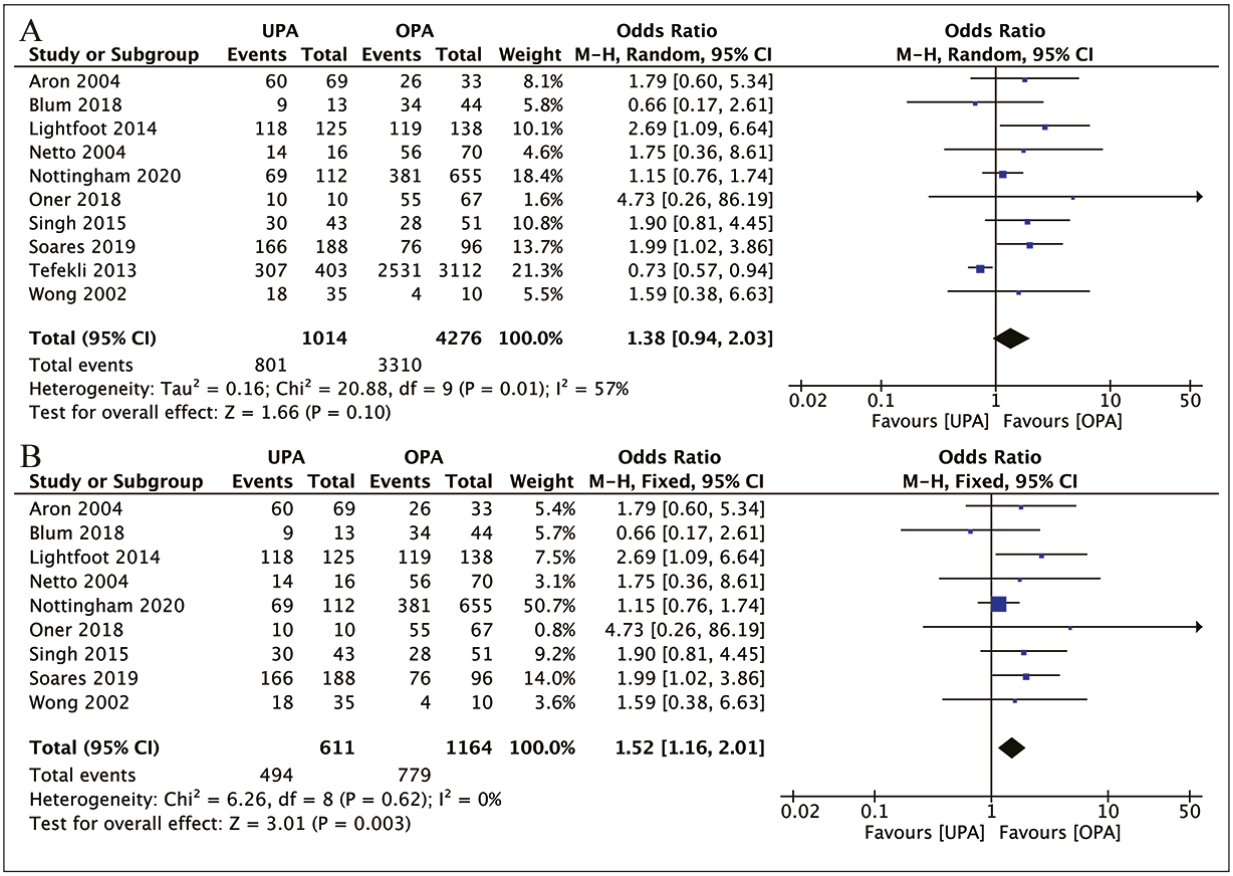

Figure 2. Forest plots and meta-analyses. **A**, SFR; (**B**) SFR (sensitivity analysis) (95% CI: 95% confidence intervals, df: degrees of freedom, Fixed: fixed effects model, Random: random effects model, IV: inverse variance, SD: standard deviation).

