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Supine versus prone pediatric percutaneous nephrolithotomy: A systematic review and meta-analysis

Mohamed Ramez[a], Esam A. E. Desoky[b] and Ahmed R. EL-Nahas[a]

[a]Urology Department, Urology and Nephrology Center, Mansoura University, Mansoura, Egypt; [b]Urology Department, Faculty of Medicine, Zagazig University, Zagazig, Egypt

ABSTRACT

Percutaneous nephrolithotomy (PCNL) is the treatment of choice for pediatric nephrolithiasis more than 20 mm. Prone position was the preferred position for decades. Recently, supine position has gained more interest. This meta-analysis aims to evaluate the safety and efficacy of PCNL in supine versus prone position in pediatric population. A systematic search of PubMed, Scopus, Web of Science, and Cochrane Library was performed till 28 February 2024. The study included comparative studies comparing both positions in children that were written in English. A total of three randomized studies and three retrospective studies were included with a total number of 290 patients. Cochrane risk-of-bias tool for randomized trials was used for quality assessment, while Newcastle–Ottawa scale was used for non-randomized controlled trials. The meta-analysis was conducted using Review Manager software. Numerical data were analyzed using standardized mean difference (SMD), while the risk ratio was used for analysis of categorical data. Fixed or random effects models were used according to heterogeneity. There were statistically insignificant differences between both groups for stone-free rate (RR 1.08, 95% CI [0.98–1.18], $p = 0.11$) and overall complications (RR 0.93, 95% CI [0.59–1.47], $p = 0.76$). Operation time was significantly shorter in supine group (SMD −0.99, 95% CI [−1.67 to −0.30], $p = 0.005$). Therefore, comparable efficacy and safety outcomes were proved between both supine and prone positions for PCNL in pediatrics.

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Introduction

PCNL has been established as a gold standard minimally invasive procedure for treatment of pediatric nephrolithiasis more than 20 mm [1]. PCNL has been performed in the prone, but the supine position has proven to be a good option with a number of benefits [2]. The first publication of supine PCNL in pediatrics was through the report of Clinical Research Office of the Endourological Society (CROES), where 12% of included pediatric patients were performed in supine position [3].

Prone position gained its popularity as it provides a wider surface area, a more distended pelvicalyceal system, and easier identification of renal anatomy which led to easier puncture [4]. However, it can have some disadvantages too. It requires changing of position after ureteral catheter fixation. Also, it has its drawbacks for anesthesia, especially in patients with cardiac and pulmonary diseases or those who are obese [5].

On the other hand, the supine position is easier for ventilation and carries a lower risk for anesthesia, which is relevant especially in children [6]. In addition, there is no need for repositioning, and it allows simultaneous use of ureteroscopy, which can be helpful in management of complex stones. However, it has some drawbacks like limiting the surface area for puncture that can increase the risk of trauma to intrarenal vessels [7].

Given those controversies between the two positions, the debate over the advantages and limitations of both approaches and which one is better will continue. This meta-analysis aims to compare the efficacy and safety of supine versus prone PCNL in pediatric population.

Methods

Search strategy

A literature search was carried out through PubMed, Scopus, Web of science and Cochrane library for studies comparing supine and prone PCNL in pediatric population till 28 February 2024. The search strategy included the following terms: Supine AND Prone AND ('Percutaneous Nephrolithotomy' OR 'PCNL') AND ('child*' OR 'Pediatric'). Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for conducting meta-analyses were followed [8].

CONTACT Mohamed Ramez Mohamed.ramez@hotmail.com Urology Department, Urology and Nephrology Center, Mansoura, Egypt

Inclusion criteria

Inclusion criteria included comparative studies written in English, comparing prone and supine PCNL in pediatric patients, and reporting efficacy and safety outcomes.

Data extraction and quality assessment

Endnote X8 (Clarivate Analytics, London, UK) was used for duplicate removal then the Rayyan web application was used for screening [9]. Data extraction was done using Microsoft Excel. The extracted data were publication year, number of patients in each arm, patients' characteristics, stone characteristics, operative data, outcomes, and complications. The Cochrane risk-of-bias tool for randomized trials [10] was used for quality assessment of RCT. The Newcastle–Ottawa Scale (NOS) was used for quality assessment of non-RCT [11].

