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Review

Comparison of DJ stented, external stented and stent-less procedures for pediatric pyeloplasty: A network meta-analysis

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ABSTRACT

Objective: To assess the efficacy and safety of double J (DJ) stented, external stented and stent-less procedures in pediatric pyeloplasty by adopting a network meta-analysis (NMA).

Material and methods: Electronic databases including PubMed, Cochrane Library, Web of science and Embase database were retrieved. The trials that compared double J (DJ) stented, external stented or stent-less procedures in pediatric pyeloplasty were identified. A network meta-analysis was conducted with the software of STATA 14.0. Probability-based ranking results were performed to identify the best treatment, and publication bias was analyzed by funnel plots.

Results: 15 studies with 1731 participants were enrolled in the analysis, including 4 randomized controlled trials (RCT) and 11 retrospective studies. The NMA results revealed that no significant differences were detected in the outcomes of operative time, operative success, hospital stay, improvement of renal functions, overall complications and redo pyeloplasty. DJ stented and external stented procedures were associated with more postoperative pain than that of stent-less procedures [DJ stented: OR = 4.47, 95%CI(1.05,19.08); external stented: OR = 5.83, 95%CI(0.09,1.43)]. DJ stented procedure had a lower rate of urine leakage than those of external stented procedure [OR = 0.18, 95%CI (0.04, 0.76)] and stent-less procedure [OR = 0.07, 95%CI = (0.01, 0.34)]. No significant difference was observed in other types of complications such as urinary tract infection (UTI), stent migration, recurrent ureteropelvic junction obstruction (UPJO) and fever. The probabilities of ranking results indicated that the DJ stented procedure was the best treatment in the outcomes of hospital stay, operative success, improvement of renal functions, and the complication of urine leakage. Stent-less procedure showed its advantages in the outcomes of operative time, flank pain and UTI. External stented procedure had the lowest rate of overall complications and redo pyeloplasty.

Conclusions: There were no obvious differences in operative time, operative success, hospital stay, improvement of renal functions, overall complications between external stented, DJ stented and stent-less procedures for pediatric pyeloplasty. When considering the ranking results, the DJ stented procedure seemed to be more beneficial for pediatric pyeloplasty than the other methods. However, with the limitation of our study, additional high-quality studies are needed for further evaluation.

1. Introduction

Ureteropelvic junction obstruction (UPJO) is defined as the failure of urine outflow from the renal pelvis to the ureter, which may lead to progressive kidney damage [1]. The UPJO is one of the most common congenital causes of antenatally diagnosed hydronephrosis, with an incidence of about 1 in 1000–2000 live births [2]. It is estimated that about 20–50% of UPJO children end up with surgical treatments [3]. Since its introduction in the 1940s, Anderson-Hynes dismembered pyeloplasty has remained the standard surgical treatment for UPJO [4]. Laparoscopic pyeloplasty is the first minimally invasive surgery for pyeloplasty and has become a well-established treatment for UPJO in

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the past decades [5,6]. In recent years, robot-assisted laparoscopic pyeloplasty has also rapidly gained popularity [7]. Compared with the open approach, laparoscopic pyeloplasty is associated with similar results, shorter hospitalization, and fewer complications [8–10]. Nowadays, Many hospital centers have promoted LP as the first-line treatment for UJPO [11].

Despite the rapid development of surgical techniques, there are still some debates about whether it is necessary to place a urinary stent to drain, and which type of stent is better [12]. Many types of stents can be used when performing a stented pyeloplasty. The commonly seen stents can be divided into two categories: external stent and internal stent (DJ stent). Both external and internal stents have been widely used for many years and have been proved effective in clinical practices worldwide. However, both external stents and DJ stents are associated with various complications, such as postoperative pain, urinary tract infection (UTI), etc. In recent years, stent-less pyeloplasty has been reported to have similar results and fewer complications than stented pyeloplasty [13–15]. It has gained much popularity among many surgeons worldwide. However, which is superior among DJ stented, external stented, and stent-less procedures remains unclear. Even though many studies have compared the differences between these three procedures, no clear conclusions have been drawn. Nowadays, Whether or not to place stents and which type of stents to place in clinical practices mainly depends on the surgeons' preference and experience.

With the network meta-analysis (NMA), we can make comparisons with all direct and indirect evidence, and make the pooled results more powerful and persuasive than the traditional meta-analysis. In addition, we can find out which method is the best treatment by the ranking analysis. As far as we know, this is the first network meta-analysis comparing three procedures for pediatric pyeloplasty. The main goal of this study was to compare the efficacy and safety of DJ stented, external stented and stent-less procedures, and to find out which one is the optimal treatment for pediatric pyeloplasty.