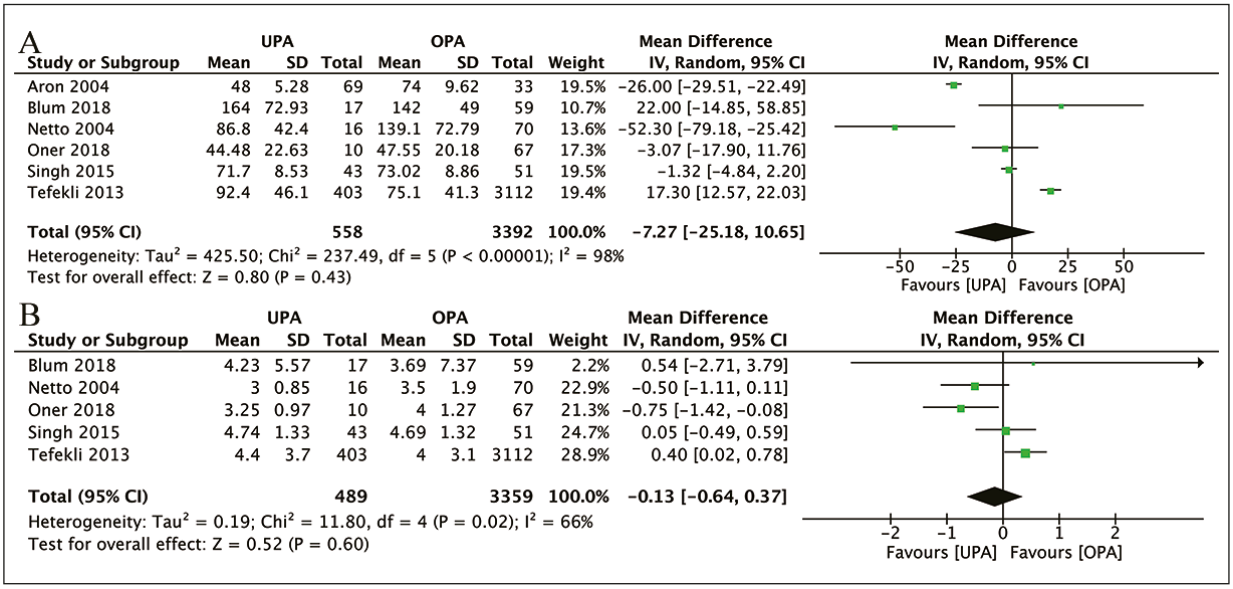

Figure 3. Forest plots and meta-analyses. **A**, Operation time; (**B**) hospitalization time (95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, IV: inverse variance, SD: standard deviation).

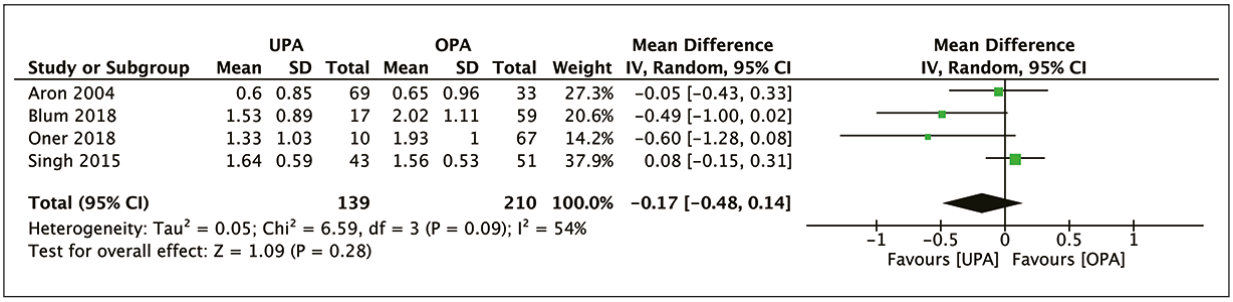

Figure 4. Forest plots and meta-analyses of hemoglobin decreases (95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, IV: inverse variance, SD: standard deviation).

Blood Transfusion

A total of six studies[15,16,17,19,20,22] involving 4,092 participants met the inclusion criteria for this outcome. Meta-analysis with a fixed-effects model (I^2 =15%) demonstrated that the UPA group had more blood transfusions than the OPA group. With a fixed-effects model, the results indicated that the OPA group had a higher blood transfusion rate. [OR: 1.50; 95% CI: (1.03, 2.19), p=0.04] (Figure 5A).

Pulmonary Adverse Events

Six studies[14-17,19,23] provided data on thoracic complications, and very few adverse events were reported. A meta-analysis using a fixed-effects model showed that there was no obvious difference between UPA and OPA with respect to pulmonary adverse events [OR: 2.71; 95% CI: (0.85, 8.70), p=0.09] (Figure 5B).

Postoperative Fever/Asepsis

Five studies[14,15,17,19,20] were included for this outcome. A meta-analysis performed using a fixed-effects model demonstrated that the incidence of postoperative fever/asepsis was not significantly different between the two groups [OR: 1.31; 95% CI: (0.60, 2.85), p=0.50] (Figure 6A).

