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Review

Supine versus prone position for percutaneous nephrolithotripsy: A meta-analysis of randomized controlled trials

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ABSTRACT

Objective: To compare the safety and efficacy of percutaneous nephrolithotripsy (PCNL) in supine versus prone position for patients with renal or upper ureteral calculi.

Methods: A systematic search of Pubmed, Embase and Cochrane Central Register of Controlled Trials was performed to identify all eligible studies. All included randomized controlled trials (RCTs) were evaluated based on the inclusion and exclusion criteria. After quality assessment and date extraction, a meta-analysis was performed using RevMan 5.3 software.

Results: A total of 15 RCTs with 1474 patients were included in our meta-analysis. Pooled data showed that PCNL in supine position could significantly reduce the operative time [weighted mean difference (WMD) −12.02, 95% confidence interval (CI) −20.49 to −3.54, p = 0.005] and rate of fever [risk ratio (RR) 0.67, 95% CI 0.46 to 0.97, p = 0.03] compared to prone position. In addition, no significant differences could be found between groups in stone-free rate (p = 0.31), hospital stay (p = 0.59) and rate of overall complications (p = 0.11), mainly including urinary leakage (p = 0.83), pleural effusion (p = 0.74) and blood transfusion (p = 0.58).

Conclusions: The current study found comparable stone-free rate and significant lower rate of postoperative fever in supine PCNL compared with prone PCNL. PCNL in supine position could be a safe and efficient choice for patients with renal or upper ureteral calculi.

1. Introduction

Percutaneous nephrolithotomy (PCNL) is the standard treatment for patients with complex or large upper urinary tract stones. Because it allows a large surface area for renal puncture, PCNL is routinely performed in prone position, which can also provide a wide space for instrument manipulation and avoid abdominal visceral injuries as much as possible. However, it has some potential drawbacks, especially in cardiac, obese and elderly patients. It may also increase the happening of anesthesia complications (position-related circulatory and ventilator difficulties) and be difficult for intraoperative reposition. In addition, this position is also unsuitable for numerous patients with a skeletal deformity [1].

In 1998, Valdivia et al. [2] firstly reported their experience of PCNL in supine position and described the advantages of this technique. For PCNL in supine position, not only does it overcome the drawbacks by prone PCNL, but also provide some potential advantages. For example, it can provide an opportunity for surgeons to simultaneously perform PCNL and ureteroscopic procedures, save the operation time of turning over patients. However, disadvantages coexist, such as it limits the space for renal puncture and it may be difficult for manipulating nephroscope.

Considering the advantages and limitations of these two positions, more and more controversies presented focusing on how to choose the optimal position for PCNL. Though several researches had compared supine with prone position for PCNL, the results were still inconclusive. The aim of our meta-analysis is to update the previous publications and provide more accurate conclusions on the safety and efficacy of PCNL in supine versus prone position for patients with renal or upper ureteral calculi.

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2. Materials and methods

Our meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement (PRISMA) and Assessing the methodological quality of systematic reviews (AMSTAR) guidelines [3,4]. Before this meta-analysis, a prospective protocol was made.

2.1. Search strategy

A systematic search of Pubmed, Embase and Cochrane Central Register of Controlled Trials was performed to identify all eligible studies (up to April 1, 2019), with no limitation in language and publication date. The following terms and their combinations were employed in the Title/Abstract field: ("Nephrostomy, Percutaneous" OR "PCNL" OR "percutaneous nephrolithotomy" OR "nephrolithotripsy") AND prone AND supine. We also conducted manual search of references list from the included studies to identify additional eligible studies.

2.2. Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) randomized controlled trials (RCTs); (2) patients with renal or upper ureteral stones; (3) studies comparing PCNL in supine with prone position; (4) publications including at least one outcome of interest, such as stone-free rate, operative time, hospital stay and operative complication. Studies would be excluded if: (1) included patients had renal abnormalities (such as whole horseshoe kidney and ectopic kidney); (2) included pediatric patients; (3) described unclear position of PCNL; (4) published as conference abstracts.

2.3. Data extraction

Two reviewers independently screened the titles and abstracts of articles after initially identified. All disagreements would be resolved by consensus. The following data were extracted from eligible full-text RCTs: author, year of publication, number of patients, basic characteristics of patients and stones, tools for detecting of residual fragments, definition of stone free, PCNL technique: tubeless or non-tubeless, and outcomes of interest. Basic data of patients included: age, gender, body mass index (BMI), stone burden, and side of stone. Outcomes of interest included: primary outcome, such as stone-free rate, and secondary outcomes, such as operative time, hospital stay, and operative complications, including fever, urine leakage, pleural effusion and blood transfusion.

2.4. Assessment of risks of bias

Risk of bias was assessed independently by two reviewers. The Cochrane Collaboration's tool was used to assess the risk of all RCTs [5]. This tool assesses the quality of study according to following aspects: Selection bias (random sequence generation and allocation concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other biases. For each domain, the risk of bias could be marked as low, unclear and high.

2.5. Statistical analysis

The meta-analysis was performed by using Review Manager (RevMan v.5.3). The weighted mean difference (WMD) was used for continuous variables and risk ratio (RR) was used for dichotomous parameters. If studies reported continuous data as median and range values, an approximate transformation formula described by Hozo [6] was used to calculate mean and standard deviations (SD). We evaluated the heterogeneity among studies by using the Chi-squared statistics and quantified the degree of heterogeneity with *I*-square (I^2) tests. A p-value < 0.10 indicated the existence of heterogeneity, and I^2 values of 25%, 50%, and 75% corresponded to low, moderate, and high degrees of heterogeneity, respectively. If the I^2 value was < 50% and p-value > 0.10, a fixed-effects model was used for analysis. Otherwise, a random-effects model would be used. And whole effects with p-value < 0.05 was considered statistically significant. Sensitivity analyses were respectively conducted to avoid the effects of studies using tubeless PCNL technique or quasi-randomization method. The funnel plots were used to assess potential publication bias.

