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Systematic Review / Meta-analysis

Comparative efficacy and safety between Micro-Percutaneous Nephrolithotomy (Micro-PCNL) and retrograde intrarenal surgery (RIRS) for the management of 10–20 mm kidney stones in children: A systematic review and meta-analysis

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ABSTRACT

Objectives: Kidney stone in children is a recurring problem that requires multiple interventions over time. Minimally-invasive approach, such as Extracorporeal Shockwave Lithotripsy (ESWL) is recommended for moderately-sized stones. However, since ESWL is associated with multiple interventions, Micro-Percutaneous Nephrolithotomy (Micro-PCNL) and Retrograde Intrarenal Surgery (RIRS) can also be considered to treat kidney stones in pediatric patients. Both approaches have their respective advantages and disadvantages. In this study, we aimed to compare the efficacy and safety of Micro-PCNL and RIRS in pediatric patients with kidney stones.

Methods: This systematic review and meta-analysis adhered to the PRISMA guideline and Cochrane Handbook of intervention. The included studies were obtained from the PubMed and ScienceDirect databases. The protocol of this review has been registered in PROSPERO (CRD42021265894). The quality of the studies was assessed using the Newcastle-Ottawa Scale, outcomes were analyzed using STATA®16, and certainty of evidence was evaluated using GRADE.

Results: A total of 239 participants were included in this study, divided into the Micro-PCNL ($n = 112$) and RIRS ($n = 127$) procedure groups. Statistical analysis revealed a significantly lower requirement of postoperative stenting procedure in Micro-PCNL compared to RIRS (OR 0.09; 95%CI 0.02, 0.47; $p < 0.01$). However, no significant difference was found in stone-free rate ($p = 0.86$), operative time ($p = 0.09$), UTI incidence ($p = 0.67$), blood transfusion requirement ($p = 0.95$), and length of stay ($p = 0.77$).

Conclusion: Micro-PCNL is superior to RIRS in managing pediatric kidney stones,10–20 mm in size based on their comparable SFR and fewer requirements of additional stenting procedures.

1. Introduction

Kidney stone is reported as one of the most commonly encountered urinary tract diseases across all ages [1,2]. During the last few decades, the prevalence of kidney stones in pediatrics has been increasing with a growth rate of 10.6% per year [3]. Pediatric stone disease is a recurring condition that frequently necessitates multiple interventions [4]. The primary aim of pediatric kidney stone management is to remove the stone burden and improve the patients' quality of life [5]. There are currently a plethora of options available for treating pediatric kidney stones, from non-invasive approaches such as pharmacological management to less invasive approaches such as extracorporeal shockwave lithotripsy (ESWL), retrograde intrarenal surgery (RIRS), or percutaneous nephrolithotomy (PCNL) [6]. The selection of the most optimal intervention is primarily determined by the location, size, and complexity of the stone. Additionally, surgical interventions should be focused on achieving the highest Stone-free rate (SFR) with the lowest complication rate [6]. According to the recent literature and

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international guidelines, ESWL is regarded as the first-line modality in treating moderately sized pediatric kidney stones due to its high SFR and low morbidity rate. However, this treatment is commonly associated with multiple interventions and anesthesia sessions. Alternatively, PCNL and RIRS are also recommended as treatment procedures [7]. The advancements of RIRS technology in thinner ureteroscopes and better deflection capacity have widened the feasibility of this intervention in pediatric patients. The conventional PCNL (24-30Fr) is known for its high efficacy but is associated with various complications such as bleeding, renal parenchymal trauma, and vascular trauma due to the large tract dilation [8]. In order to minimize the consequence of the procedure, various instrument sizes of PCNL have been developed [6]. Recent publications demonstrated that a smaller percutaneous access, such as mini-PCNL (14-20Fr) [9], Ultramini-PCNL (11-13Fr) [10], and Micro-PCNL (4.8Fr) [11] are safer in children than standard PCNL and have greater efficacy than ESWL [6]. Micro-PCNL (MicroPerc), one of the smallest size PCNL, was first performed by Desai et al., in 2011. It has been shown to be feasible and may be more effective in pediatric patients [11]. Recent studies comparing Micro-PCNL and RIRS in pediatrics indicated that these procedures have their respective advantages and disadvantages [12–15]. In this review, we aim to evaluate the efficacy and safety between Micro-PCNL and RIRS in treating moderately sized pediatric kidney stones.