Statistics

Review Manager software (Cochrane Collaboration, Oxford, UK) was used for statistical analysis. Continuous data were analyzed using standardized mean difference (SMD) with 95% confidence interval (CI), while the risk ratio (RR) was used for analysis of dichotomous data. Heterogeneity was evaluated with the chi-square test. If heterogeneity was detected, a sensitivity analysis in multiple scenarios, excluding one study in each scenario was conducted. A $p < 0.1$ was considered significant. Random or fixed effects models were used according to heterogeneity. A p value of <0.05 was used to indicate statistical significance.

Results

Search strategy and screening results are shown in the PRISMA flow chart (Figure 1). Six studies were included in the meta-analysis: three RCT [12–14] and three retrospective comparative studies [15–17]. Risk of bias assessment results for RCT are shown in Figure 2, while risk of bias assessment for non-RCT is shown in Table 1.

Table 2 shows the characteristics of the included studies, which contained 290 patients. Table 3 shows patients and stone characteristics. In all studies, fluoroscopy was used for gaining percutaneous renal access except two studies [15,17] where ultrasound and fluoroscopy were used. Mini-PCNL was used in five studies, with a percutaneous sheath size of 16 F in two studies [13,14], 14–18 F in one [17], 15–20 F in one [15], and 14–20 F in one, while ultra-mini-PCNL of 13 F was used in one [12]. Holmium Laser lithotripsy was used for stone disintegration in all studies.

Stone-free rate

Stone-free rate was defined as no residual stones >4 mm in all studies except one [15] where residual fragments ≤3 mm were considered clinically insignificant. KUB and ultrasound were used for the detection of residual stones in two studies [12,14], KUB only was used in one [17], KUB and NCCT were used in one [13] and KUB, ultrasound, and NCCT in one [15].

The overall risk ratio between supine and prone was comparable (RR 1.08, 95% CI [0.98–1.18], $p = 0.11$). Pooled studies were homogeneous (Chi-square $p = 0.89$, I-square = 0%) (Figure 3).

Operative time

The overall SMD between supine and prone groups favored supine (SMD −0.99, 95% CI [−1.67 - −0.30], $p = 0.005$). Pooled studies were heterogeneous (Chi-square $p < 0.00001$, I-square = 86%).

Heterogeneity was resolved by excluding the three non-RCTs [15–17] ($p = 0.2$, I-square = 0%). After removing them from the meta-analysis model, the overall SMD was still in favor of supine PCNL (SMD −1.62, 95% CI −2.01 to −1.23, $p < 0.00001$) (Figure 4).

Fluoroscopy time

The overall SMD between supine and prone was comparable (SMD 0.06, 95% CI [−0.41–0.53], $p = 0.80$). Pooled studies were heterogeneous (Chi-square $p = 0.002$, I-square = 73%).

Heterogeneity was resolved by excluding Campobasso 2022 [15] ($p = 0.69$, I-square = 0%). After removing it from the meta-analysis model, the overall SMD was still insignificant (SMD −0.16, 95% CI −0.42 to 0.09, $p = 0.21$) (Figure 5).

Length of hospital stay

Hospital stay was reported in all studies except one [15]. The overall SMD between supine and prone groups favored supine (SMD −0.52, 95% CI [−0.87 to −0.26], $p < 0.0001$). Pooled studies were heterogeneous (Chi-square $p = 0.27$, I-square = 23%).

Heterogeneity was resolved by excluding Bitkin 2023 [17] ($p = 0.75$, I-square = 0%). After removing it from the meta-analysis model, the overall SMD was still in favor of supine PCNL (SMD −0.68, 95% CI −0.98 - −0.38, $p < 0.0001$) (Figure 6).

Complications

The overall risk ratio of complications between supine and prone was comparable (RR 0.93, 95% CI [0.59–1.47], $p = 0.76$) (Figure 7). Pooled studies were homogenous (Chi-square $p = 0.81$, I-square = 0%).