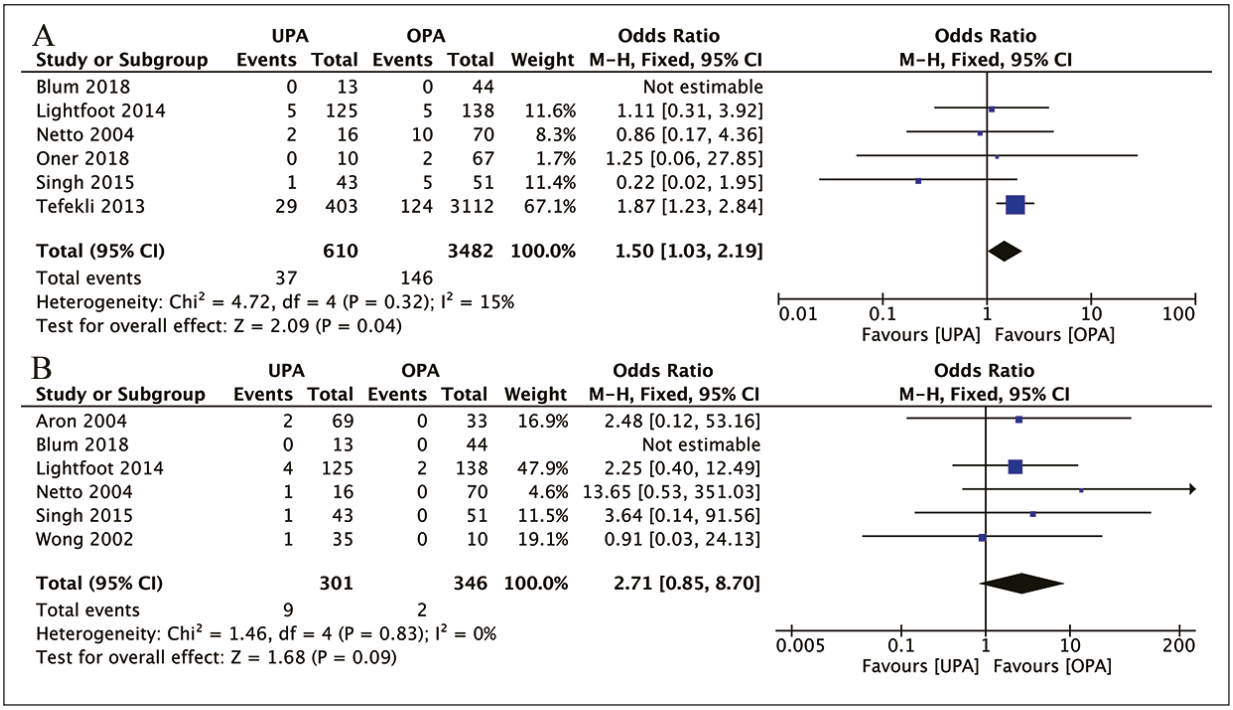

Figure 5. Forest plots and meta-analyses. **A**, Blood transfusion; (**B**) pulmonary adverse events (95% CI: 95% confidence intervals, df: degrees of freedom, Fixed: fixed effects model, Random: random effects model, IV: inverse variance, SD: standard deviation).

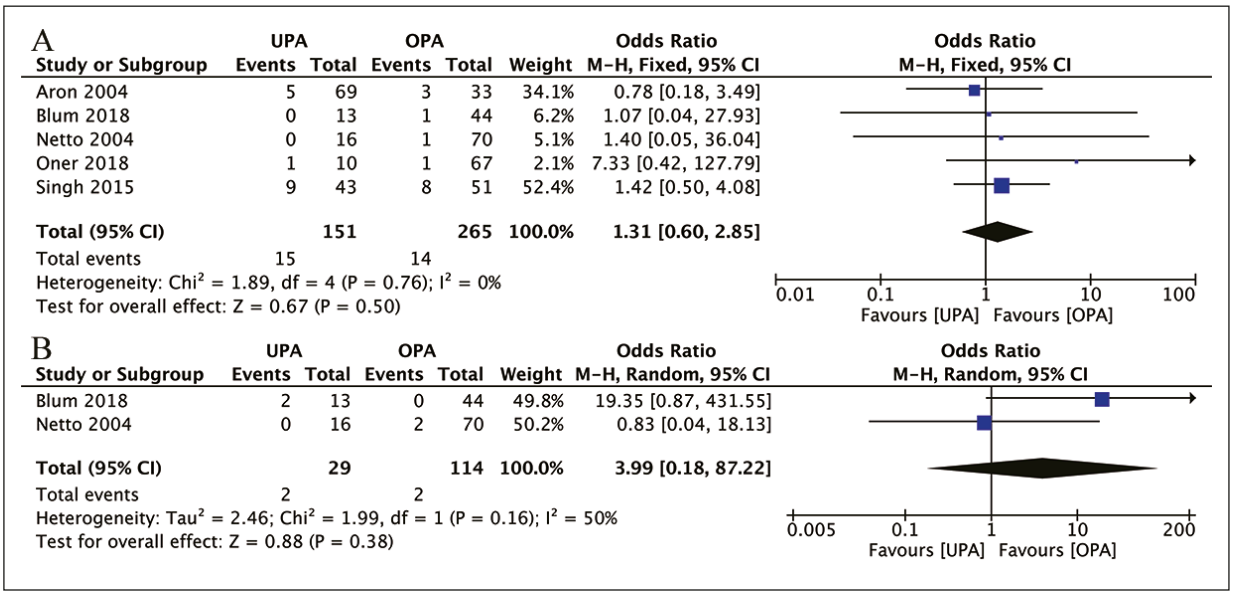

Figure 6. Forest plots and meta-analyses. **A**, Postoperative fever/asepsis; (**B**) urine leakage (95% CI: 95% confidence intervals, df: degrees of freedom, Fixed: fixed effects model, Random: random effects model, IV: inverse variance, SD: standard deviation).