2. Materials and methods

This was a systematic review and meta-analysis comparing the efficacy and safety between Micro-PCNL and RIRS in children with 10–20 mm kidney stones. A systematic search was carried out following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [16]. The protocol of this review has been registered in the PROSPERO (CRD42021265894), research registry (reviewregistry1412), and appraised using AMSTAR 2 [17].

2.1. Search strategy and study selection

Multiple databases including PubMed and ScienceDirect were systematically searched for relevant articles up to November 2021. A further manual search was performed from the references of published reviews and articles. Relevant articles comparing Micro-PCNL and RIRS were searched using medical subject heading (MeSH®) terms. The full-search strategy was provided in Table 1.

Table 1
Search strategy used in PubMed and Sciencedirect.

Database	Keyword	Result (n)
PubMed	((((((“micro"[All Fields] OR “micros"[All Fields]) AND “PCNL"[All Fields]) OR ((“micro"[All Fields] OR “micros"[All Fields]) AND (“percutaneous"[All Fields] OR “percutaneously"[All Fields] OR “percutanous"[All Fields]) AND (“lithotripsy"[MeSH Terms] OR “lithotripsy"[All Fields] OR “lithotripsies"[All Fields])) OR ((“micro"[All Fields] OR “micros"[All Fields]) AND (“percutaneous"[All Fields] OR “percutaneously"[All Fields] OR “percutanous"[All Fields]) AND (“lithotomies"[All Fields] OR “lithotomy"[All Fields]))) AND (“child"[MeSH Terms] OR “child"[All Fields] OR “children"[All Fields] OR “child s"[All Fields] OR “children s"[All Fields] OR “childrens"[All Fields] OR “childs"[All Fields])) OR (“paediatrics"[All Fields] OR “pediatrics"[MeSH Terms] OR “pediatrics"[All Fields] OR “paediatric"[All Fields] OR “pediatric"[All Fields])) AND ((“retrograde"[All Fields] OR “retrogradely"[All Fields]) AND (“intrarenal"[All Fields] OR “intrarenally"[All Fields]) AND (“surgery"[MeSH Subheading] OR “surgery"[All Fields] OR “surgical procedures, operative"[MeSH Terms] OR (“surgical"[All Fields] AND “procedures"[All Fields] AND “operative"[All Fields]) OR “operative surgical procedures"[All Fields] OR “general surgery"[MeSH Terms] OR (“general"[All Fields] AND “surgery"[All Fields]) OR “general surgery"[All Fields] OR “surgery s"[All Fields] OR “surgerys"[All Fields] OR “surgeries"[All Fields]))) OR ((“retrograde"[All Fields] OR “retrogradely"[All Fields]) AND “Intra"[All Fields] AND (“renal"[All Fields] OR “renals"[All Fields]) AND (“surgery"[MeSH Subheading] OR “surgery"[All Fields] OR “surgical procedures, operative"[MeSH Terms] OR (“surgical"[All Fields] AND “procedures"[All Fields] AND “operative"[All Fields]) OR “operative surgical procedures"[All Fields] OR “general surgery"[MeSH Terms] OR (“general"[All Fields] AND “surgery"[All Fields]) OR “general surgery"[All Fields] OR “surgery s"[All Fields] OR “surgerys"[All Fields] OR “surgeries"[All Fields])) (183)	184
Science Direct	Title, abstract or author-specified keywords: micro PCNL OR micro percutaneous lithotripsy OR micro percutaneous lithotomy AND children OR pediatric AND Retrograde Intrarenal Surgery OR Retrograde Intra renal Surgery	88

2.2. Eligibility criteria

Studies were considered eligible if they met the following criteria: (1) Randomized controlled trial (RCT), cohort, cross-sectional, or case-control studies, (2) comparing pediatric patients with kidney stones 10–20 mm in size undergoing Micro-PCNL and RIRS procedures, (3) reporting at least one outcome of interest, and (4) accessible full-text articles. Single-arm studies and modified endoscopic approaches were excluded from the analysis.

2.3. Outcome determination and quality assessment

Several outcomes on the efficacy aspect were analyzed using SFR, operative time, and postoperative double J (DJ)-stent requirement. The outcomes on the safety aspect were analyzed using the requirement of blood transfusion, urinary tract infection (UTI) incidence, and length of stay (LOS). SFR was defined as no evidence of residual fragments according radiologic imaging after undergoing a single procedure. The quality of studies was assessed using the Newcastle-Ottawa Scale (NOS).