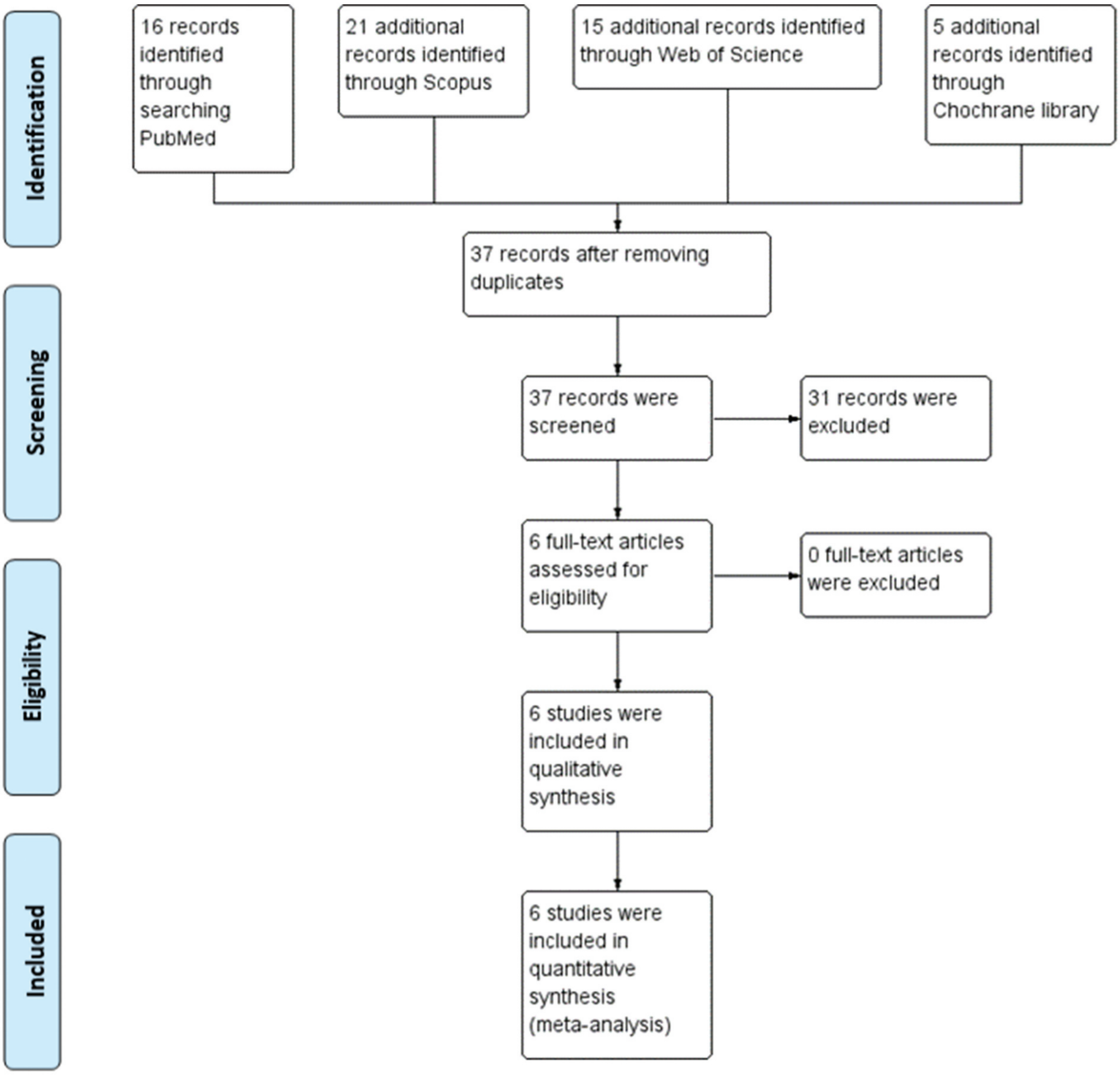

Figure 1. PRISMA flow chart of the meta-analysis.

Sensitivity analysis

When only RCTs [12–14] were included for sensitivity analysis, similar results were obtained in all outcomes. Therefore, the results are considered stable (Table 4).

Discussion

Prone PCNL has been performed for years. It has been familiar for urologists, and it provides wider operative field and adequate pelvicalyceal system. However, it has its issues, especially in children as it can be difficult to observe a child in a prone position by anesthesiologist [18]. Recently, supine PCNL has gained more interest, most probably because of being more comfortable for surgeons and no need for repositioning the patient in addition to the ability to do combined intrarenal surgery [19]. It is very important to keep in mind that supine PCNL is still a new technique for most urologists that needs a learning curve.

Our meta-analysis revealed comparable results in stone-free and complication rates between supine and prone PCNL. While operative time and length of hospital stay was shorter in the supine position. This ensures that supine PCNL is a safe and effective approach.

Even though prone PCNL can give a better stone-free rate due to full exposure of the lumbar area allowing multiple puncture sites and better access to the upper pole [20], our meta-analysis showed no difference in stone-free rate between both positions.

