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Efficacy and Safety of Percutaneous Nephrolithotomy versus Ureteroscopy for Pediatric Kidney Stone Management: A Systematic Review and Meta-Analysis

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Introduction. Percutaneous Nephrolithotomy (PCNL) and ureteroscopy are surgical options performed in children with kidney and/or ureteral calculi, despite no differences in stone clearance. Percutaneous nephrolithotomy was reported to have a high Stone Free Rate (SFR) for paediatric patients. The use of ureteroscopy in children has increased with high ureteral and kidney Stone-Free Rate (SFR) and low complication rate. The safety of PCNL and ureteroscopy is assessed by the complaints of patients. The study aims to comprehend the efficacy and safety of percutaneous nephrolithotomy and ureteroscopy procedures for paediatric kidney stone management.
Methods. A systematic search was carried out following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA). Multiple databases, including Medscape, Science Direct, and ProQuest, were systematically searched for relevant articles. Relevant parameters explored using Review Manager V5.4.1.
Results. Three prospective and two retrospective comparative studies involving a total of 1443 renal units, with 209 cases done using PCNL and 1229 cases using ureteroscopy. There was no significant difference in stone-free rate and sepsis between these two groups of patients (OR: 0,89; 95% CI: 0,59-1,35; P=0,58 and OR: 0,34; 95% CI: 0,04-3,13; P=0,97, respectively). The risk of fever and hematuria was significantly lower in patients treated with ureteroscopy compared to PCNL (OR: 2,41; 95% CI: 1,07-5.46; P=0.04 and OR: 17,93; 95% CI: 2,28-140,93; P=0,006, respectively).
Conclusion. The analysis found that PCNL has a similar SFR compared to ureteroscopy. The risk of fever and hematuria was significantly lower in patients treated with ureteroscopy compared to PCNL. Further randomized clinical trials are required to compare the safety and efficacy of PCNL versus ureteroscopy for pediatric kidney stone management.

Keywords: pediatric, percutaneous nephrolithotomy, ureteroscopy

Introduction

The prevalence of urolithiasis in Asia has been increasing with urinary tract stone formation rising with age [1]. In children, Percutaneous Nephrolithotomy (PCNL) and ureteroscopy (URS) are the main surgical options for managing kidney and ureteral calculi. Although both achieve comparable stone clearance, PCNL shows excellent and consistent results for large stones, while URS results better for smaller stones and offers advantages such as shorter hospital stays and fewer complications [2]. Studies have shown that ureteroscopy is safe and effective even in young children, including those with neurogenic bladders [3-4].

According to the European Association of Urology (EAU) pediatric guidelines, PCNL is indicated for stones larger than 2 cm or when Shock Wave Lithotripsy (SWL) and URS fail. PCNL provides a high Stone-Free Rate (SFR) after a single session, with minimal risk of renal parenchymal injury. Meanwhile, flexible ureteroscopy (FURS) has gained popularity due to its minimally invasive nature and good efficacy, especially for lower calyceal stones [5]. Given the variation in reported outcomes, this study aims to evaluate and compare the efficacy and safety of

PCNL and URS in pediatric kidney stone management to support evidence-based clinical decision-making.

Materials and Methods

This was a systematic review and meta-analysis comparing the efficacy and safety of percutaneous nephrolithotomy and ureteroscopy for pediatric kidney stone management. A systematic search was carried out following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) in Figure 1. All keywords used were searched for their respective medical subject heading (MeSH®) terms. This data searching process was not limited by date of publication, and we only included full-text articles in Indonesian and English. Only studies comparing PCNL and ureteroscopy in Pediatric Kidney Stone Management were assessed for further analysis. Participants were boys and girls who were under 18 years old. Studies with adult subjects and patients with congenital kidney anomalies were excluded from this review. Data from all selected articles were extracted independently by two reviewers.