Urine Leakage

Only two studies[15,17] provided data for this outcome. When pooled and analyzed with a fixed-effects model, no significant difference was found between UPA and OPA with regard to urine leakage [OR: 3.99; 95% CI: (0.18, 87.22), p=0.38] (Figure 6B).

Auxiliary Treatment

Auxiliary procedures to achieve stone-free status included shockwave lithotripsy, repeat PCNL, and URS. A pooled analysis using a random-effects model showed no significant difference between the two groups [OR: 0.96, 95% CI: (0.64, 1.44), p=0.85, I^2=59%] (Figure 7).

Complications

A comparison of total complication rates between the two groups is shown in Figure 4. The data on overall complications were provided by six studies[15,16,18,19,21,22]. The meta-analysis showed that the total complication rates were significantly different in both groups [OR: 1.67; 95% CI: (1.36, 2.05), p<0.00001]. The outcome also strongly supports that the UPA group had a lower incidence rate of minor and major complications than the OPA group. [OR: 1.47, 95% CI: (1.16, 1.85), p=0.001; OR: 1.91, 95% CI: (1.30, 2.80), p=0.001, respectively] (Figure 8). With the aim of detecting complications based on Clavien-Dindo grade, four studies[15,16,19,22] were used for the statistical analy-

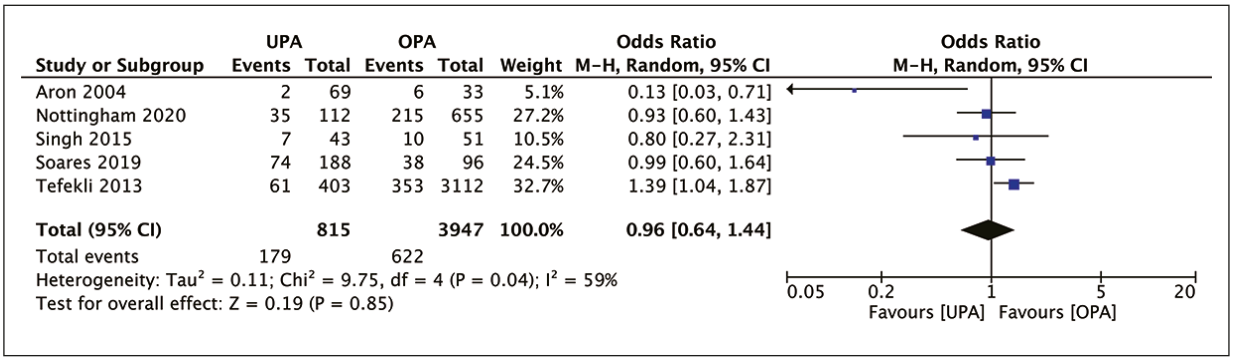

Figure 7. Forest plots and meta-analyses of auxiliary treatment; (95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, IV: inverse variance, SD: standard deviation).