3. Results

3.1. Characteristics of included studies

A total of 455 records were initially retrieved, in which 153 articles were excluded for duplication, 269 articles were excluded after screening of the title and abstract, and 2 articles were excluded for unable to access full text. A further detailed evaluation of the remaining 31 full-text articles resulted in excluding additional 16 studies due to non-RCTs (n = 13), unclear position (n = 1), unextractable data (n = 1), and PCNL for children (n = 1). Finally, 15 studies [7–21] consist of 1474 patients were included for meta-analysis (Fig. 1). Tubeless PCNL technique was applied in 4 studies [9,14,18,19]. The basic characteristics of the included studies were summarized in Table 1.

3.2. Quality assessment

Among 15 RCTs, 2 studies [8,16] were considered to have high risk because of using quasi-randomization for random sequence generation. Considering ethics factor of surgery, it's impossible to achieve allocation concealment and blind methods. Therefore, all trails were evaluated to have high risk for blinding of patients and practitioners. And there was a high risk of selective reporting bias in one study [19] for not reporting sufficient data of some important outcomes (Fig. 2).

3.3. Meta-analysis of included studies

3.3.1. Stone-free rate

All of 15 enrolled studies [7–21] including 1474 patients reported stone-free rate. In total, the stone-free rate could be calculated to be 78.1% (574/735) in supine group and 80.0% (591/739) in prone group. There was no significant difference between two groups (RR 0.97, 95% CI 0.93 to 1.02, p = 0.31). For insignificant heterogeneity, a fixed-effects model of analysis was used (P = 0.53, I^2 = 0%) (Fig. 3).

3.3.2. Operative time

13 studies [7–12,14–18,20,21] were pooled to assess operative time between two groups. We used the random-effects model as there was a significant heterogeneity among studies (P < 0.00001, I^2 = 93%). Pooled data indicated significantly less operative time in supine group than prone group (WMD −12.02, 95% CI −20.49 to −3.54, P = 0.005) (Fig. 4).

3.3.3. Hospital stay

Data of hospital stay could be obtained in 13 studies [7,9–18,20,21]. Insignificant difference was found in supine group compared to the prone group (WMD −0.08, 95% CI −0.36 to 0.20, P = 0.59). However, significant heterogeneity was found among studies (P < 0.00001, I^2 = 85%) (Fig. 5).

3.3.4. Complications

All studies provided information of complications. The rate of overall complications was 16.1% (118/735) in supine group and 19.2% (142/739) in prone group. Result from meta-analysis showed