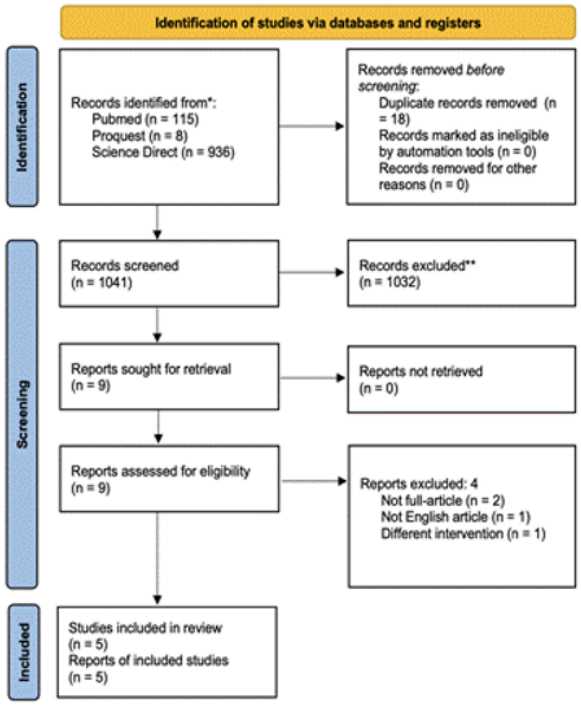

Figure 1. PRISMA Flowchart

Search Strategy and Study Selection

Multiple databases, including Medscape, Science Direct, and Proquest, were systematically searched for relevant articles. Relevant articles comparing PCNL and Ureteroscopy were searched using medical subject headings (MeSH®) terms. The full-search strategy was provided in Table 1.

Eligibility Criteria

Studies were considered eligible if they met the following criteria: (1) prospective or retrospective cohort studies, (2) comparing pediatric patients undergoing PCNL and ureteroscopy procedures, (3) discussing at least one outcome of interest, and (4) accessible full-text articles.

Outcome Determination and Quality Assessment

Outcomes on the efficacy aspect were analyzed using SFR. The outcomes on the safety aspect were analyzed using fever, sepsis, hematuria, and blood transfusion. SFR was defined as no evidence of residual fragments of stones according to radiologic imaging after undergoing a single procedure. The quality of studies was assessed using the Newcastle-Ottawa Scale (NOS) in Table 2. There are four studies that have nine stars and one study has seven stars.

Data Collection and Analysis

Data were extracted and assessed by two reviewers independently. This study used the Cochrane Risk of Bias assessment tools to assess interventional studies. Quantitative synthesis of included studies was done using Review Manager 5.4. Odds ratios (OR) and 95% confidence intervals (CIs) were calculated for binary variables. Heterogeneity of studies was assessed using I2. Fixed-effect models were used for homogeneous data, and random effects analysis was considered for heterogeneous data. Forest plots were used to present meta-analysis results.

Result

Search Result and Quality Assessment

The initial search yielded 1059 articles. Following the duplication removal and extended text article evaluation, 5 studies [2,6–9] remained and were then included. Three prospective and two retrospective comparative studies involving a total of 1315 cases, with 209 cases done using PCNL and 1106 cases using ureteroscopy. In the present time, there is no randomized controlled study that compares PCNL and ureteroscopy for pediatric

kidney stone management. Study characteristics and aspects included are shown in Table 3.

Stone Free Rate

In total, 172 of the 209 patients in the PCNL group experienced stone-free status, while 892 of the 1106 patients in the Ureteroscopy group experienced stone-free status. We can see that there was no significant difference in stone-free rate between these two groups of patients (OR: 1,08; 95% CI: 0,73-1,60; P=0,70). Because of homogeneous data (I2: 44% and P: 0,13), we performed a fixed effect measure for this quantitative analysis in Figure 2.