2.4. Data collection and analysis

Data were extracted by independent reviewers using a piloted form. The results of continuous and binary outcomes were expressed as mean differences (MD) and Odds Ratio (OR) with 95% Confidence interval (95% CI), respectively. The formula by Wan et al. [18] was used to calculate the mean and standard deviation (SD) from median and range data. The heterogeneity of studies was evaluated by the I^2 test. If the I^2 was observed to be significant (>50%), the random-effects model was chosen. Otherwise, a fixed-effects model was selected. Publication bias was assessed using Egger's Test and Harbord's test and the certainty of evidence was evaluated using Grading of Recommendations, Assessment, Development and Evaluations (GRADE). All analyses were performed using STATA®16 (StataCorp LLC, United States).

3. Results

3.1. Search result and quality assessment

Our initial search yielded a total of 272 records. Following the full-text article evaluation, 11 articles were excluded. The remaining four articles [12–15] were further analyzed as presented in Fig. 1. Clinical characteristics of the included participants and surgical aspects were described in Supplementary Table 1 and Supplementary Table 2, respectively. The NOS ranged from 6 to 8, with a median of 7 as presented in Supplementary Table 2. Table 3 provides detailed information regarding the GRADE evaluation.

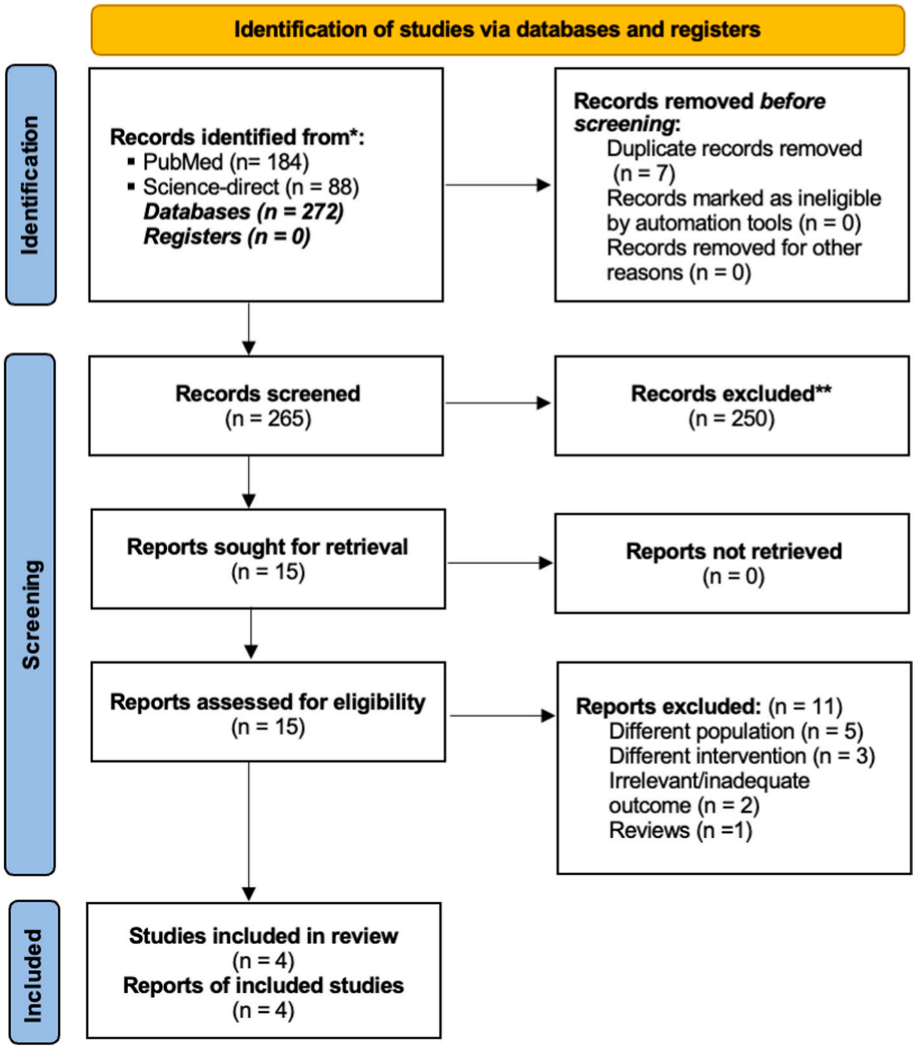

Fig. 1. PRISMA flow diagram 2020.