2. Materials and methods

2.1. Search strategy

A systematic review was performed according to the guidelines of Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) [16] and Assessing the methodological quality of systematic reviews (AMSTAR) [17]. Computer-based retrieval of PubMed, Cochrane Library, Embase and Web of Science databases was conducted. The MeSH terms and related synonyms including "pyeloplasty", "double J", "DJ", "stent*", "catheter", "tube", "catheter", "double-J", "children", "pediatric", etc. were combined in the search strategy. We also manually searched reference lists of related publications including reviews, meta-analyses and other types of articles. After importing the retrieved results into the endnote library, the eligibility of these publications were carefully checked. All duplicates and irrelevant publications were removed after scanning the title and abstract. The remaining publications were further accessed by full-text scanning.

2.2. Selection criteria

The studies were considered eligible if they met the following inclusion criteria: (1) clinical trials. (2) Patients were diagnosed with UPJO and underwent pyeloplasty. (3) Patients were infants or young children. (4) Patients were treated with DJ stented, external stented, or stent-less procedures.

The following criteria were conducted for study exclusion: (1) In addition to UPJO, patients were accompanied by other diseases. (2) Besides pyeloplasty, some other surgeries or treatments unrelated to UPJO were performed. (3) Patients over 18 years old were involved in studies. (4) Sufficient data of necessary information such as treatments or outcomes were not provided. (5) Data were unavailable to calculate odds ratios (OR) or standardized mean difference (SMD).

2.3. Data extraction and quality assessment

Two reviewers extracted the data from the included studies independently. The extracted data were as follows: the first author's name, year of publication, country, study design, the total study sample, interventions, samples of each group, mean age of patients, follow-up durations and main clinical outcomes. The main outcomes included operative time, operative success, hospital stay, improvement of renal functions in the follow-ups, overall complications, specific types of complications, and redo pyeloplasty due to reobstructions, operative failure, or complications. Operative success was defined as unobstructed urine outflow from the renal pelvis to the ureter, or resolved or improved hydronephrosis under ultrasound. Overall complications were the sum of all specific types of complications.

Two reviewers independently assessed methodological quality with the assessment tool presented by the Cochrane Handbook for Systematic Reviews Interventions version 5.1.3. For included trials, the following criterions were evaluated and graded as having a low, medium, or high risk bias: random sequence generation, allocation concealment, blinding of participants and personnel blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Disagreements were resolved through discussion by the two reviewers or consultation with a third team member.

2.4. Data synthesis and analysis

We conducted a pair-wise meta-analysis to synthesize all direct evidence. The corresponding odds ratios(ORs) or weighted mean difference (WMD) and their 95% confidence intervals (95% CIs) were calculated. The Mantel–Haenszel Chi-square based test and I^2 parameter test were applied for evaluating the heterogeneity. The statistical significance was defined as $P < 0.05$. The network meta-analysis was performed based on the Bayesian framework model using STATA version 14.0. The random-effects model was utilized in this study to calculate the evidence inconsistency. The relative ranking of each intervention was presented as probability. In addition, publication bias was evaluated via observing the symmetry characteristics in funnel-plots. A symmetrical and concentrated distribution of dots indicated no obvious deviation.

3. Results

3.1. Included studies characteristics

The entire process of literature retrieval and screening for NMA was illustrated in Fig. 1. A total of 1896 publications were obtained. After removing the duplicates, 1430 studies were screened by reading titles and abstracts. 42 articles were performed with full-text assessment. Finally, 15 [13,18–31] studies were enrolled in our analysis. The baseline characteristics of the included studies were presented in Table 1.

According to the Cochrane Collaboration tool for assessing the risk of bias, the qualities of the included trials were assessed in seven aspects. 4 of 15 included studies had adequate randomization. The remaining trials were the retrospective study. 2 article reported the detail information about allocation sequence concealment. Blind design was hard to perform in surgical treatments. Attrition bias and reporting bias were generally well performed in included trials. The risk-of-bias assessment of the included trials was presented in Fig. 2. The network plots of three procedures was shown in Fig. 3.