Table 1. Database and search term

Database	Search Term
Medscape	(percutaneous nephrolithotomy OR percutaneous nephrolithotomies OR PCNL) AND (ureteroscopy) AND (nephrolithiasis OR renal calculi OR urinary calculi OR renal stone) AND (pediatric)
Science Direct	(percutaneous nephrolithotomy OR percutaneous nephrolithotomies OR PCNL) AND (ureteroscopy) AND (nephrolithiasis OR renal calculi OR urinary calculi OR renal stone) AND (pediatric)
ProQuest	(TI("percutaneous nephrolithotomy" OR "percutaneous nephrolithotomies" OR PCNL) OR AB("percutaneous nephrolithotomy" OR "percutaneous nephrolithotomies" OR PCNL) OR SU("percutaneous nephrolithotomy")) AND (TI(ureteroscopy OR URS) OR AB(ureteroscopy OR URS) OR SU(ureteroscopy)) AND (TI(nephrolithiasis OR "renal calculi" OR "urinary calculi" OR "renal stone" OR "kidney stone") OR AB(nephrolithiasis OR "renal calculi" OR "urinary calculi" OR "renal stone" OR "kidney stone") OR SU(nephrolithiasis OR "renal calculi" OR "urinary calculi" OR "renal stone" OR "kidney stone")) AND (TI(pediatric OR pediatrics OR child OR children OR adolescent OR teen) OR AB(pediatric OR pediatrics OR child OR children OR adolescent OR teen) OR SU(pediatric OR pediatrics OR child OR children OR adolescent OR teen))

Table 2. Quality of studies

Authors	Study type	Selection				Comparability		Outcome		Final Score
		Representative-ness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of the exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for long enough for outcomes to occur	Adequacy of follow-up of cohorts	
Ellison et al	prospective cohort studies	*	*	*	*	**	*	*	*	9
Zhang et al	prospective cohort studies	*	*	*	*	**	*	*	*	9
Jones et al	retrospective cohort studies	*	*	*	*	**	*	*	*	9
Erdnetsesteg et al	prospective cohort studies	*	*	*	*	**	*	*	*	9
Charalambous et al	retrospective cohort studies	*	*	*	*	**	*	-	-	7

Table 3. Characteristic of studies

Authors	Method	Number of Patients	Number of Kidney Site	Number of Stone Free Rate	Age Mean	Patient's Experiences	Number of Complications							Length of Hospital Stay (Days)
							Fever	Hema-turia	Blood Transfu-sion	Perforation of Renal Pelvis	Right Flank Tenderness with Leucocytosis	UTI	Sepsis	
Ellison et al	PCNL	93	98	72	15,6 (12,5-17,3)	✔	-	-	-	-	-	-	-	-
	URS	946	1069	754			-	-	-	-	-	-	-	-
Zhang et al	PCNL	40	42	34	3,2 (2,8-5)	-	12	6	0	-	-	-	0	2 (1-4)
	URS	73	84	67	3,0 (2,3-5)	-	13	0	0	-	-	-	2	2 (1-3)
Jones et al	PCNL	40	-	39	8,8 (5,5-14)	-	2	3	-	-	-	0	0	2,2 (1-3)
	URS	55	-	55	9,3 (2-16)	-	0	0	-	-	-	2	1	(1-2)
Erdnetsesteg et al	PCNL	23	25	23	10,1 ± 5.3 (1-17)	-	3	0	3	1	1	-	-	-
	URS	6	6	6	9,1 ± 7,2 (1-17)	-	0	0	0	0	0	-	-	-
Charalambous et al	PCNL	4	-	4	9-14	-	-	-	-	-	-	0	-	-
	URS	10	-	10	9-14	-	-	-	-	-	-	0	-	-