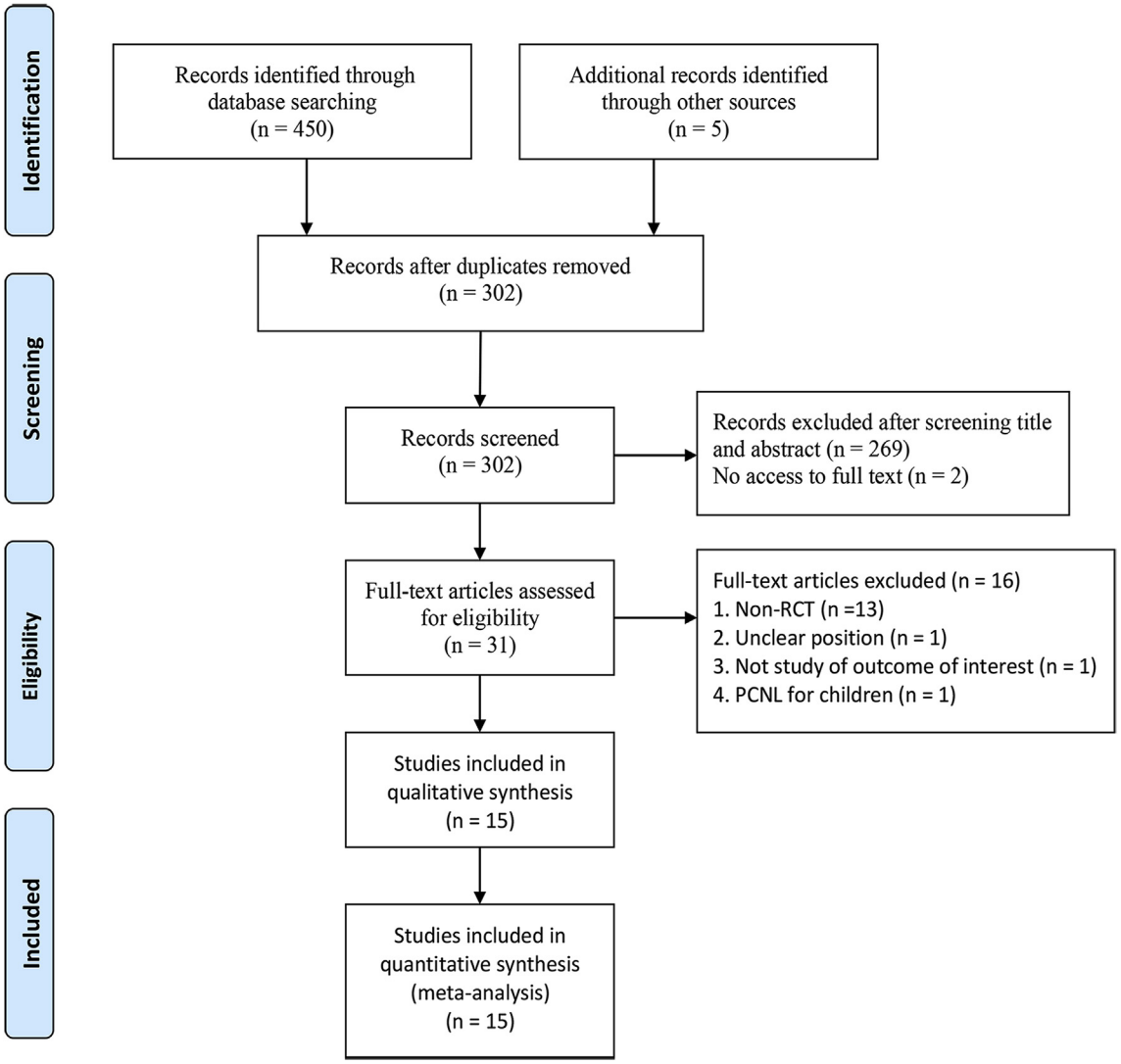


Fig. 1. Flowchart of the literature search and studies selection.

insignificant difference between two groups (RR 0.84, 95% CI 0.67 to 1.04, p = 0.11). Because no heterogeneity was observed, the fixed-effects model was used (P = 0.75, I^2 = 0%) (Fig. 6).

Further, we compared each complication, which showed a significant lower risk in rate of fever in supine group (RR 0.67, 95% CI 0.46 to 0.97, p = 0.03) and insignificant differences between two groups in rate of urinary leakage (RR 0.92, 95% CI 0.45 to 1.88, p = 0.83), pleural effusion (RR 0.79, 95% CI 0.20 to 3.18, p = 0.74) and blood transfusion (RR 1.14, 95% CI 0.72 to 1.80, p = 0.58) (Fig. 7).

3.4. Sensitivity analysis

Sensitivity analysis was performed by deleting studies using tubeless PCNL technique [9,14,18,19] and quasi-RCTs [8,16], respectively. After the studies using tubeless PCNL were excluded, the result showed no significant difference in rate of postoperative fever between supine and prone group (RR 0.69, 95% CI 0.44 to 1.06, p = 0.09), while other outcomes were similar. Moreover, after quasi-RCTs were excluded, all outcomes remained constant, indicating that the pooled results had a satisfactory reliability.

3.5. Publication bias

The publication bias was tested by funnel plot. The result demonstrated no evident bias existed regarding to all outcomes. And the funnel plot of stone free rate was presented (Fig. 8).

4. Discussion

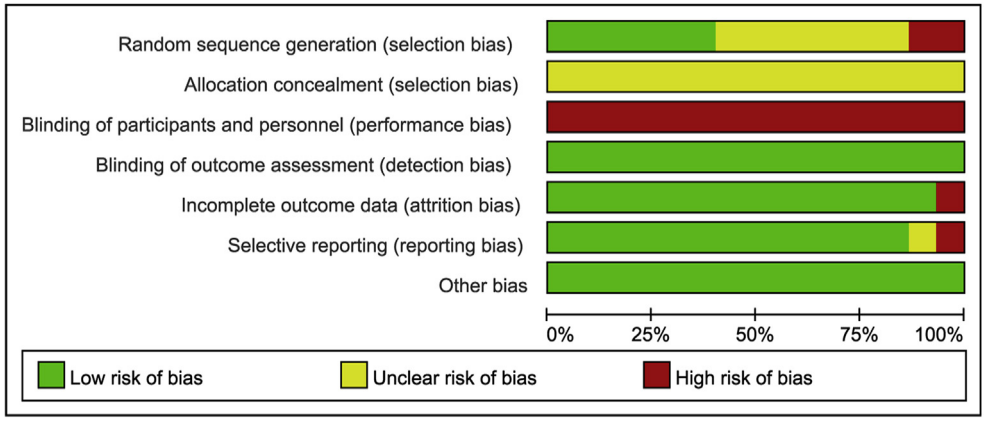
To our knowledge, this study would be the first meta-analysis based on RCTs to compare the safety and efficacy of PCNL in supine and prone position. Though some meta-analyses were previously published, it was still inconclusive because of the quality and quantity of included literatures. To overcome these limitations, only RCTs were included in our study. Moreover, sensitivity analysis was preformed to eliminate possible confounding factors. Pooled data revealed comparable results in stone-free rate, hospital stay, rate of overall complications, urinary leakage and blood transfusion between supine PCNL group and prone PCNL group. However, PCNL in supine position would be superior in operative time and rate of postoperative fever. These indicated that supine PCNL would be a safe and effective procedure.

Stone-free rate was comparable between two position in our study, which was different from the two previous meta-analyses [22,23]. It was once thought that stone-free rate was lower in supine position because it would be difficult in approaching the upper calyx and manipulating nephroscope through this position. In our opinion, the reasons for comparable stone-free rate might be attributed to: firstly, with a variety of modified supine positions were applied, such as Galdakao-

Table 1
Characteristics of included randomized controlled trials.