3.2. Network meta-analysis of operative time

7 trials with 637 patients described the outcomes of operative time,

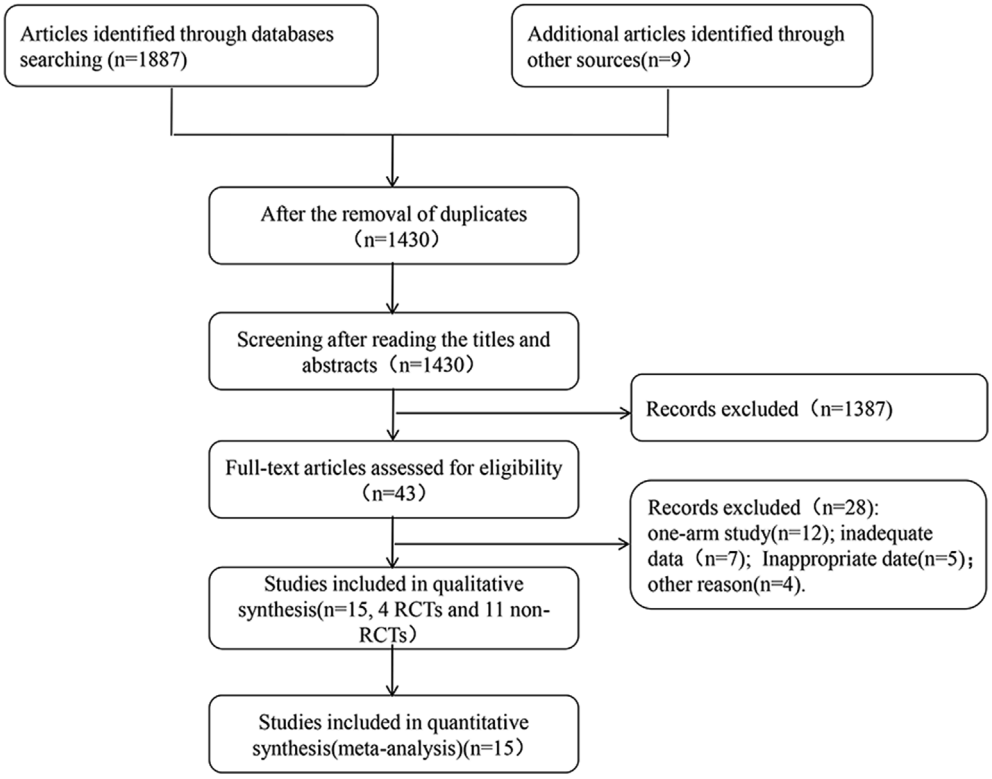

Fig. 1. PRISMA flow diagram of the study selection process for network meta-analysis.

Table 1
Characteristics of the included studies in meta-analysis.

Authors, country	Study design, year	Sample	Inventions	Groups sample, Mean age	Follow-up	Outcomes
Nagdeve et al. India	RCT, 2018	n = 42	Group 1: DJ stenteded Group 2: Stent-less	Group 1: n = 21, age 4.227 y Group 2: n = 21, age 4.257 y	3 mos	a, c, d, e
Chu et al. USA	Retrospective study, 2018	n = 64	Group 1: DJ stented Group 2: External stented	Group 1: n = 47 age:6.5 y Group 2: n = 17 age:7.7 y	12.3 mos	a, b, c, e
Nasser et al. Egypt	RCT, 2017	n = 30	Group 1: Stent-less Group 2: External stented	Group 1: n = 15, age 4mos Group 2: n = 15, age 3.1 mos	22/21.46mos	a, b, c, d, e,f
Garg et al. India	RCT, 2015	n = 40	Group 1: External stented Group 2: DJ stented	Group 1: n = 20, age 2.7y Group 2: n = 20, age 3.67y	≥3 mos	b, c,e,f
Lee et al.Canada	Retrospective study, 2015	n = 62	Group 1: External stented Group 2: DJ stented	Group 1: n = 24; age:40 mos Group 2: n = 38; age:80 mos	23.8/21.1 mos	a,b, c, e
Zoeller et al. Germany	Retrospective study, 2014	n = 86	Group 1: DJ stented Group 2: External stented	Group 1: n = 48, age:5.6 y Group 2: n = 38, age:5.6 y	12mos	b,e,f
Kocvara et al. Czech	Reprospective study, 2014	n = 70	Group 1: Stent-less Group 2: DJ stented Group 3: External stented	Group 1: n = 34, age: 35 mos Group 2: n = 21, age: 46 mos Group 3: n = 15, age: 34 mos	36.2mos	a,b,d,e
Kim et al. Korea	Reprospective study, 2012	n = 70	Group 1: DJ stented Group 2: Stent-less	Group 1: n = 22 Group 2: n = 54	29.6mos	c,e
Helmy et al. France	Retrospective study, 2011	n = 22	Group 1: External stented Group 2: DJ stented	Group 1: n = 11, age:31 mos; Group 2: n = 11, age 37mos	34/35mos	a, c, d, e, f
Son et al. Vietnam	Retrospective study, 2011	n = 155	Group 1: Stent-less Group 2: External stented	Group 1: n = 33 Group 2: n = 122	6mos-4y	e,f
Bayne et al. US	Retrospective study, 2011	n = 367	Group 1: Stent-less Group 2: External stented	Group 1: n = 231, age 4.486 y Group 2: n = 136, age 5.012 y	480.98 d	e,f
Braga et al. Canada	Retrospective study, 2008	n = 470	Group 1: DJ stented Group 2: External stented	Group 1: n = 242, age 19 y Group 2: n = 228, age 18 y	41/39 mos	b,c, d,e
Elmalik et al. UK	Retrospective study, 2008	n = 105	Group 1: Stent-less Group 2: DJ stented	Group 1: n = 47, age 65.0mos Group 2: n = 58, age 53.8mos	40.3mos	a,b, c,d, e
Arda et al. Turkey	RCT, 2002	n = 31	Group 1:External stented Group 2: Stent-less	Group 1: n = 15, age 31.6mos Group 2: n = 16, age 38.9mos	35 mos	c, e
Smith et al. US	Retrospective study, 2002	n = 117	Group 1: Stent-less Group 2: External stented	Group 1: n = 65 Group 2: n = 52	unclear	c,e,f