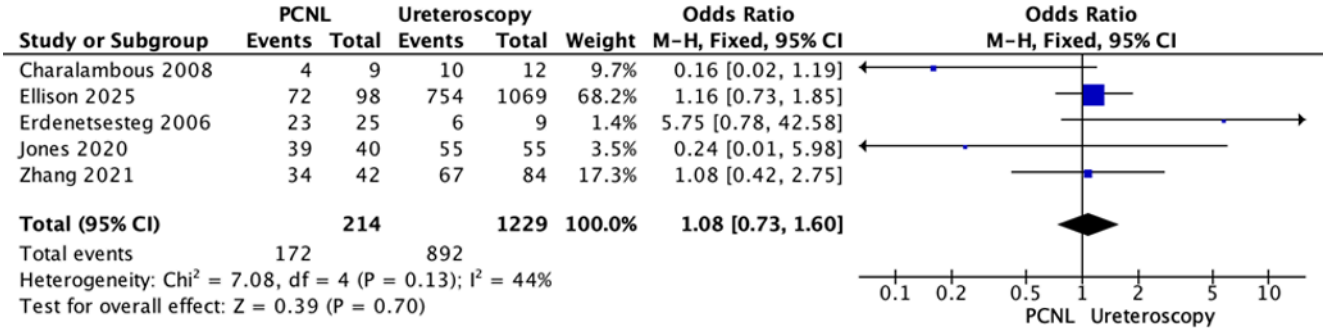

Figure 2. Forest plot comparing stone-free rates between PCNL and ureteroscopy using a fixed-effects model

Fever

In total, 17 of the 103 patients in the PCNL group experienced fever, while 13 of the 136 patients in the Ureteroscopy group experienced fever. The risk of fever was significantly lower in patients treated with ureteroscopy compared to PCNL (OR: 2,33; 95% CI: 1,03-5.30; P=0,04). We used fixed effect analysis to analyze this homogeneous data (I2: 0% and P: 0,72) in Figure 3.

Hematuria

In total, 9 of the 80 patients in the PCNL group experienced hematuria, while 0 of the 128 patients in the Ureteroscopy group experienced hematuria. The risk of hematuria was significantly lower in patients treated with ureteroscopy compared to PCNL (OR: 17,93; 95% CI: 2,28-140,93; P=0,006). We used fixed effect analysis to analyze this homogeneous data (I2: 0% and P: 0,64) in Figure 4.

Sepsis

In total, 0 of the 80 patients in the PCNL group experienced sepsis, while 3 of the 128 patients in the Ureteroscopy group experienced sepsis. We can see that there was no significant difference in sepsis between these two groups of patients (OR: 0,39; 95% CI: 0,04-3,60; P=0,41). Because of homogeneous data (I2: 0% and P: 0,92) we performed fixed effect measures for this quantitative analysis in Figure 5.

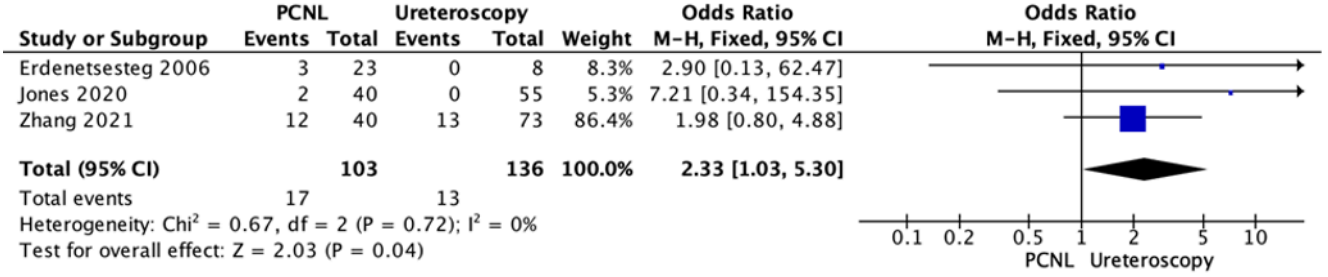

Figure 3. Forest plot comparing postoperative fever rates between percutaneous nephrolithotomy (PCNL) and ureteroscopy using a fixed-effects model