First author, year	No. of patients (supine vs. prone)	Age, year (supine vs. prone)	Gender, M/F (supine vs. prone)	BMI,kg/m2 (supine vs. prone)	Stone burden (supine vs. prone)	Side, right/left (supine vs. prone)	Tools for detecting of residual fragments	Definition of stone free
Aal AMA, 2013	30 vs.30	34.33 ± 11.4 vs. 37.27 ± 13.8	17/13 vs.12/18	27.17 ± 4.23 vs. 26.57 ± 4.28	2.21 ± 1.2 vs. 2.7 ± 0.84 cm	NA	CT	NA
Abdel-Mohsen, 2013	39 vs.38	40.8 ± 10.5 vs. 44.2 ± 10.4	24/15 vs.13/15	28.8 ± 4.7 vs. 29.2 ± 3.8	3.4 ± 0.7 vs. 3.4 ± 0.8 cm	17/22 vs.20/18	US	no stone ≥ 4 mm
Al-Dessoukey, 2014	101 vs.102	34.84 vs.37.21	68/33 vs.68/34	27.24 vs.26.87	3.68 vs.3.93 cm	NA	X-ray and US	no stone ≥ 4 mm
Basiri, 2013	43 vs.46	45.7(23–70) vs. 44.8(18–80)	30/13 vs.31/15	25.29(19.6–37.3) vs. 24.86(19.8–35.9)	352(100–1200) vs. 345(100–900)mm^2	NA	X-ray and US	no stone ≥ 5 mm
De Sio, 2008	39 vs.36	38(25–72) vs. 41(28–69)	17/22 vs.16/20	28(24–30) vs. 26(23–30)	3.4(2.5–5.1) vs. 3.3(2.7–4.5) cm	20/19 vs.19/17	X-ray and US	no stone ≥ 3 mm
El-Shaer, 2019	129 vs.132	38.8 ± 11 vs. 39.6 ± 9.6	91/38 vs.89/43	28.8 ± 3.4 vs. 27.9 ± 3.2	32.2 ± 9 vs. 31.2 ± 8.9 mm	70/59 vs.79/53	X-ray, US and CT	NA
Falahatkar, 2008	40 vs.40	45.35 ± 11.43 vs. 43.02 ± 13.08	23/17 vs.18/22	25.6 ± 3.5 vs. 26.3 ± 4.2	40.6 ± 15.4 vs. 40.3 ± 16.3 mm	25/15vs.24/16	X-ray	no stone ≥ 5 mm
Falahatkar, 2011	18 vs.15	49.9 ± 12.4 vs. 47.06 ± 7.5	15/3 vs.10/5	26.9 ± 3.4 vs. 24.8 ± 3.07	31.2 ± 14.5 vs. 27.3 ± 6.9 mm	NA	X-ray	no stone ≥ 5 mm
Giusti, 2018	45 vs.45	53.06 ± 13.17 vs. 51.13 ± 15.23	29/16 vs.25/20	25.555 ± 3.724 vs. 24.588 ± 3.257	2.52 ± 0.468 vs. 2.34 ± 0.411 cm	25/20 vs.19/26	CT	no stone ≥ 3 mm
Karami, 2013	50 vs.50	44.4 ± 9.4 vs. 41.5 ± 8.8	34/16 vs.31/19	27.8 ± 4.3 vs. 26.1 ± 4.1	28.2 ± 4.1 vs. 28.3 ± 3.6 mm	24/26 vs.26/24	CT	no stone ≥ 4 mm
Mehrabi, 2014	29 vs.31	39 ± 13 vs. 43 ± 11	17/12 vs.14/17	NA	34.9 ± 13.2 vs. 36.4 ± 10.6 mm	NA	X-ray and US	NA
Mehrabi, 2016	32 vs. 32	46.28 ± 14.49 vs. 50.25 ± 12.34	17/15 vs. 16/16	NA	32.81 ± 5.2 vs. 36.25 ± 4.3 mm	NA	X-ray and US	no stone ≥ 4 mm
Sofer, 2017	27 vs.24	59.5 vs.56.8	9/18 vs.9/15	30.9 vs.28.4	30.9 vs.30.8 mm	11/16 vs.13/11	CT	NA
Wang, 2013	60 vs.62	44(30–69) vs. 42(22–70)	28/32 vs.34/28	24(21–28) vs. 25(20–28)	3.1(1.8–6) vs. 3.0(1.6–5.8)cm^3	31/29 vs.31/31	NA	no stone ≥ 5 mm
Zhan, 2013	53 vs. 56	45 ± 13.0 vs. 44 ± 15.0	36/17 vs. 38/18	24 ± 3 vs. 25 ± 4	3.3 ± 0.4 vs. 3.4 ± 0.5 cm	22/31 vs.25/31	X-ray	no stone ≥ 3 mm

Supine = percutaneous nephrolithotomy in supine position; prone = percutaneous nephrolithotomy in prone position.
BMI, Body Mass Index; NA, Not Available (Insufficient Information Provided).
Age, stone burden and BMI were summarized as mean ± SD or mean (range: minimum–maximum).



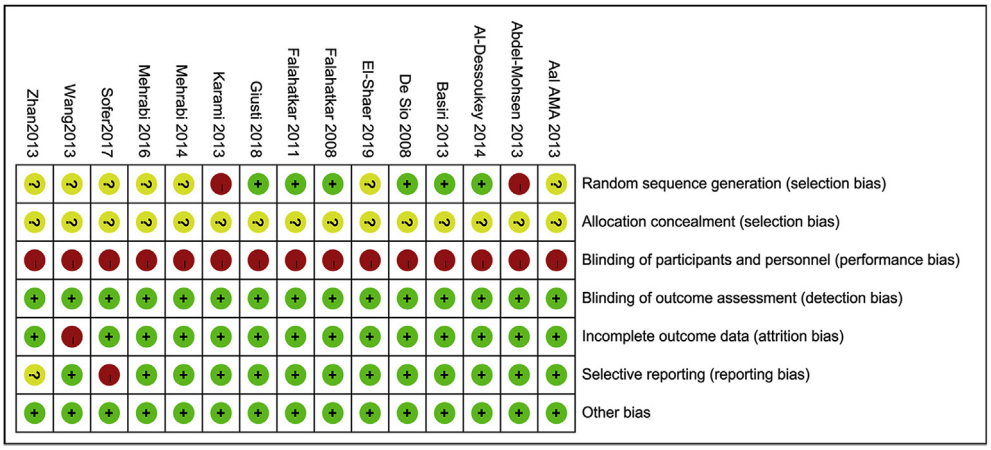


Fig. 2. Graph indicating risk of bias in each included trial.