RCT: randomized controlled trial; a: operative time (mins); b: operative success; c:hospital stay (days); d:renal functions; e:postoperative complications; f: redo pyeloplasty.

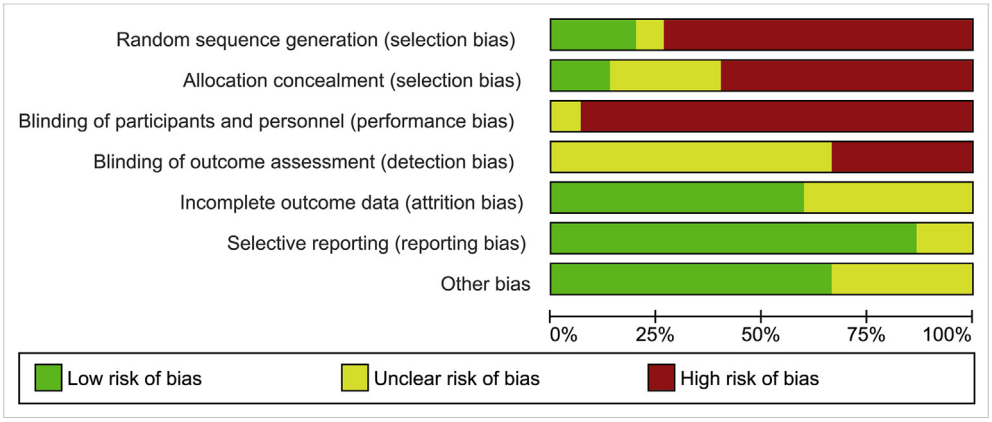

Fig. 2. Risk of bias graph and summary of the included studies.

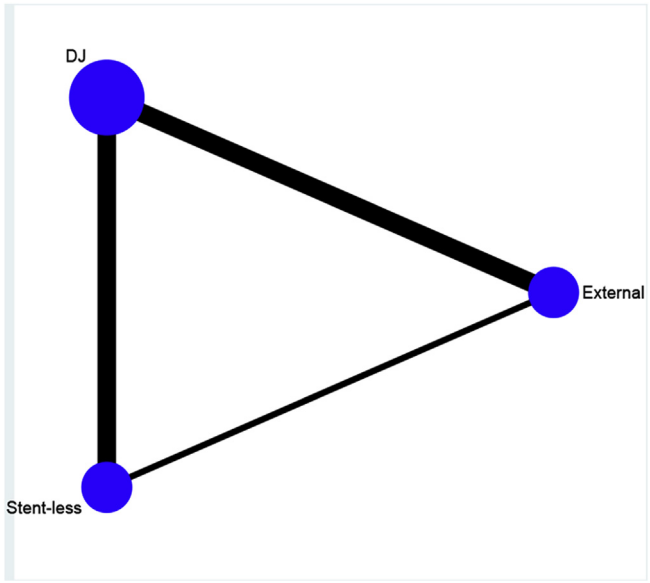

Fig. 3. Network plots of the comparisons between DJ stent, external stent and stent-less.

and the time between studies varied greatly. The average operative time of DJ stented, external stented and stent-less groups in the 7 studies were 147.23min (range: 60.4–190min), 154.96min (range:78.9–205min), 123.47min (range:85.3–162min). In the pooled meta-analysis results shown in Table 2, we didn't find significant differences between three groups. The probability-based ranking results were shown in Table 4. Stent-less group ranked 1st (39.5%), DJ stented group ranked 2nd (38.2%), external stented group ranked 3rd (40.6%). In this result, ranking 1st meant the shortest operative time, and the last meant the longest time.