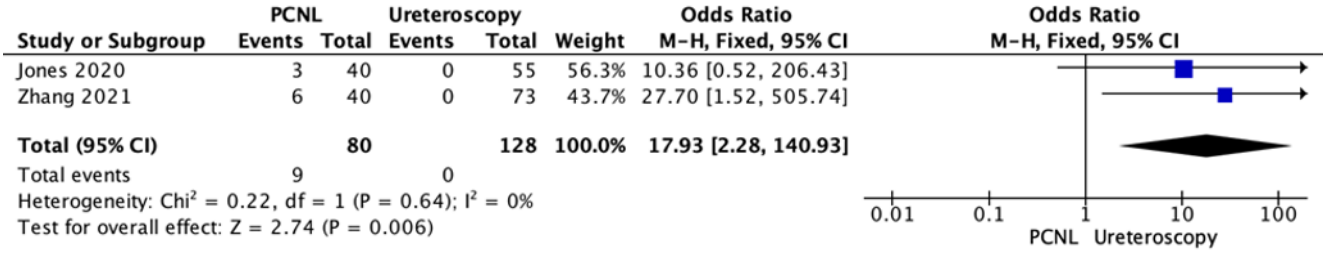

Figure 4. Forest plot of comparing postoperative hematuria rates between PCNL and ureteroscopy using a fixed-effects model

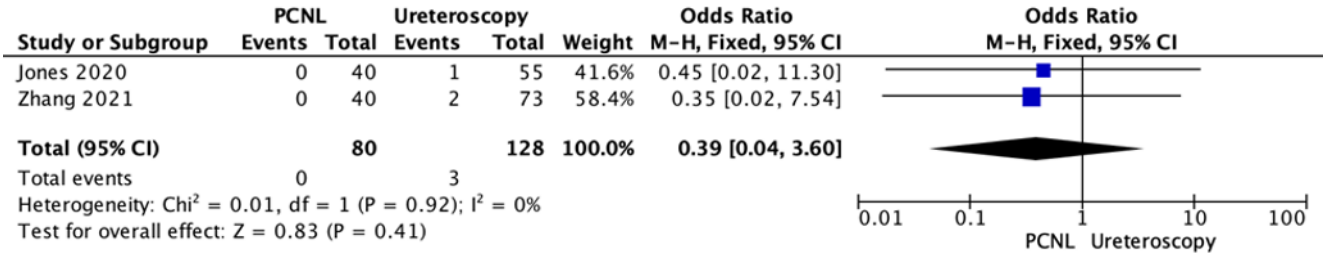

Figure 5. Forest plot comparing postoperative sepsis rates between PCNL and ureteroscopy using a fixed-effects model

Discussion

PCNL is performed under general anesthesia. After anesthesia was provided to the patient in the lithotomy position, retrograde ureteral catheterization was performed to occupy the collecting system during percutaneous access. Thereafter, the patient is repositioned in the prone position with a 30°-45° upward tilt of the affected site. Percutaneous renal access is achieved with fluoroscopic or ultrasonic guidance. A lower pole posterior calyx location is more preferable, but the position of renal puncture depends on the localization of stones, burden of the stone, and renal anatomy. Puncture tract dilatation is performed using dilators, followed by the placement of a sheath. Stone breaking is performed with laser or pneumatic lithotripsy [10].

Because of the small kidney in pediatrics and the risk of blood loss, PCNL is a difficult procedure. There is no guideline on the exact definition of SFR, but it is considered stone fragments smaller than 3 or 4 mm. It is important to achieve complete stone clearance. Complication rates have reduced with the development of the smallest traumatic endoscopic. PCNL is reported intraoperative bleeding with duration of surgery, stone burden, and sheath size [10].

Ureteroscopy is performed under general anesthesia and the patient is positioned in the lithotomy position. The prophylactic antibiotics are administered and procedures are seen using a video camera. The patient is performed an initial cystoscopy to place a guide wire. After the guide wire was located into the stone and proximal ureter or collecting system, ureteroscopy was performed with a safety wire. The ureteroscope was inserted into the urethra and Ureterovesical junction (UVJ) dilatation was performed in the procedure [11].