3.2. Stone-free rate

Four articles were included in the analysis of SFR, as presented in Fig. 2. The meta-analysis revealed that Micro-PCNL had a similar SFR compared to RIRS (OR 0.94; 95%CI 0.46, 1.93; p = 0.86, I2 = 0%).

3.3. Operative time

Table 2 displays the analysis of operative time outcomes. Based on the result from the forest plot, there was insignificant difference in operative time between Micro-PCNL and RIRS (MD 7.25, 95%CI -1.07, 15.57; p = 0.09, I2 = 62%).

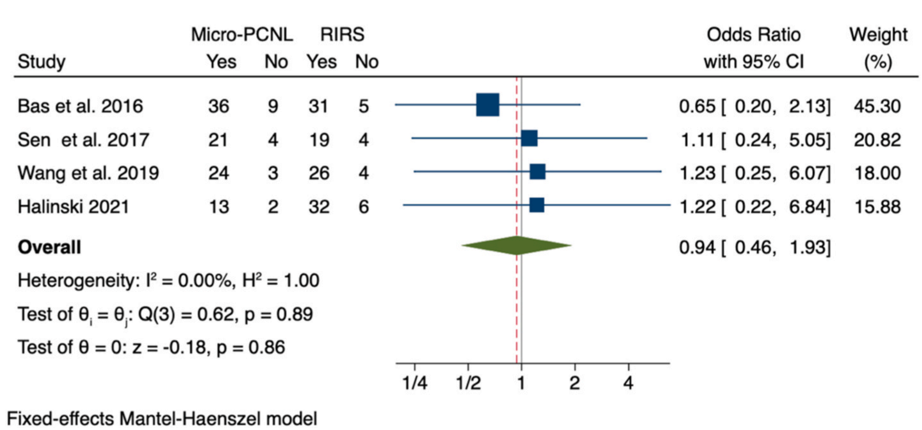

Fig. 2. Forest plot comparing micro-PCNL and RIRS procedures on SFR.

Table 2
Summary of meta-analysis results from the included studies.

Outcomes	n	Estimated Pooled Effects		95%CI	p-value	I^2(%)	Meta-analysis model	Publication bias (p-value)
		MD	OR					
Stone-free rate	4	–	0.94	0.46, 1.93	0.86	0	Fixed-effects	0.4381[a]
Mean operative time (minutes)	2	7.25	–	−1.07, 15.57	0.09	61.9	Random-effects	0.5269[b]
Postoperative DJ-Stent placement	4	–	0.09	0.02, 0.47	<0.01[c]	73.2	Random-effects	0.9616[a]
Urinary Tract Infection	2	–	0.71	0.15, 3.29	0.67	0	Fixed-effects	0.5664[a]
Blood Transfusion	3	–	0.94	0.1, 9.17	0.95	0	Fixed-effects	0.9509[a]
Length of Hospitalization (days)	3	0.09	–	−0.53, 0.71	0.77	85.9	Random-effects	0.5915[b]

[a] Evaluated using Harbord's test.
[b] Evaluated using Egger's test.
[c] Significant results.

Table 3
Summary of certainty of evidence evaluated using GRADE approach.

Quality Assessment								Summary of Findings			
Outcomes	n	Study design	Risk of Bias	Inconsistency	Indirectness	Imprecision	Other Consideration	No of Patients		Effects (95% CI)	Certainty
								Micro-PCNL	RIRS		
Stone-free rate	4	observational studies	not serious	not serious	not serious	not serious	none	94/112 (83.9%)	108/127 (85.0%)	OR 0.94 (0.46, 1.93)	⊕⊕◯◯ Low
Operative time	2	observational studies	not serious	serious	not serious	not serious	none	52	53	MD 7.25 min (−1.07, 15.57)	⊕◯◯◯Very low
Postoperative DJ-Stent placement	4	observational studies	not serious	serious	not serious	not serious	none	25/112 (22.3%)	91/127 (71.6%)	OR 0.09* (0.02, 0.47)	⊕◯◯◯Very low
Urinary Tract Infection	2	observational studies	not serious	not serious	not serious	not serious	none	3/72 (4.2%)	4/66 (6.1%)	OR 0.71 (0.15, 3.29	⊕⊕◯◯ Low
Blood Transfusion	3	observational studies	not serious	not serious	not serious	serious	none	0/97 (0%)	0/89 (0%)	OR 0.94 (0.1, 9.17)	⊕◯◯◯Very low
Length of Stay	3	observational studies	not serious	serious	not serious	not serious	none	97	89	MD 0.09 days (−0.53, 0.71)	⊕◯◯◯Very low

OR = Odds ratio, MD = Mean difference,*Significant results.