Results of meta-analyses conducted to compare supine and prone PCNL in adults showed controversial results. A study by Yuan showed a higher stone-free rate in prone position [21]. This was explained by the more space available for manipulation of the nephroscope in prone position in addition to some difficulties with following migratory stones in supine PCNL as well as difficulties with upper pole access. Another meta-analysis [22] in adults concluded a comparable stone-

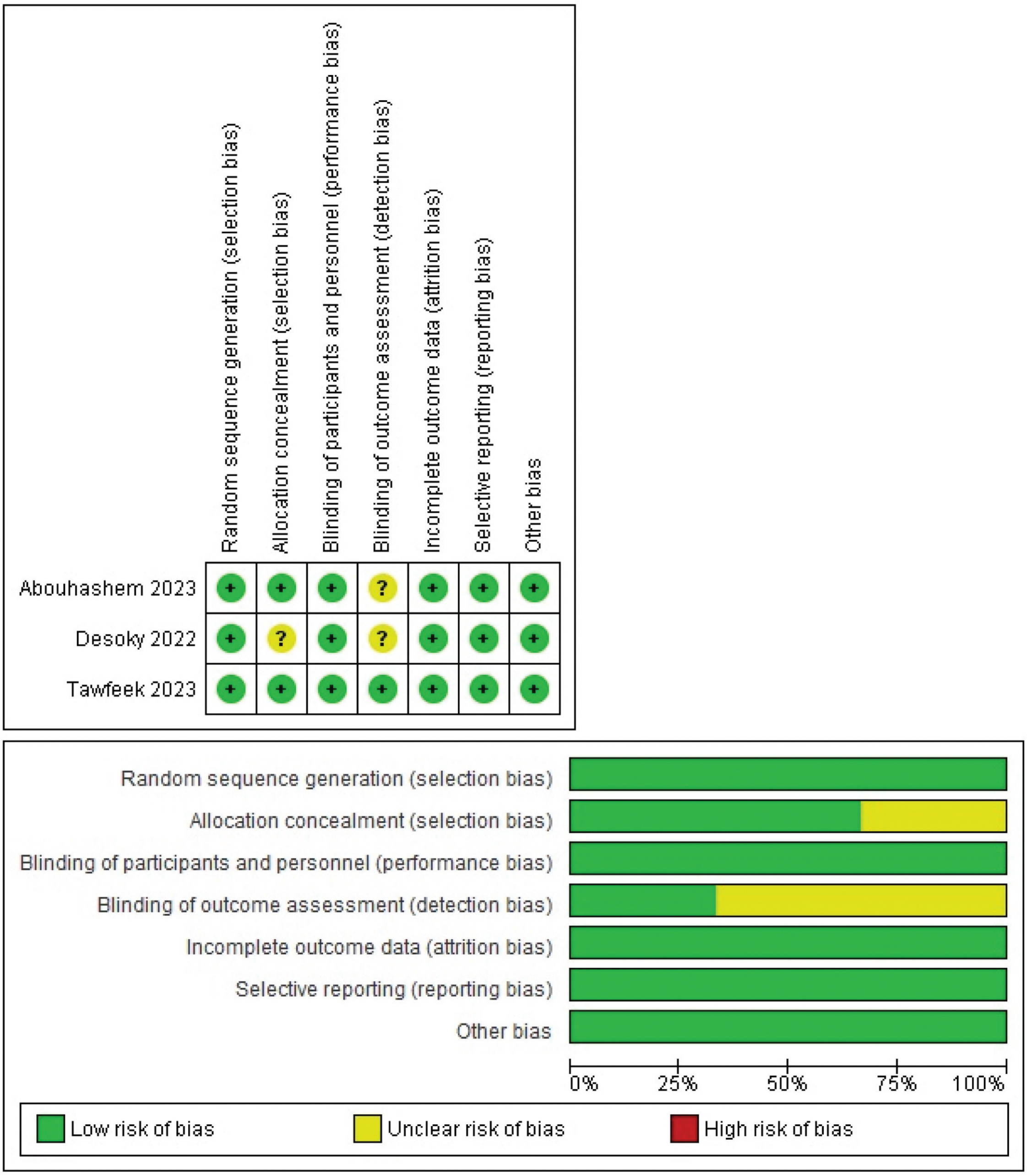

Figure 2. Risk of bias summary: review authors' judgements about each risk of bias item for included randomized controlled trials.