Controlled pressurized irrigation device enters through the UVJ that is guided by the safety guidewire it directs the tip of the ureteroscope into the lumen of the ureter. The ureteroscope was moved along the ureter. The stones were broken into small pieces using a pneumatic lithoclast. The residual stones were extracted using stone grasping forceps or a basket. When the procedure was finished, the guide wire was removed. The decision to place a stent postoperatively was based on the duration of the procedure and the degree of ureteral trauma [11].

From the study of Sultan et al, 500 PCNL procedures were performed for pediatric patients and stone clearance rates were 89% with monotherapy [12]. From the study of Bilen et al, the stone-free rate in children who underwent percutaneous nephrolithotomy with 3 different sizes of instruments (26Fr, 20F, and 14Fr) and stone-free rates were 69.5%, 80% and 90%, respectively [13]. From the study of Zaheer et al, the frequency of stone clearance was 56 (93.33%) patients after micro PCNL in pediatric patients with renal stones [14]. From the study of Madarriaga et al, PCNL is safe in children with a stone-free rate above 85% and a complication rate below 7% [15]. From the study of Faure et al, the mean of single-session SFR for kidney stone removal was 67.4% (56.3 and 89.2% for flexible URS and semi-rigid URS, respectively) [4]. We found that there was no significant difference in stone-free rate between these two groups of patients.

Fever is one of the most frequent complications. It is not always caused by microbes. PCNL has a fever rate of 31% in 188 procedures [10]. A meta-analysis found the prevalence rates of fever and sepsis among patients undergoing PCNL were 9.5% and 4.5%, respectively. Risk factors of sepsis include renal abnormalities, preoperative bacteriuria, prolonged operation, neurological bladder dysfunction, and high intraoperative irrigation pressure [16]. From the study of Chugh et al, the total amount of complications from ureteroscopy was 7.9% (n = 1919) and 3.9% (n = 972) were infectious complications and 4% (n = 1147) were non-infectious complications. From the infectious complications, fever was reported in 66% (n = 642) [17]. We found that the risk of fever was significantly lower in patients treated with

ureteroscopy compared to PCNL and there was no significant difference in sepsis between these two groups of patients.

Bleeding is a serious complication and hemoglobin drop requires transfusion is reported in 0.4%-24% of patients. In another study, high hemoglobin drop has been determined in pediatric patients who underwent PCNL when the size of dilatation exceeded 22F [10]. From a study of Monroy et al. (2025), the important factor that reduces the risk of perioperative bleeding is accurate renal puncture. The safest access from the skin to the renal collecting system is through the posterior lower calyx. Moreover, a flexible nephroscope can reduce the risk of injury. Bleeding from parenchymal vessels or vessels in the nephrocutaneous tract is not immediately apparent during surgery and it is often detected after the access sheath is removed [16]. From the study of Bilen et al, the children who underwent percutaneous nephrolithotomy with 3 different sizes of instruments (26Fr, 20F, and 14Fr), the blood transfusion rate was higher in groups 1 and 2 [13].

The main causes of postoperative bleeding are arteriovenous fistulas and arterial pseudoaneurysms, which can occur in around 1.2% of procedures and the patient has the symptom of persistent hematuria 1 to 3 weeks after the procedure [16]. From the study by Valecha et al, hematuria is a rare and serious outcome of PCNL, but can be safely managed without serious consequences [18]. From the study of Li et al, there were 33 patients in the micro-PCNL group and 31 patients in the ultramini-PCNL group. The complications were similar between groups and no severe hematuria was observed [19]. From the study of Zaheer et al, post op hematuria was 4 patients (6.66%) after micro PCNL in pediatric patients with renal stones [14]. We found that the risk of hematuria was significantly lower in patients treated with ureteroscopy compared to PCNL.

Conclusion

The present analysis found that PCNL has similar SFR compared to ureteroscopy, and PCNL has more risk of complications, including fever and hematuria, compared to ureteroscopy. Further randomized clinical trials are required to compare the safety and efficacy of PCNL versus ureteroscopy for pediatric kidney stone management.

Conflict of Interest

The authors declare no conflict of interest.

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