3.3. Network meta-analysis of operative success

8 of 15 studies with 839 patients reported the outcomes of surgery. All groups achieved a high success rate, and the average success rate of DJ stented, external stented and stent-less groups were 93.2% (range: 88%–95%), 92.6% (range: 86%–94.7%), 89.2% (range: 85%–93.4%), respectively. The pooled results showed that the success rates in three groups were similar, and no significant differences were detected (Table 2). The ranking results with probability were as follows: DJ stented group was the best (76.3%), external stented group was the second (63.7%), and stent-less group was the last (56.6%) (Table 4).

Table 2
The network meta-analysis results for surgical outcomes.

Outcomes	DJ	External	Stent-less
Operative time [SMD(95%Cl)]			
DJ	1	−0.17(-1.05, 0.71)	−0.08(-1.38, 1.21)
External	0.17(-0.71, 1.05)	1	0.09(-1.22, 1.39)
Stent-less	0.08(-1.21, 1.38)	−0.09(-1.39, 1.22)	1
Success rate [OR(95%Cl)]			
DJ	1	0.83(0.7, 1.22)	0.74(0.64, 1.14)
External	1.20 (0.82, 1.43)	1	0.86(0.75, 1.32)
Stent-less	1.36 (0.88, 1.57)	1.16 (0.76, 1.33)	1
Hospital stay [SMD(95%Cl)]			
DJ	1	0.67(-0.83, 2.61)	1.64(-0.12, 3.41)
External	−0.67(-2.16, 0.83)	1	0.98(-0.66, 2.61)
Stent-less	−1.64(-3.41, 0.12)	−0.98(-2.61, 0.66)	1
Renal functions improvement [SMD(95%Cl)]			
DJ	1	0.73(0.38, 1.22)	0.64(0.15, 1.09)
External	1.37 (0.82, 2.60)	1	0.62(0.31, 1.12)
Stent-less	1.56 (0.92, 6.80)	1.62 (0.89, 3.20)	1
Overall complications [OR(95%Cl)]			
DJ	1	1.67(0.71, 4)	1.49(0.6, 3.7)
External	0.60(0.25,1.40)	1	0.89(0.32, 2.5)
Stent-less	0.67(0.27,1.66)	1.12(0.40,3.13)	1
Redo pyeloplasty [OR(95%Cl)]			
DJ	1	0.19(0.02, 1.69)	0.21(0.02, 2)
External	5.26(0.59,50)	1	1.11(0.69, 1.79)
Stent-less	4.78(0.50,45.52)	0.90(0.56,1.45)	1

DJ: double-J; OR: odds ratio; SMD: standardized mean difference; CI: credible intervals.

3.4. Network meta-analysis of hospital stay

As for the outcome of hospital stay, 9 studies with 940 patients were taken into analysis. The average hospital stay of DJ stented, external stented and stent-less procedures were 2.93d (range: 1.0–5.15d), 3.80d (range: 1.0–11.95d), and 4.2d (range: 2.6–5.9d), respectively. The pooled results revealed that there were no significant differences in the comparisons of DJ stented, external stented, and stent-less procedures (Table 2). Probabilities of the ranking results were as follows: DJ stented group ranked 1st (81.4%), external stented group ranked 2nd (75.2%), stent-less group ranked 3rd (91.6%) (Table 4). In this outcome, ranking 1st had the minimal length of hospital stay, and the 3rd had the maximal.

3.5. Network meta-analysis of the improvement of renal functions

Among all included studies, 6 trials with 457 patients described the improvement of renal functions. Compared with preoperative renal function, all groups were significantly improved during follow-up ($P < 0.05$). However, the comparisons of the improvement of renal

Table 3
The meta-analysis results of all types of postoperative complications.

Complications	DJ vs external	DJ vs stent-less	External vs stent-less
Urine leakage	0.18(0.04,0.76)	0.07(0.01, 0.34)	0.36(0.09,1.43)
Pain	0.78(0.57, 4.49)	4.47(1.05,19.08)	5.83(1.21,27.98)
UTI	2.63(0.75,9.09)	3.37(0.92,12.32)	1.28(0.50,3.23)
Stent migration	2.17(0.68,6.88)		
Recurrent UPJO	0.85(0.43,1.66)		
Fever	0.39(0.06, 2.70)	2.02(0.61, 6.73)	5.14(0.66, 40.20)
Pyelonephritis	P = 0.24		
Bladder spasms	P = 0.03		
Urinoma	P = 0.65		
Hematuria	P = 0.03	P = 0.743	
Hydronephrosis	P = 0.78		P = 0.73

DJ: double-J; UTI: urinary tract infection; UPJO: Ureteropelvic junction obstruction.

functions between three groups did not show significant differences. The results were presented in Table 2. In the ranking results with probabilities, DJ stented group ranked 1st(71.4%) in the improvement of renal function, followed by stent-less group (65.7%) and external stented group(45.8%).