Table 1. Quality assessment of non-randomized controlled trials.

Study	Selection	Comparability	Outcome	Quality score
Bitkin 2023	★★★	★	★★★	7
Campobasso 2022	★★★	★	★★★	7
Sezer 2024	★★★	★	★★★	7

Good quality: 3 or 4 stars (★) in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome domain; Fair quality: 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain; Poor quality: 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome/exposure domain.

free rate. Furthermore, a meta-analysis of RCT in adults showed a comparable stone-free rate between the two positions [23].

The need to change position after ureteral catheter fixation of prone PCNL usually prolongs the operation time. Our study confirmed this with statistically significant shorter operation time in supine position than in prone one. This is consistent with the results of a meta-analysis comparing the two positions in adults, which also showed longer operative time in prone position [21].

The overall complications showed no difference between the two positions. However, reporting complications was not detailed in our studies with different definitions and scales used. We believe that using a standardized approach for

Table 2. Characteristics of the included studies.

Study	Year	Country	Study Design	Level of Evidence	Overall Quality According to Risk of Bias Assessment
Tawfeek et al.	2023	Egypt	RCT	1b	High
Abouhashem et al.	2023	Egypt	RCT	1b	High
Desoky et al.	2022	Egypt	RCT	1b	High
Bitkin et al.	2023	Turkey	Retrospective	2b	Good
Campobasso et al.	2022	Italy	Retrospective	2b	Good
Sezer et al.	2024	Turkey	Retrospective	2b	Good

Table 3. Patients and stone characteristics.

Study ID	Group	Patients' Number	Age (Years) Mean (SD)	Gender (Male) n. (%)	BMI (kg/m^2) Mean (SD)	Stone Size (mm) Mean (SD)	Stone Side (Right) n. (%)	Stone Density (Hounsfield Unit) Mean (SD)
Tawfeek	Supine	33	4.9 (3.5)	14 (42.4)	24.5 (2)	20.2 (6.65)	15 (45.5)	623 (246)
2023	Prone	30	5.9 (2.8)	17 (56.7)	24.6 (2.5)	18.7 (4.66)	18 (60)	750 (281)
Abouhashem	Supine	10	9.5 (3.1)	7 (70)	-	24.5 (3.3)	4 (40)	7801 (132)
2023	Prone	10	10.3 (3.4)	6 (60)	-	24.3 (3.4)	5 (50)	779 (133)
Desoky	Supine	28	9.5 (3.1)	18 (64)	22.2 (2)	24.7 (2.32)	15 (53.5)	775 (135)
2022	Prone	27	10.3 (3.4)	19 (70.1)	21.9 (2.5)	25.1 (2.12)	14 (51.8)	782 (144)
Bitkin	Supine	25	9.7 (4.3)	14 (56)	18.8 (2.5)	20 (5.4)	12 (48)	983 (314)
2023	Prone	36	9.1 (5.1)	21 (58.3)	18.3 (2.6)	19.2 (5.6)	16 (44.4)	1002 (371)
Campobasso	Supine	17	10.3 (3.9)	8 (47)	-	-	-	-
2022	Prone	32	6.4 (3.2)	20 (62.5)	-	-	-	-
Sezer	Supine	21	10.2 (4.4)	6 (29)	17.7 (3.3)	27.8 (13.4)	10 (48)	1087 (44)
2024	Prone	21	9.1 (5.5)	12 (57)	20.7 (6.1)	29.7 (14.1)	7 (33)	932 (43)