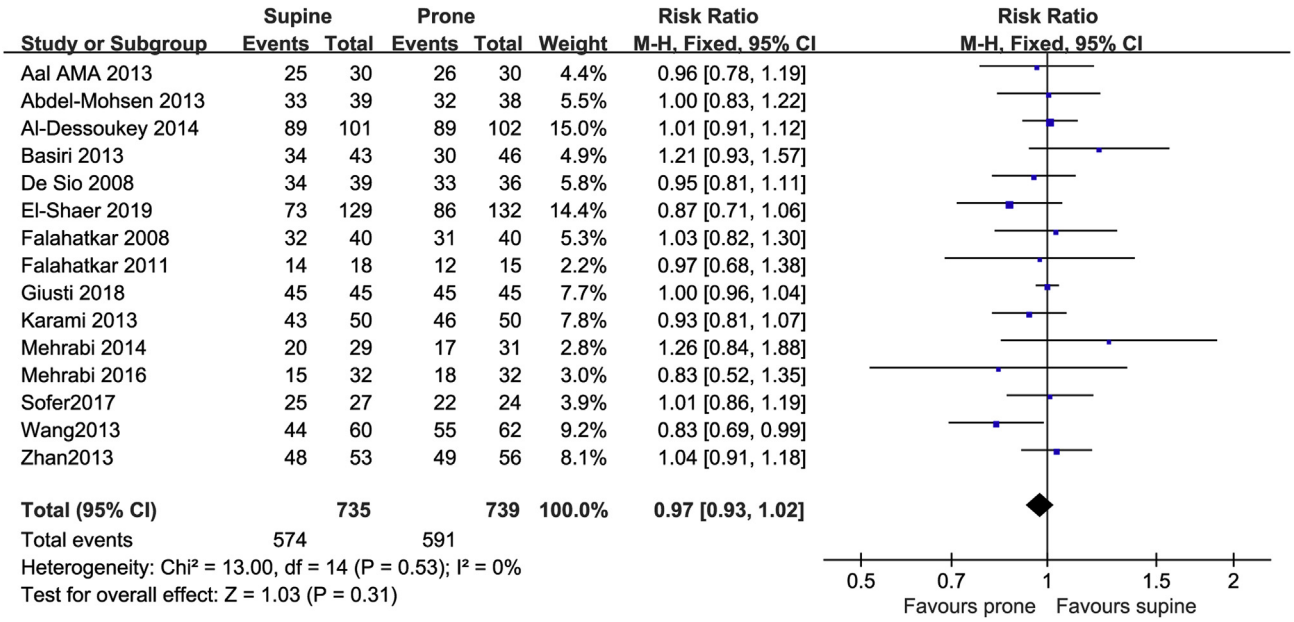


Fig. 3. Forest plot and meta-analysis of stone-free rate in supine group vs. prone group. Supine = percutaneous nephrolithotomy in supine position; prone = percutaneous nephrolithotomy in prone position; CI = confidence interval; M-H = Mantel-Haenszel test.

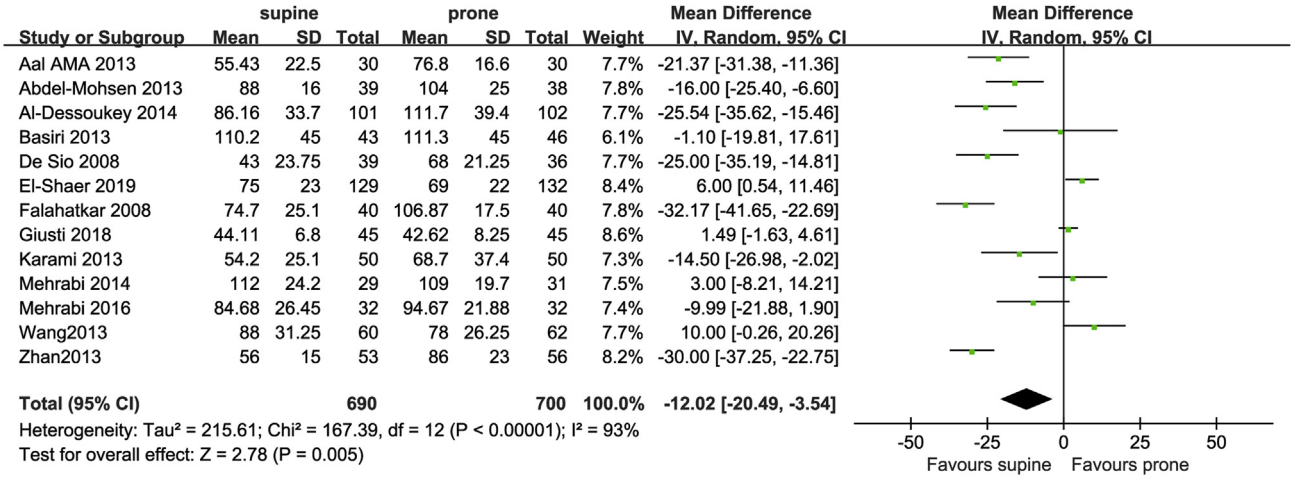


Fig. 4. Forest plot and meta-analysis of operative time in supine group vs. prone group.

modified Valdivia position, modified supine Double-S position and so on, the limitations in original supine position were greatly overcome. These modified positions could provide a wider area for puncture, more space for nephroscope manipulation, and even solve the technical difficulty in approaching upper pole of kidneys [15]. Secondly, supine PCNL offered a possibility to simultaneously perform PCNL and ureteroscopic procedures, described as endoscopic combined intrarenal surgery, which could significantly increase stone-free rate [24]. What's more, horizontal or downward sheath angle accelerated the evacuation of stone fragments, and low intrapyelocaliceal system pressure prevented fragments from migrating to ureter and other calyces [25]. Thus, reducing the possibility of residual stones.