3.6. Network meta-analysis of overall complications

11 of 15 studies reported overall complications, recruiting of 765 patients. The average overall complication rate of DJ stented, external stented, and stent-less procedures were 34.8%, 20.2%, and 27.1%, respectively. The NMA results revealed that there were no significant differences in three groups (Table 2). The ranking results based on probabilities were as follows: external stented group ranked 1st (77.3%), stent-less group ranked 2nd (42.8%), DJ stented group ranked 3rd (56.0%) (Table 4). For this outcome, rank 1st had the lowest overall complications, the 3rd one was associated with the highest overall complications rate.

The specific types of complications were also analyzed in our analysis, including urine leakage, pain, UTI, stent migration, fever, pyelonephritis, recurrent UPJO, bladder spasms, urinoma, hematuria, and hydronephrosis. Data integration was performed when complications were described with a sufficient number of studies. The analysis results of different complications were presented in Table 3. From pooled results, we found that the urine leakage rate of DJ stented group was lower than that of the external stented group [OR = 0.18, 95%CI(0.04, 0.76)] and stent-less group [OR = 0.07, 95%CI = (0.01, 0.34)]. The DJ stented group and external stented group were associated with more postoperative flank pain than stent-less did [DJ stented: OR = 4.47, 95%CI(1.05, 19.08); external stented: OR = 5.83, 95%CI = (1.21, 27.98)]. No significant differences were observed between three groups in the outcome of UTI, stent migration, recurrent UPJO, and fever. Based on the ranking results shown in Table 4, we could find that DJ stented group ranked 1st (99%), external stented group ranked second (91.7%), then stent-less (92.6%) was the least in urine leakage. Stent-less was the best in postoperative pain (96.8%), DJ stented group was second (61.9%) and external stented group was the last(63.7%). The sequence of UTI from best to worst was stent-less group (67.3%), external stented group (63.9%), and DJ stented group (92.2%). In the complications of pyelonephritis, bladder spasms, hematuria, and hydronephrosis, the relevant data were limited and could not be integrated. We listed the P value of comparisons reported in the studies in Table 3. According to the results, we could find that most of the P values were ≥ 0.05, which suggested that there were no significant differences in the comparison.

3.7. Network meta-analysis of redo pyeloplasty

A total of 7 studies with 1114 participants reported the outcome of redo pyeloplasty. The average rate of DJ stented, external stented, and stent-less procedures were 8.5% (range: 5.3%–9.1%), 7.6% (range: 0%–13.2%), and 7.2% (range: 4.6%–13.4%), respectively. NMA results suggested that there were no significant differences between the comparisons of three groups (Table 2). The probabilities of ranking results were as follows: external stented group ranked 1st (62.5%), stent-less group ranked 2nd (61.9%), DJ stented group ranked 3rd (90.8%) (Table 4). Among all interventions, rank 1st was associated with the lowest redo surgery rate, and the last one was the highest.

Table 4
Ranking results based on simulations.

Endpoints (%)	Ranks	DJ	External	Stent-less
Operative time (rank 1 is the best, rank 3 is the worst)	Rank 1	38.4	21.2	39.5
	Rank 2	23.9	38.2	37.9
	Rank 3	37.7	40.6	22.7
Success rate	Rank 1	76.3	23.1	18.5
	Rank 2	16.0	63.7	24.9
	Rank 3	7.7	13.2	56.6
Hospital stay	Rank 1	81.4	17.4	1.2
	Rank 2	17.6	75.2	7.2
	Rank 3	1.0	7.3	91.6
Renal functions improvement	Rank 1	71.4	23.9	19.1
	Rank 2	18.9	50.3	65.7
	Rank 3	9.7	45.8	16.2
Overall complications	Rank 1	9.0	73.6	17.4
	Rank 2	35.0	22.2	42.8
	Rank 3	56.0	4.2	39.8
Redo pyeloplasty	Rank 1	6.3	62.5	31.2
	Rank 2	2.9	35.2	61.9
	Rank 3	90.8	2.3	6.9
Urine leakage	Rank 1	99.0	1.0	0.1
	Rank 2	1.0	91.7	7.3
	Rank 3	0.0	7.4	92.6
Pain	Rank 1	2.1	1.1	96.8
	Rank 2	61.9	35.3	2.8
	Rank 3	35.9	63.7	0.4
UTI	Rank 1	2.1	30.6	67.3
	Rank 2	5.7	63.9	30.4
	Rank 3	92.2	5.5	2.3

UTI: urinary tract infection.