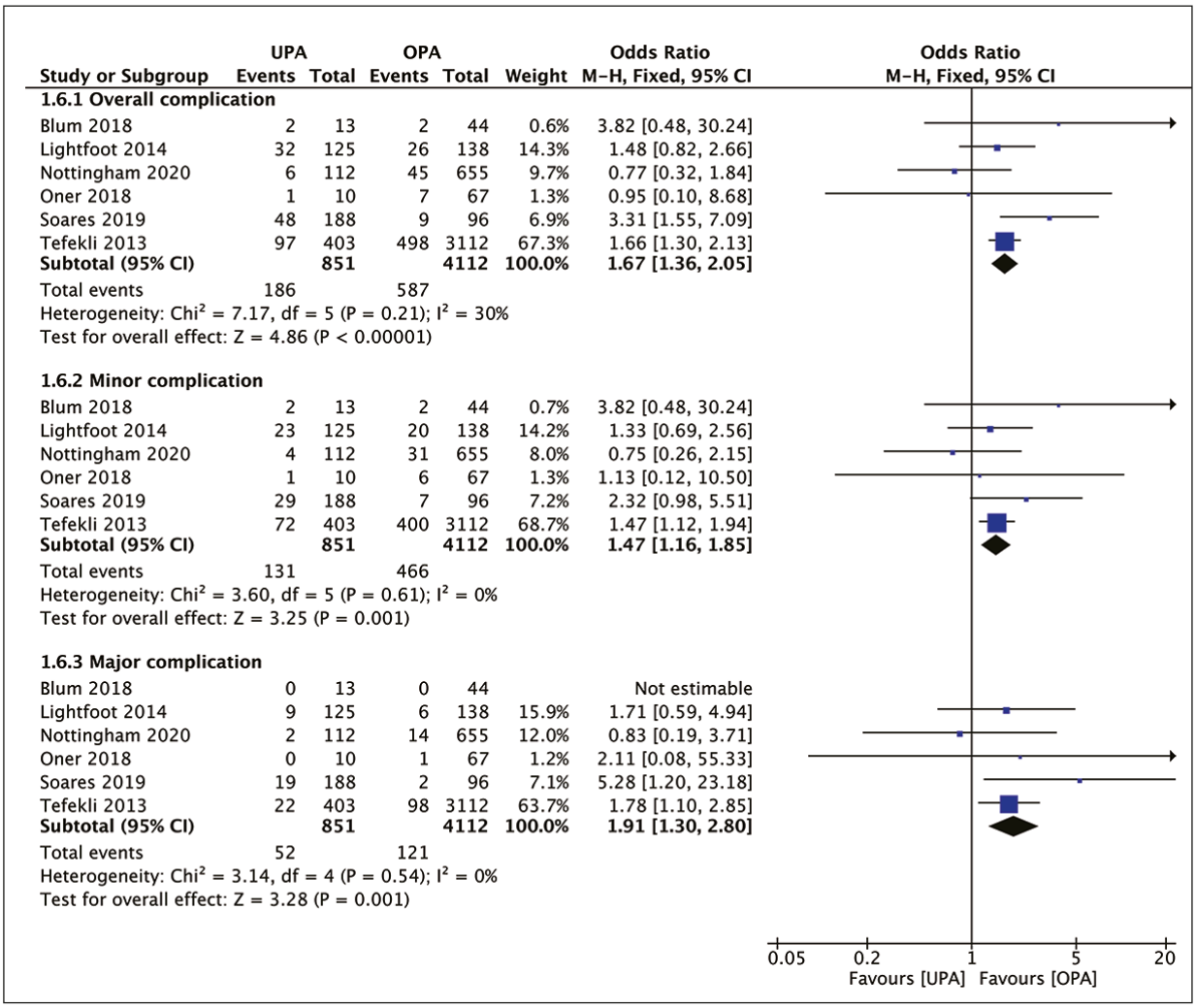

Figure 8. Forest plots and meta-analyses of overall complications, minor and major complications (95% CI: 95% confidence intervals, df: degrees of freedom, Fixed: fixed effects model, IV: inverse variance, SD: standard deviation).

sis. The results showed that there was no evidence of significant differences with respect to the incidence of Clavien-Dindo grades I and IV complications [OR: 1.29; 95% CI: (0.95, 1.75), p=0.10; OR: 1.19, 95% CI: (0.39, 3.62), p=0.76, respectively]. However, the result was statistically significant in that the UPA group had a lower incidence of Clavien-Dindo grades II and III complications [OR: 1.71, 95% CI: (1.16, 2.51), p=0.007; OR: 1.92, 95% CI: (1.21, 3.05), p=0.006] (Figure 9).

Publication Bias

A funnel plot was constructed to assess publication bias (Figure 10). Apparent asymmetry was observed, which indicated the existence of publication bias.

Discussion

The incidence of nephrolithiasis continues to increase worldwide across all ages, leading to an increasing number of both adults and children requiring treatment for renal stone disease. At present, PCNL has become the preferred treatment for upper urinary calculi, especially complex renal calculi and recurrent nephrolithiasis[24,25]. Although PCNL is associated with a high success rate, it is also associated with complications, with a recent multicentre study showing an overall complication rate of 20.5%[26]. Among the different studies reported, bleeding and injury to the pleura were the most common and concerning complications[27]. The SFR and complications differ accord-