The reduction of operative time in supine PCNL would be mainly attributed to saving time in turning over patients from the lithotomy position to prone position. As mentioned above, simultaneously PCNL and ureteroscopic procedures in supine PCNL could save time as well. Notably, it would be likely to neglect the difference of time spent on some exactly procedures, such as establishing the access and lithotripsy, which were closely related to the surgical complications. Only a research by Giusti et al. [15] reported that the mean time between the first kidney puncture and the creation of a valid access was longer in supine group than that in prone group but with no statistical significance. However, significant heterogeneity was found in our study, which could not be eliminated by sensitivity analysis. Several factors might have contributed to it, such as different characteristics of stones, instruments, or techniques, as well as different definition of operative time among included studies.

Recently, a novel technique of simultaneous bilateral endoscopic surgery (SBES) was reported since 2016 by Giusti et al. [26]. They used this technique to treat a patient with bilateral renal stones combining supine PCNL on the right side and flexible ureteroscope lithotripsy (fURS) on the left side, which showed a satisfactory feasibility and safety. Subsequently, another study [27] reported 26 consecutive patients who underwent SBES combining supine PCNL with retrograde intrarenal surgery, verifying the efficacy and safety of SBES in supine position. In addition, a latest study described the SBES for renal stones combining supine PCNL and fURS in tandem fashion, which was demonstrated to have the potential advantages of shorter operative time, reduced anesthesia, and shorter hospital stay [28]. However, the application of this promising technique should be further explored.

Our study suggested that the length of hospital stay was similar in both groups. Considering previous study reported that patients experienced tubeless PCNL were associated with shorter hospitalization [29], a sensitivity analysis was performed by omitting these studies [9,14,18,19]. However, similar result was obtained. This was in agreement with previous meta-analyses [22,23].

More, complication was a key parameter in evaluating the safety of a surgical procedure. The occurrence of complications not only prolonged the length of hospital stay, but also increased the cost. In our meta-analysis, the rate of fever occurring was significantly lower in supine position compared to the prone position. It might be caused by shorter operative time accompanying with lower intrapyelocaliceal

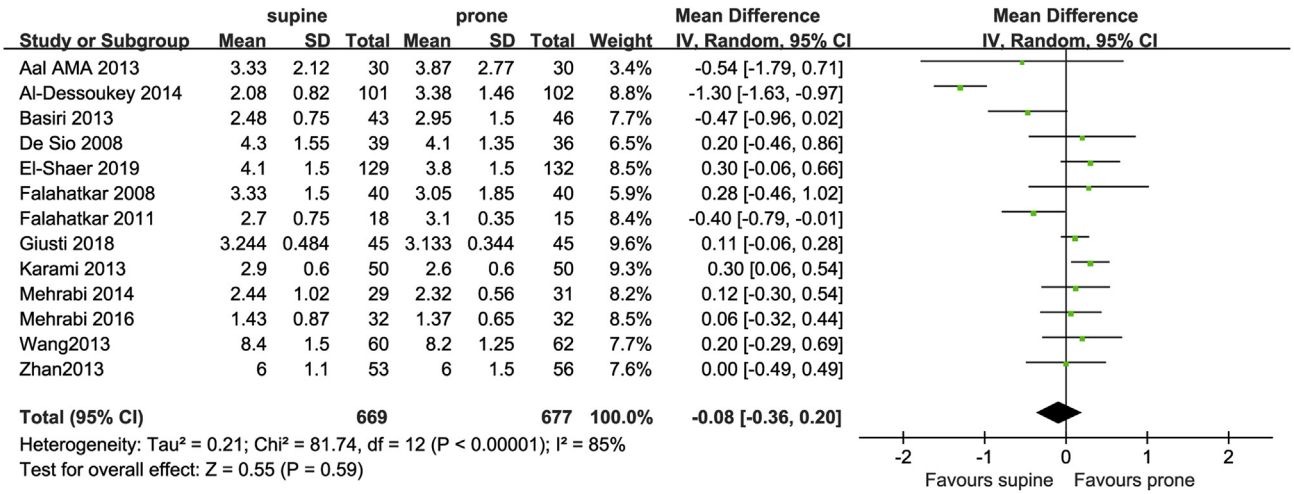


Fig. 5. Forest plot and meta-analysis of hospital stay in supine group vs. prone group.