3.8. Consistency and convergence analysis

The node-splitting analysis was applied to evaluate inconsistency by comparing the differences between direct and indirect evidence. No significant inconsistency was detected among the various treatments with the P-value were lower than 0.05. That meant the consistency model was reliable. The publication bias was analyzed by the funnel plot, and no obvious publication bias was detected in most outcomes. The funnel plots of all outcomes were shown in Fig. 4.

4. Discussion

For external stented, DJ stented, and stent-less pyeloplasty, each procedure is associated with its advantages and disadvantages. The external stented procedure allows for the assessment of the repair in pyeloplasty and can be simply removed without sedation. But it has several potential unfavorable conditions such as increased risk of renal parenchyma damage, bleeding, flank pain, UTI and reduced quality of life [32]. DJ stented procedure can provide support and prevent edema in the anastomotic site for the patients who undergoing pyeloplasty

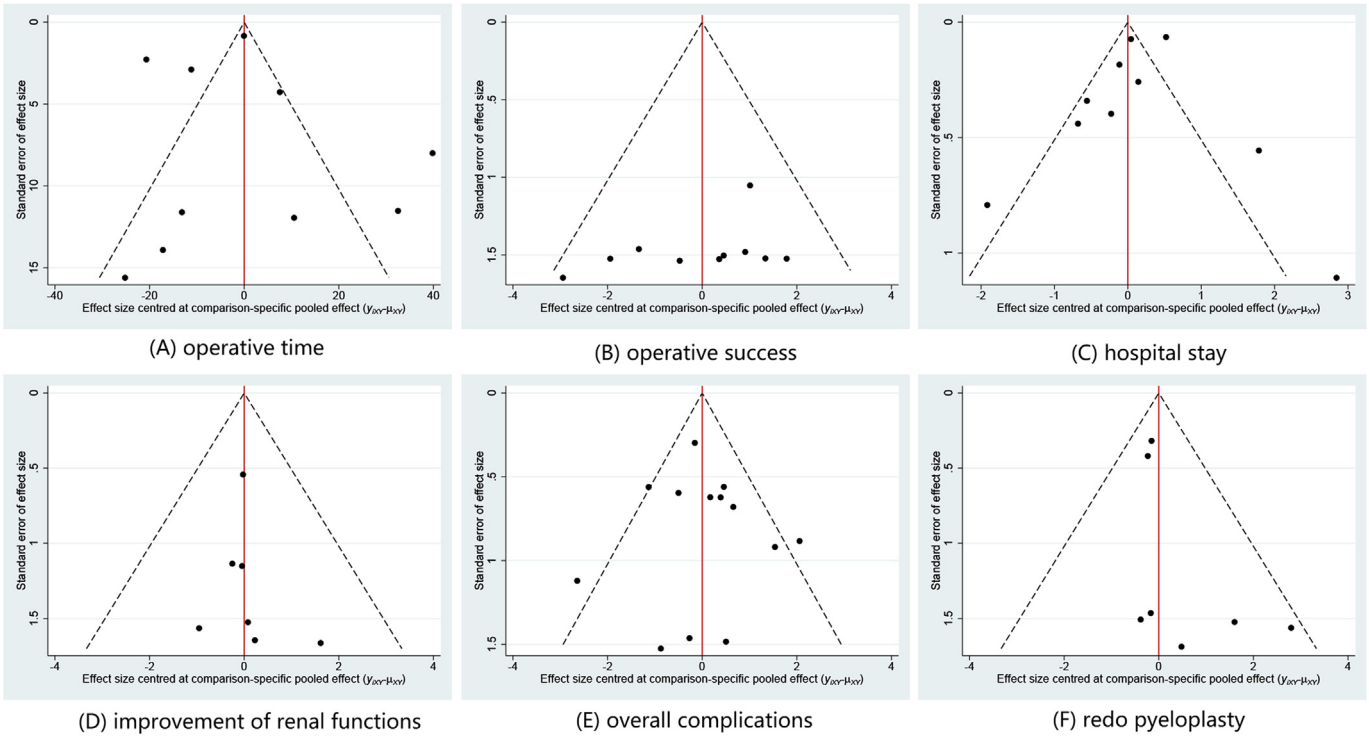

Fig. 4. Funnel plots of all outcomes: (A) operative time; (B) operative success (C) hospital stay; (C) improvement of renal functions; (D) overall complications; (E) redo pyeloplasty.