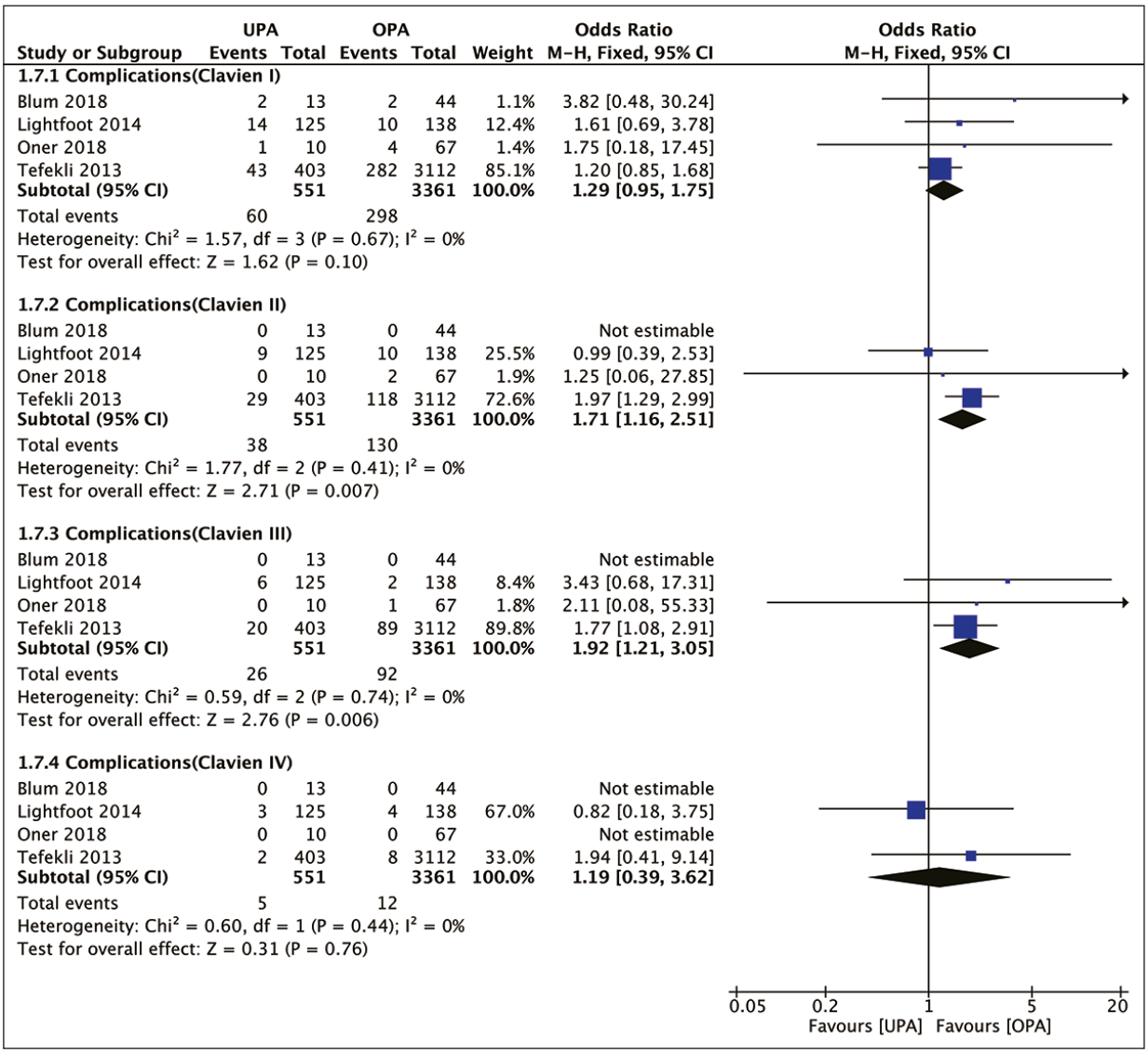

Figure 9. Forest plots and meta-analyses of Clavien-Dindo grade complications (95% CI: 95% confidence intervals, df: degrees of freedom, Fixed: fixed effects model, IV: inverse variance, SD: standard deviation).

ing to the type of calyceal access used for PCNL in the treatment of upper urinary calculi, and the selection of the target calyceal puncture site is still being discussed. Choosing a suitable, accurate, and atraumatic percutaneous renal access is paramount to the success of any PCNL. Doing so maximizes both its effectiveness, in terms of the SFR, and its safety by reducing the risk for complications[28]. There is no consensus on the influence of different target calyces on the outcome of PCNL. Therefore, it is worth comparing the efficacy and safety of UPA and OPA for the treatment of upper urinary stones.

The SFR is the main outcome used in this article to identify whether there is a difference in efficacy between UPA and OPA. Meta-analysis results showed that there were no statistically significant differences in SFR between the two groups [OR: 1.38, 95% CI: (0.94, 2.03), p=0.10]. However, the results showed high heterogeneity. When performing the sensitivity analysis, we found that the study by Tefekli et al[22] caused high heterogeneity. After excluding this study, no heterogeneity was found, and the results indicated that the UPA group had a higher SFR. A potential reason may be that the data in this study were

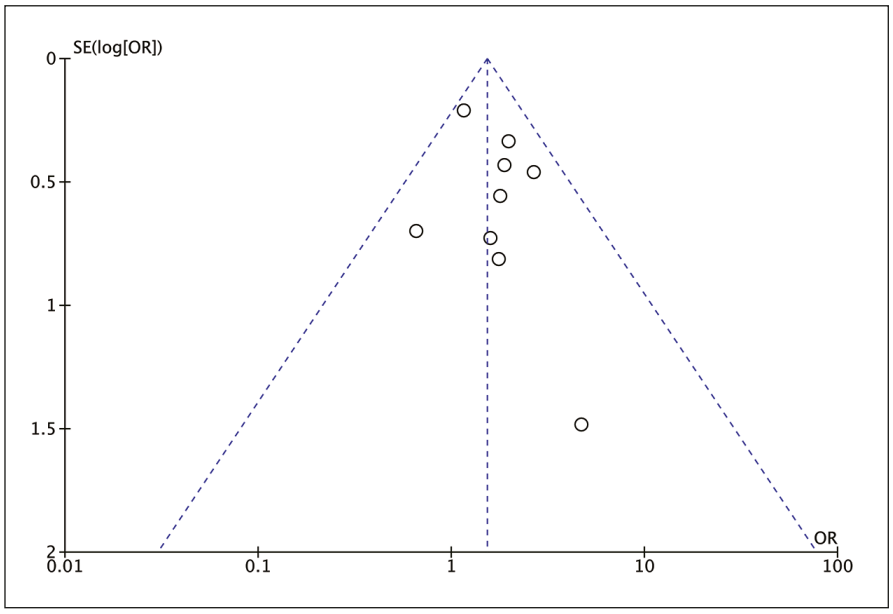

Figure 10. Funnel plot of SFR for publication bias.