3.4. Postoperative DJ-Stent placement

Four studies were enrolled in the analysis of postoperative DJ-Stent placement, as displayed in Fig. 3. Our analysis demonstrated that Micro-PCNL had a significantly lower requirement of postoperative DJ-stent placement compared to RIRS (OR 0.09; 95% CI 0.02, 0.47; $p < 0.01$, I2 = 73%).

3.5. UTI incidence

Two studies were included in the analysis of UTI incidence. The meta-analysis in Table 2 revealed that there was an insignificant difference in the incidence of UTI between both approaches ($p = 0.67$,I2 = 0%)

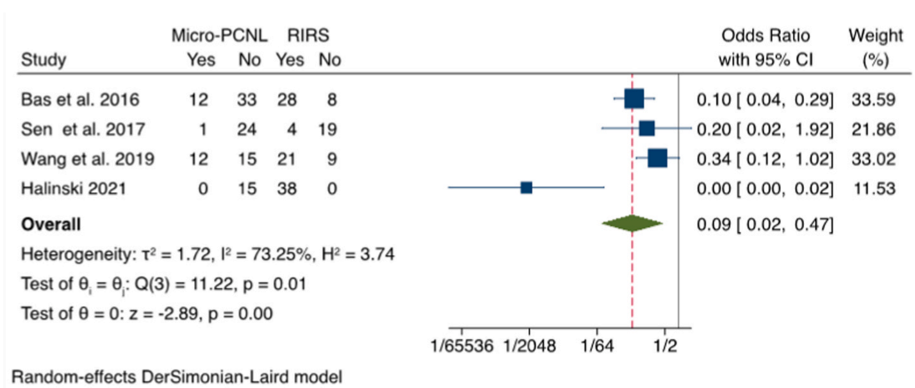

Fig. 3. Forest plot comparing micro-PCNL and RIRS procedures om requirement of postoperative DJ-stent placement.

3.6. Blood transfusion requirement

Table 2 presented the result of meta-analysis on blood transfusion requirement. Our analysis demonstrated insignificant difference in blood transfusion between children undergoing Micro-PCNL and RIRS ($p = 0.95$, $I2 = 0\%$).

3.7. Length of stay

Analysis of LOS was performed using three studies. The meta-analysis result in Table 2 showed that there was insignificant difference in terms of length of stay between Micro-PCNL and RIRS ($p = 0.77$, $I2 = 86\%$).

4. Discussion

One of the main focuses in studies of endourological procedures to achieve the most optimal management for pediatric kidney stones [6]. Several innovations have been made to obtain the most optimal pediatric kidney stone management by using minimal-invasive approaches such as ESWL, RIRS, and PCNL. When compared to other minimally invasive treatment options, PCNL generates a higher SFR but it is also more invasive due to the dilatation of the percutaneous tract [6]. Various advancements have been made to decrease the complication caused by the large tract used in conventional PCNL, one of which is by miniaturizing the diameter of the dilation tract. Despite being introduced for more than a decade, miniaturized PCNL techniques have not gained widespread acceptance, and their place in the armamentarium of kidney stone management is still unclear. Miniaturized PCNL seems to be a viable option for treating patients with small-to-medium-sized stones, and it has been linked to a lower morbidity rate [1,6]. Researchers have been interested in evaluating the effectiveness of the Micro-PCNL, which consists of a telescope, working channel, and irrigation system combined in one small caliber (4.8 Fr) in the pediatric population [12–15]. According to the European Urological Association (EAU) guideline for pediatric urinary stones, Micro-PCNL is recommended for treating pediatric kidney stones in renal pelvis with stones in various sizes. However, there is still currently no recommendation on using this modality for treating pediatric kidney stones, 10–20 mm in size.