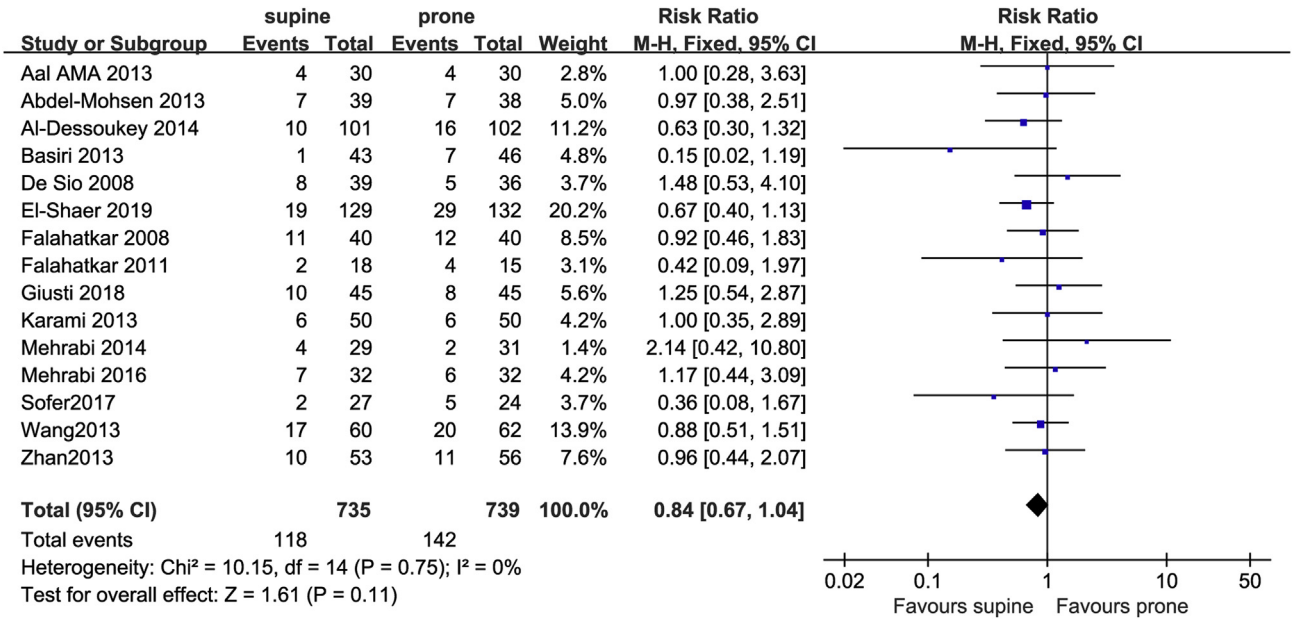


Fig. 6. Forest plot and meta-analysis of overall complication rate in supine group vs. prone group.

system pressure, which might be associated with less frequent bacteremia [10,25,30]. Further, though some authors deemed that bleeding would be more likely to occur in the supine position because the percutaneous access was always through the inferior calix and lower calyx in the supine position [31], the rate of transfusion was insignificant between two groups in our study. As described by Shoma [32], the incidence of acute bleeding was higher in the supine position, but this would be related to the early learning curve which presented some difficulties during dilation and lateral displacement of puncture.

Since the supine PCNL was proposed, one of the major concerns was that whether PCNL in supine poison could increase the risk of colon injury, which was thought to be the major reason why the supine position was not being widely used. Tuttle et al. used computed tomography (CT) to demonstrated that the colon was closer to the kidney in the prone position than the supine position [33]. Desoky et al. [34] also in their study reported that the mean perpendicular distance between colon and the renal access in supine position appears to be farther than in prone position. Moreover, another study by Hopper [35] indicated that the retrorenal colon was found by CT in 1.9% supine patients while 10% in the prone patients. According to these studies, it seemed that the risk of colon injure was lower in supine PCNL. In our study, only two colon injuries were reported in prone group and none in the supine group.

In recent years, increasing attention had been paid on supine PCNL, especially since the Galdakao-modified Valdivia position was introduced in 2007. It made supine PCNL more preferable and economical when compared with prone PCNL because of no need for repositioning, less radiation exposure, opportunity for simultaneous retrograde procedures, more comfortable for surgeons and patients. Nevertheless, though many studies had found that supine PCNL presented a comparable stone-free rate and complication rate, we must be clearly noted that supine PCNL was a new technique for most of urologists, which presented a learning curve. Moreover, probably greater challenges existed in supine PCNL when approaching the upper calyx. So, it would be important to perform supine PCNL by experienced surgeon for selected patients.

Above all, several potential limitations of this meta-analysis should be considered. Firstly, the quality of included RCTs was poor. Two studies used quasi-randomization for random sequence generation which might lead to a selective bias. However, it could be avoided by sensitivity analysis. Secondly, the sample size was small in some studies. Thirdly, for studies included in our meta-analysis, authors used different stone characteristics, supine position, PCNL techniques and definition for outcomes, such as stone free rate and operative time, which would contribute to the heterogeneity among studies. What's more, in the study of Basiri [10], the surgery in supine group was carried out using ultrasound-guided puncture, whereas fluoroscopy-guided puncture in the prone group. It would also bring some biases to our meta-analysis. Finally, tubeless PCNL technique was applied in 4 studies [9,14,18,19], subgroup analysis could not be performed because of non-detailed data.

5. Conclusion

Different from two previous meta-analyses, the current study found comparable stone-free rate and significant lower rate of postoperative fever in supine PCNL compared with prone PCNL. PCNL in supine position would be a safe and effective choice for patients with renal or upper ureteral calculi. The supine position could be an effective option for PCNL by experienced surgeons.

Data statement

Data sharing applicable to this article, and I wish to share my data. All of our data are got from included studies, and presented in tables and figures.

Provenance and peer review

Not commissioned, externally peer reviewed.

Ethical approval

Ethical approval or patient consent was not required since the present study was a review of previous published literatures.