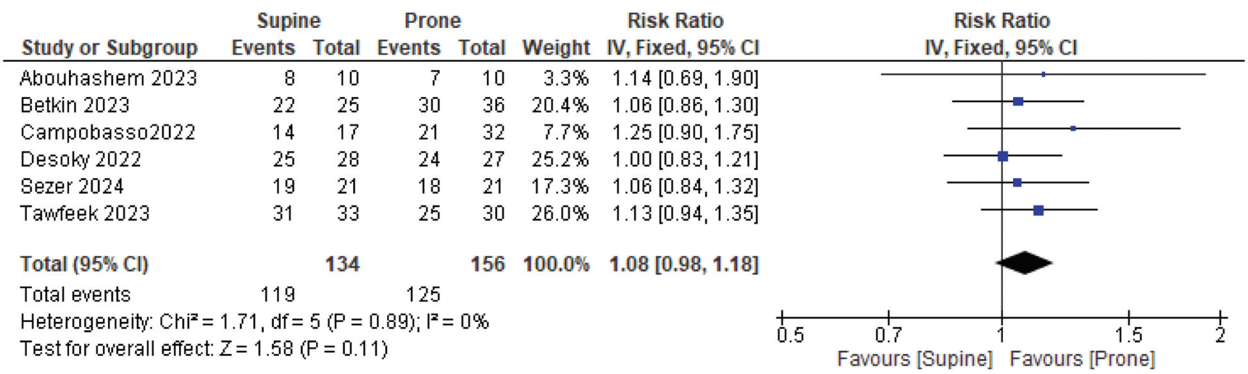

Figure 3. Forest plot showing stone free rate between supine and prone PCNL.

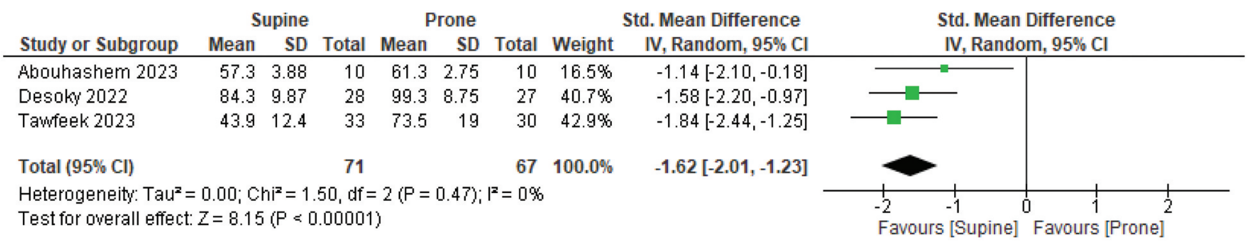

Figure 4. Forest plot showing operative time between supine and prone PCNL.

reporting complications like the modified Clavien–Dindo classification would give better evidence and data [24].

Supine pediatric PCNL has some potential advantages. The surgeon is working while sitting, the anesthetist had easier monitoring of the endotracheal tube, and the child is subjected to less manipulation in repositioning [25]. Nevertheless, supine position is still less familiar for many urologists, and there is a smaller operative field with possible hypermobility of the kidney during tract dilatation [26].

It is worth mentioning that several limitations should be considered. There is a paucity of randomized controlled trials in the literature comparing supine and prone PCNL in pediatric population. In addition, sample size was small in one study [13]. Different stone characteristics, surgeons' experience, supine position, PCNL techniques in addition to some non-detailed data on outcomes and complications could also be a shortcoming.

Finally, assessment of outcomes in all studies was done using objective measures like stone-free

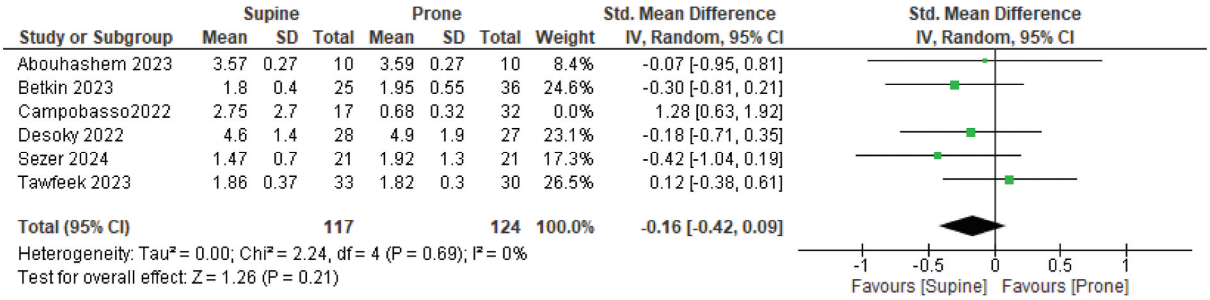

Figure 5. Forest plot showing fluoroscopy time between supine and prone PCNL.