collected from large samples of patients at 96 centers worldwide. UPA for PCNL provides anatomic advantages for better stone clearance, such as easy entry into the desired calyx, and it also allows easy manipulation of instruments[29]. Due to the limited scope of nephroscopic activity, calculi in the upper and lower calyx regions are difficult to remove *via* middle calyx puncture, which leads to a low stone clearance rate[30]. On the other hand, LP access restricts the manipulation of the nephroscope into other calyces or even the renal pelvis, where stone/fragments migrate in some cases. However, with the development of minimally invasive techniques and improvements in surgical experience and skills, PCNL of the upper and lower middle calyces achieved approximately the same SFR. This result is different from other studies[31-33], which may be due to the following factors. First, we analyzed single-access PCNL in patients with different types of calculi (simple, multiple, staghorn calculi), while the majority of other studies[31-33] rarely analyzed staghorn stones or single-access PCNL alone. Comparisons of the SFR among different types of accesses need to be performed in groups that are similar in terms of the stone burden, localization, and number of tracts. Unfortunately, we could not conduct a subgroup analysis to analyze the influence of the number of tracts on treatment effectiveness due to insufficient data. Second, different definitions and imaging modalities were adopted to evaluate the SFR among the 10 studies. For example, imaging modalities that included kidney-ureter-bladder (KUB) plain-film X-rays and/or ultrasonography and/or non-contrast computed tomography (CT) were used to assess whether patients were free of stones. It is worth noting that there was no consensus on the definition of the SFR among the 10 included studies, which could have led to conclusion bias. Third, the SFR was also related to the follow-up time, as the SFR 1 month after surgery was higher than that 1 day after surgery. Time is needed for stone fragments to be flushed out with urine. The size and location of the stone also make a difference. Some large stones even need a second round of treatment to be completely removed. The articles included in the present study used different types of lithotripsy techniques, which may have influenced the SFR. Clinical evaluation demonstrated that the combined use of pneumatic and ultrasonic devices significantly increased the efficiency of stone fragmentation. The surgeon experience should also be considered when mentioning the SFR. Li et al[34] reported that PCNL was performed by finger touching combined with X-ray guidance, which also achieved a high SFR.

Complications were recorded according to the Clavien-Dindo classification system[35]. Complications with Clavien-Dindo scores of I or II were categorized as minor, whereas those with Clavien-Dindo scores of III, IV and V were classified as major. Our evidence suggested that there was no significant difference in grade I, IV or V complications between the two groups, and the incidence of Clavien-Dindo grades II and III complications in the OPA group was higher than that in

the UPA group. According to the selected studies, Clavien-Dindo grade II complications included blood loss requiring transfusion and urinary tract infection (UTI) requiring antibiotics, and Clavien-Dindo grade III complications included pneumothorax requiring a chest tube, secondary cystoscopy, or ureteral stent placement.

One of the most common and concerning complication seen in patients undergoing PCNL is blood loss, either intraoperatively or postoperatively. Additionally, a wide variation in the rate of blood transfusion for bleeding, ranging from 1% to 55%, has been described in the literature[36]. The present study showed that the OPA group was more likely to need a blood transfusion than the UPA group, but the need for blood transfusion was not associated with a postoperative hemoglobin decrease. However, in the literature was previously reported that UPA patients more easily experience blood loss. After screening related literature and combining our clinical experience, the factor that had the greatest influence on blood loss during PCNL was the stone burden. Compared to calyceal stones, complete and partial staghorn calculi were associated with greater blood loss, as shown in various studies[37,38]. In comparison to non-staghorn calculi, staghorn calculi caused greater changes in hematocrit levels[39]. Staghorn and bulky stones increase the number of maneuvers necessary for complete clearance of stone fragments from the pelvicalyceal system. Moreover, the use of rigid nephroscopes to reach the stones inside different calices may cause injury to the renal parenchyma and caliceal necks, thus increasing the risk of bleeding. The use of flexible nephroscopes, however, can decrease the need for transfusion and the risk of bleeding without affecting the success rate[40]. UPA is usually used for selected cases with complex stones or a need for multiple accesses[22,41]. Therefore, the higher bleeding volume reported for UPAs may be the result of this higher stone burden and/or multiple tracts[42]. Additionally, differences in the surgical technique and the experience of the attending surgeons may have impacted the rate of vascular complications. A history of open stone surgery and intraoperative injury (e.g., infundibular, or pelvic wall tears) have also been associated with increased blood loss[43,44]. Most of the bleeding that is related to PCNL can be managed with supportive treatment, and only 0.8% of patients need angioembolization to control intractable bleeding[45]. Unfortunately, the studies mentioned above are all retrospective studies and report relatively large differences in stone burden. Therefore, determining the safety profile of UPA will require high-quality RCTs.