Sources of funding

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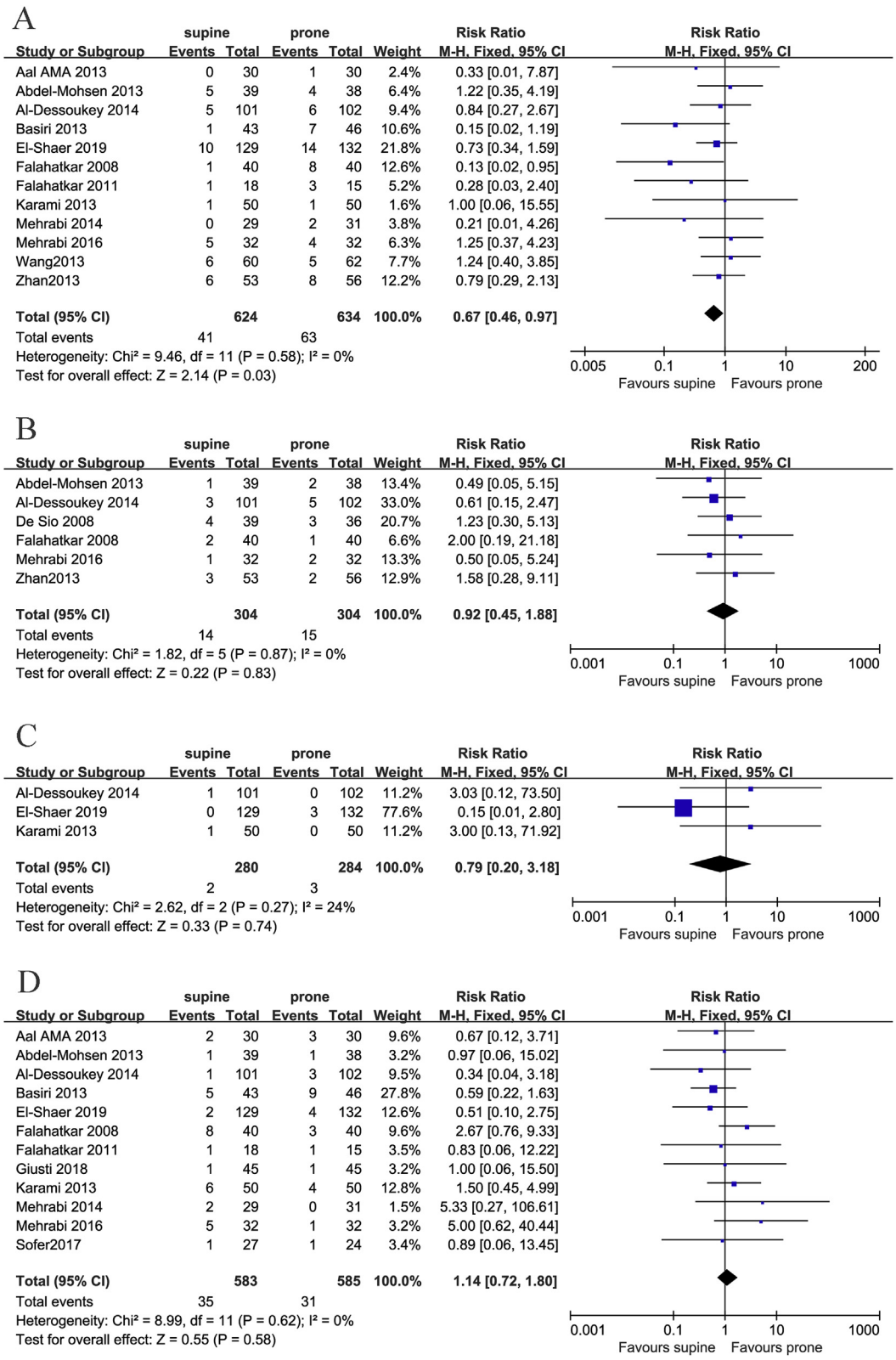

Fig. 7. A: Forest plot and meta-analysis of fever in supine group vs. prone group; B: Forest plot and meta-analysis of urinary leakage in supine group vs. prone group; C: Forest plot and meta-analysis of pleural effusion in supine group vs. prone group; D: Forest plot and meta-analysis of blood transfusion in supine group vs. prone group.

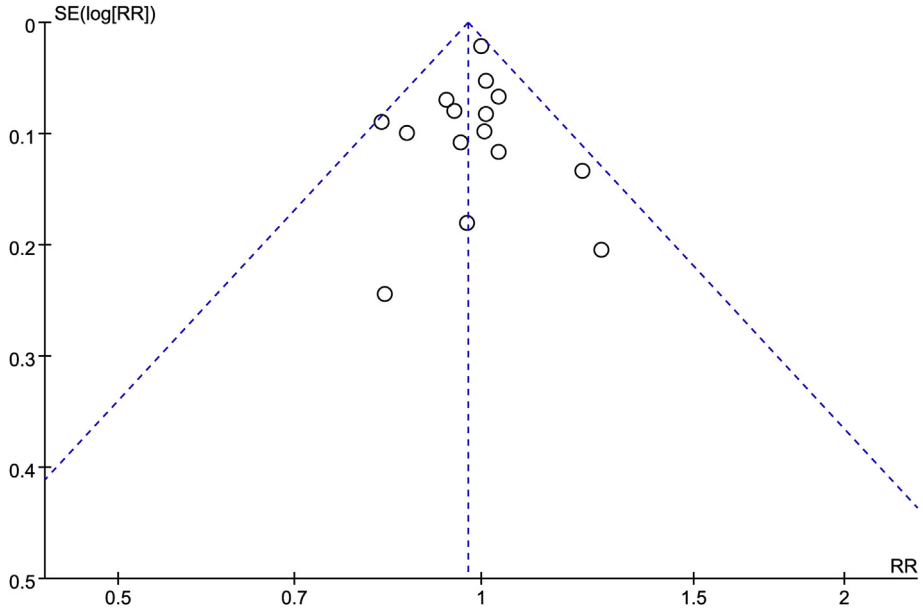

Fig. 8. Funnel plot of stone-free rate for publication bias.

Author contribution

Jie Li: manuscript writing and finish the table and figure.
Liang Gao: data analysis and manuscript editing.
Qiubo Li: data collection and evaluate the study quality.
Yuanfeng Zhang: data collection and evaluate the study quality.
Qing Jiang: study conception and design.

Conflicts of interest

No conflicts of interest.

Research registration number

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Guarantor

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.04.016.

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