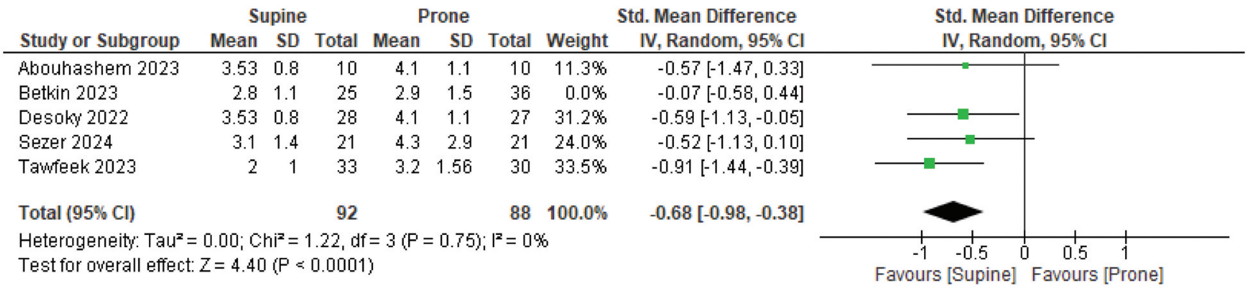

Figure 6. Forest plot showing length of hospital stay between supine and prone PCNL.

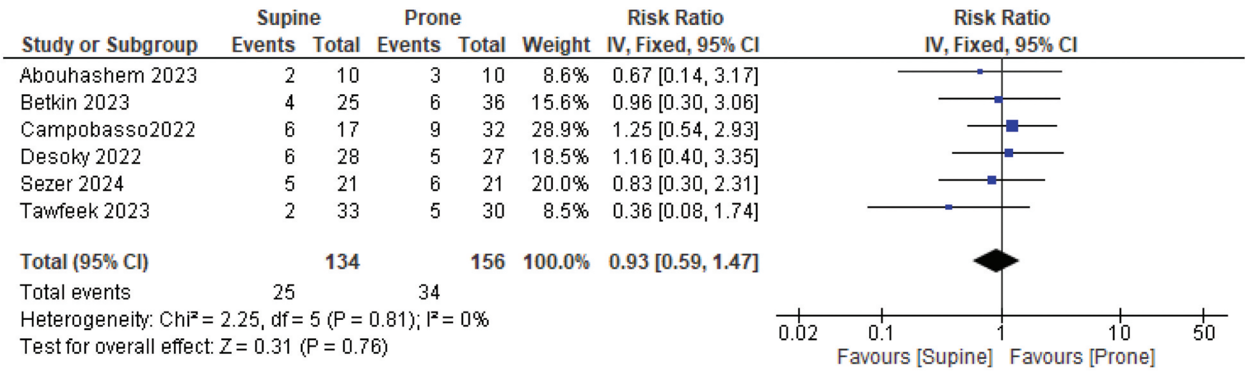

Figure 7. Forest plot showing overall complication rate between supine and prone PCNL.

Table 4. Sensitivity analysis of randomized controlled trials.

Outcome	Number of Studies	RR/SMD	95% CI	P (Overall Effect)	P (Heterogeneity)	I-square
Stone free rate	3	1.07	0.94 to 1.21	0.29	0.66	0%
Operative time	3	−1.62	−2.01 to −1.23	<0.00001	0.47	0%
Fluoroscopy time	3	−0.03	−0.36 to 0.31	0.87	0.72	0%
Hospital Stay	3	−0.73	−1.07 to −0.38	<0.00001	0.65	0%
Complications	3	0.77	0.36 to 1.65	0.50	0.48	0%

rate. We can consider this as a limitation as there has been a paradigm shift in the last few years toward subjective measures of outcomes which are important to ensure delivery of care in a patient centered manner [27]. New grading systems and nomograms have been developed in endourology such as tools for predicting stone recurrence and tools related to postoperative complications [28]. In addition, artificial intelligence and machine learning have been used to build algorithms to predict outcomes of PCNL [29].

Conclusions

Supine PCNL showed comparable stone-free and complication rates with prone PCNL in children. Longer operative time was observed in prone PCNL. Therefore, no technique has its absolute superiority with each one having its own advantages and disadvantages. Additionally, more prospective randomized controlled trials are needed in pediatric populations for better conclusions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Abbreviations

CI	confidence interval
cm	centimeter
HU	Hounsfield unit
KUB	Kidney, Ureter, and Bladder X-ray
mm	millimeter
N.	number
NCCT	non-contrast computerized tomography
PCNL	Percutaneous Nephrolithotomy
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomized controlled trial
RR	risk ratio
SD	standard deviation
SMD	standardized mean difference

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