The incidence of thoracic complications, postoperative fever and urine leakage were not significantly different between the groups. This result is probably different from the literature, and previous studies[8,46] have demonstrated that UPA was well-documented to be associated with a high risk of intrathoracic complications. Although we found that the rate of thoracic complications (hydrothorax and pneumothorax) did not differ between the two groups [OR: 2.71, 95% CI: (0.85, 8.70), p=0.09], we noted that UPA tended to be associated with a higher rate of pulmonary complications. UPA can be achieved either supracostally or subcostally. The rate of pulmonary complications is unequivocally higher with supracostal UP approaches, with some sources describing occurrence rates greater than 15%[47]. Despite this finding, the literature tends to support the continued use of UPA, citing more expeditious, direct, and complete stone removal with fewer access sites. Anatomically, the parietal pleura crosses the middle of the 12th rib posteriorly and the 11th rib at the posterior axillary line. This makes the 11th intercostal space lateral to the mid-scapular line a safe zone, thus minimizing the risk of any pleural injury. To prevent pleural complications, the surgeon usually attempts infracostal puncture[48]. Even if these thoracic complications do occur, the majority of patients will recover either spontaneously or by a simple intervention, with minimal future comorbidity.

We also found no differences in operative time between UPA and OPA. Nevertheless, some studies[14,16,22] have suggested that the mean operation time was significantly longer in the UPA group than in the OPA group. However, certain factors have been identified as reasons why UPA is associated with a longer operative time than OPA. First, the UPA group had more staghorn stones and a greater stone burden than the OPA group. A high stone burden always contributes to a longer operative time and a longer crushing time and implies a significant amount of stone dust and debris that limits visibility[49]. Placement of the nephrostomy tube and the rate of postoperative internal ureteral stent use are also associated with a long operative time. The operative time was calculated using different criteria in different studies, most of which were not clearly defined, which has an important impact on the results. We speculate that operative time was the most important source of high heterogeneity and publication bias. In the current study, the meta-analysis on operative time had high heterogeneity, and the sensi-

tivity analysis also showed no significant difference between the two groups. In addition, compared to PCNL without suction, PCNL with concurrent aspiration results in a significantly higher SFR and a shorter surgical duration. El-Nahas et al[50] noted that without concurrent negative pressure aspiration, stones need to be crushed into smaller and finer fragments to be flushed out by the infusion, which prolongs the operation time.

Our pooled data indicated that there was no statistically significant difference in the length of hospital stay between the UPA and OPA groups. Multiple comparative studies[51,52] have shown that using a ureteral stent but not a nephrostomy tube for drainage (tubeless) or not using neither a stent or nephrostomy tube (totally tubeless) reduces postoperative pain, the analgesic requirements and the length of hospital stay. In terms of operative time and length of hospital stay, there was high heterogeneity among the included study results, which may be related to the lithotripsy equipment, surgical level and experience of the operators.

To the best of our knowledge, our study is the first to evaluate the current evidence on the effectiveness and safety of performing PCNL through UPA and OPA in the surgical management of renal stones following the PRISMA guidelines. We report the most up-to-date information on the surgical treatment of patients with renal calculi, which we hope can help urologists and patients when selecting the optimal access.

Limitations

The present meta-analysis, which was performed using currently available comparative trials, has several limitations. The data from the selected studies were published results, and negative results were difficult to obtain, which resulted in certain publication bias. The descriptions of each research methodology were not detailed, and no research with high methodological quality was included. In terms of operation time, there was heterogeneity among the results due to differences in the operator's skill level and the hospital equipment used in various studies. Therefore, we look forward to more high-quality, multicenter RCTs to provide more detailed and accurate findings of evidence-based medicine and to further explore its efficacy and safety.

Conclusions

In conclusion, the current study indicates that both UPA and OPA are effective methods for treating renal stones. Compared to OPA, UPA is associated with less need for blood transfusion and fewer complications. No statistically significant differences were found in operation duration and length of hospital stay between the groups. When choosing a suitable renal access, some subjective factors, including surgeon experience and preferences and patient features and willingness, should be taken into consideration. Due to the mixed group of patients, these results should be interpreted with caution. The findings of this study should be further confirmed by well-designed prospective RCTs with larger patient samples.

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Authors' Contributions
T. Huang, B-B. Jiao made contributions to conception and design of acquisition of data. Z-K. Luo, H. Zhao have been involved in revising it critically. T. Huang, B-B. Jiao, Z-K. Luo, G. Zhang analyzed and interpreted the patient data. T. Huang, B-B. Jiao performed the data analyses and wrote the manuscript. G. Zhang helped perform the analysis with constructive discussions. L. Geng contributed analysis tools. All authors read and approved the final manuscript.

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Conflict of Interest
The authors declare that this study has received no financial support and they have no conflict of interests.

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