One of the most important parameters for evaluating the effectiveness of treatment modalities for kidney stones in children is SFR. PCNL and RIRS are known for their high SFR in treating various stone sizes in all age groups. However, there is a concern when using smaller tract PCNL such as Micro-PCNL because stone clearance during this procedure depends on adequate vaporization and pressured irrigation as this procedure is unable to provide fragment retrieval [6]. Prior studies in by Bas et al. and Sen et al. reported no significant difference in SFR between patients undergoing Micro-PCNL and RIRS ($p = 0.47$, $p > 0.05$) [12,14]. Other studies by Wang et al. and Halinski et al. reported similar results, that there was insignificant difference in SFR between patients treated with Micro-PCNL compared to RIRS ($p = 0.799$, $p = 1.00$) [13,15]. These results are consistent with the results of our meta-analysis, which demonstrated that pediatric patients who underwent the Micro-PCNL and RIRS procedures had similar SFR ($p = 0.86$). From this result, we can infer that the smaller tract in Micro-PCNL does not compromise the efficacy of the treatment.

Another paramount important parameter to be considered is operative time, because this parameter is not only correlated with complication rate but also the financial burden [19,20]. The operative time is influenced by several factors such as surgical modality, operator experience, and the type of instrumentation [21]. From the pooled analysis, we discovered that Micro-PCNL had a similar operative time to RIRS ($p = 0.09$). Although the analysis demonstrated a comparable outcome between both approaches, it should be noted that cumulatively, the total operative time is also influenced by the requirement of additional stenting procedures, which require additional anesthesia and cystoscopy for stent insertion and removal that are not considered in the meta-analysis. Based on our collected data, pre-stenting procedures were performed in 16–100% of patients undergoing RIRS, but none in Micro-PCNL. Furthermore, postoperative stent placement was more commonly required in RIRS (17–100%) than Micro-PCNL (0–44%) [12–15].

Postoperative installation of DJ-stent is performed after stone removal surgery as a drainage method in complex cases and based on operator decisions. This modality provides a beneficial role to accelerate the healing process, preventing ureteral stricture, colic, and kidney damage due to ureteral edema [22,23]. Despite their beneficial roles, postoperative DJ-stent placement is associated with stent-related symptoms [24]. Bas et al. reported that RIRS procedures had a higher requirement of postoperative DJ-stent placements compared to Micro-PCNL (78% vs 27%). Similar findings were reported by Wan et al. and Sen et al., who reported that RIRS procedures required more DJ-stent placements than Micro-PCNL procedures [12]. From the pooled analysis, we discovered that the Micro-PCNL procedure had fewer requirements for postoperative DJ-stent placement than RIRS (OR 0.09; 95% CI 0.02, 0.47; $p < 0.01$).

Micro-PCNL and RIRS are endourological procedures that highly depend on radiation to guide the procedure that could have a negative long-term health impact. One of the strategies to reduce the risk of radiation is by controlling the fluoroscopy time [25]. Sen et al. reported that Micro-PCNL required a longer fluoroscopy time than RIRS (115s vs. 39s, $p = 0.01$) [12]. A similar finding was reported by Bas et al., which shows that the Micro-PCNL procedure had a longer fluoroscopy time than RIRS [14]. In contrast, Halinski et al. reported that the fluoroscopy time required for RIRS is longer than Micro-PCNL (20s vs. 12s). The less fluoroscopy time in Micro-PCNL is mainly attributable to the use of ultrasound as the guidance for the initial puncture [15]. Unfortunately due to the incompleteness of data from available studies, we could not perform the quantitative synthesis on this outcome [14,15].

One of the limitations of Micro-PCNL is the closed irrigation system, which could cause an increase in intrapelvic pressure and therefore predispose the patients to risks of infection and urosepsis [11,26]. Prior studies by Bas et al. and Want et al. reported that the incidence of UTI is similar between Micro-PCNL and RIRS (2% vs 5%, 7.4% vs 6.6%, respectively) [14,15]. From the combined analysis, we discovered that patients undergoing the Micro-PCNL and RIRS had a similar incidence of UTI ($p = 0.67$). On the other hand, bleeding is also regarded as a severe complication in endourological procedures, especially in a percutaneous endoscopic approach [27]. A meta-analysis comparing the efficacy and safety of PCNL with RIRS in the general population showed that bleeding is more common in PCNL than RIRS [21]. The size of the tract, number of access points, and dilatation methods all play a role in determining intraoperative bleeding during PCNL. Several studies evaluating PCNL with smaller tracts revealed a consistently lower bleeding rate [6,11]. Several studies comparing Micro-PCNL and RIRS in pediatric kidney stones reported no patients in either intervention group who required blood transfusions [12–15]. Based on the combined analysis, we discovered a comparable result in terms of blood transfusion between Micro-PCNL and RIRS ($p = 0.95$). However, assessing bleeding using the number of blood transfusions might not be accurate due to confounding factors such as differences in cut-off or indications for blood transfusion at different centers that can influence the result [28]. In addition to blood transfusion, Bas et al. evaluated bleeding parameters using Hb change and discovered no changes after the RIRS procedure but a 0.53 g/dL decrease after Micro-PCNL [14]. Even though both procedures had a difference in Hb change, the difference might not be clinically relevant [12,14]. In general, our findings highlight the advantage of smaller tracts used in Micro-PCNL to reduce bleeding caused by large tract dilation and generate a comparable outcome to RIRS. The other important safety aspect that is crucial to be evaluated is the LOS after the surgery. This parameter is not only associated with patient safety, but also the quality of patient care and the costs required during treatment [29]. From the combined analysis, we found that patients who underwent the Micro-PCNL procedure had a similar LOS as those who underwent RIRS (p = 0.77). However, the LOS might also be influenced by several factors including the amount of intraoperative bleeding, postoperative bleeding, and operative time [29]. In general, we highlighted the role of Micro-PCNL as an advancement of PCNL as an alternative to the RIRS technique in managing moderately sized pediatric kidney stones.

This meta-analysis has several limitations. First, there is a lack of analysis from prospective and RCT studies, all studies included in this systematic review and meta-analysis are retrospective cohort studies, thus, there is a possibility of bias due to various confounding factors that can affect the final results. Our analysis showed statistically significant heterogeneity in several outcomes, such as the operative time and length of hospitalization parameters that might be attributable to varying operators experiences, different patient characteristics, and different operative time definitions. Furthermore, the data on the cost-analysis and bleeding parameters between the Micro-PCNL and RIRS procedures is still limited. Therefore, an assessment of the financial aspect and bleeding parameters should be one of the main focuses of future studies.

5. Conclusion

Micro-PCNL has comparable efficacy and safety to RIRS. Micro-PCNL possesses an advantage in terms of less requirement of additional stenting procedures. Our findings highlight the superiority of Micro-PCNL over RIRS in managing children with kidney stones sized 10–20 mm.

Ethics committee approval

A systematic review does not require an ethical approval. The protocol of this review has been registered in the International prospective register of systematic reviews (CRD42021265894).

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Author contributions

Concept – FWC; Design – FWC, NY, YPK; Supervision – DMS,JR,MAS; Resources – FWC, YPK,; Materials –FWC,NY,YPK; Data Collection and/or Processing – FWC,NY,YPK; Analysis and/or Interpretation –FWC; Literature Search –FWC,NY,YPK; Writing Manuscript –FWC,NY,YPK; Critical Review – JR,MAS,DMS.

Disclosure statement

The authors declare no conflict of interest.

Registration of Research Studies

Name of the registry: PROSPERO.
Unique Identifying number or registration ID: CRD42021265894.
Hyperlink to your specific registration (must be publicly accessible and will be checked): http://www.crd.york.ac.uk/prospero/display_record.php?RecordID=265894.

Guarantor

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Consent

Not applicable.

Provenance and peer review

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Declaration of competing interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

(All contributing authors must complete the ICMJE form individually and the completed forms should be submitted to the online system by the corresponding author. The form is available at http://www.icmje.org/conflicts-of-interest/After that the information which were stated at the end of the forms must be combined and declared in this section).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.104315.

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Abbreviations

PCNL: percutaneous nephrolithotomy
RIRS: retrograde intrarenal surgery
ESWL: extracorporeal shock wave lithotripsy
SFR: stone-free rate
PRISMA: preferred reporting items for systematic review and meta-analyses
RCT: randomized controlled trial
UTI: urinary tract infection
CT: computed tomography
RoB: risk of bias
NOS: Newcastle-Ottawa Scale
MD: mean difference
OR: odds ratio
SD: standard deviation
EAU: European Association of Urology
Hb: hemoglobin