[22,24]. However, it is related to a higher risk of UTI and requires additional general anesthesia to remove the stent [14,22]. Moreover, this internal approach forms artificial vesicoureteric reflux that may result in persistent kidney damage [33]. The stent-less procedure can avoid stent-related complications after pyeloplasty, without the need of instrument tube and second anesthesia. However, it is associated with some common complication such as urine leakage.

In our study, 15 studies recruiting 1731 were included and analyzed. According to the network meta-analysis results, we found that there were no significant differences in the outcomes of operative time, operative success, length of hospital stay, improvement of renal functions, overall complications and redo surgery rate. DJ stented procedure had a lower rate of urine leakage than that of external stented and stent-less procedures. The stent-less procedure was associated with less postoperative pain than that of DJ stented and external stented procedures. The ranking results showed that DJ stented pyeloplasty was the best in the outcomes of hospital stay, operative success, improvement of renal functions, and the complication of urine leakage. Stent-less pyeloplasty was the best in the outcomes of operative time, flank pain and UTI. External stented pyeloplasty had the lowest rate of overall complications and redo pyeloplasty.

For the outcome of operative time, many previous publications have drawn similar conclusions with our results. Braga et al. [20] compared the operative time of DJ stented and external stented procedures, and did not find significant differences. Similar results could be seen in Nasser's study [28]. Of course, there were different consequences. Helmy et al. [22] reported that external stented pyeloplasty had a slightly shorter operative time than that of the DJ stented pyeloplasty. As for the operative success rate, Braga et al. [20] analyzed 470 patients, and found that the operative success rate of DJ stented and external stented groups were 95% and 94.7% respectively. Similar results were found in other studies [21,28]. The operative success was greatly affected by the surgery. The Anderson-Hynes dismembered pyeloplasty was reported with a high success rate of more than 90% in many studies [12,34–36]. For the hospital stay, some studies concluded that the length of hospital stay was similar in the comparisons with DJ stented vs external stented [24,27], DJ stented vs stent-less [29,37], and external stented vs stent-less procedures [18]. Elmalik et al. [22] found that DJ stented patients had a shorter hospital stay than that of unstented patients. As pyeloplasty can eliminate the obstruction of the ureteropelvic junction, renal functions will be improved in most patients. It is especially obvious for patients with poor renal functions before surgery. Nagdeve et al. [31] compared DJ stented and stent-less procedures in a randomized controlled study, and conducted a 3-month follow up. He found that the renal functions in DJ stented group improved from 30.41% preoperatively to 32.78% postoperatively, and increased from 28.71% preoperatively to 30.8% postoperatively in stent-less group. In another randomized comparative study, Nasser et al. [28] found that the mean renal functions improved from 26.7% to 32.7% in external stented patients, and increased from 32.6% to 42.4% in stent-less patients. The improvements in renal functions were not different significantly between the two groups.

As for the outcome of overall complications, we didn't find statistical differences between the external stented, DJ stented, and stent-less procedures. Several previous studies [20,22,27,29] also proved this result. As for the outcome of redo pyeloplasty, our results showed that there were no obvious differences between the three procedures. Similar results were reported in other studies [13,19,20,38]. When it came to specific complications, many studies had similar results to our findings. The stent-less group was associated with more urinary leakage [19,20,29], and less flank pain than stented groups [20,37,39]. Nagdeve et al. [31] concluded that the DJ stented patients were more symptomatic than unstented patients in the postoperative period, but the difference was not statistically significant.

Although no significant differences found in main surgical outcomes, the ranking results identified the best treatment for all outcomes. According to the ranking results, the DJ stented procedure had the highest operative success, renal function improvement, and the shortest hospital stay. External stented method had the lowest rate of overall complications and redo pyeloplasty. Stent-less procedure had the shortest operative time. As for specific types of complications, DJ stented procedure had a lower rate of urine leakage than the external

stented procedure. When compared with DJ stented and external stented procedures, the stent-less procedures had less postoperative flank pain. Based on all analysis results, it seems to be that DJ stented pyeloplasty has more benefits than external stented and stent-less pyeloplasty. While in clinical practice, the choice of DJ stented, external stented and stent-less procedures still require the consideration of the patients' willing, surgeons' experience and the individuals' condition.

As far as we know, our study is the first comprehensive meta-analysis that evaluated the difference of external stented, DJ stented and stent-less procedures in pediatric pyeloplasty. We performed data consolidations with all included studies in the main outcomes, making the summary results accurate and convincing. However, our analysis does have certain limitations. Firstly, only 15 studies were included, so it might not be sufficient to conduct a powerful meta-analysis. Furthermore, only 4 RCTs were included and the rest were mostly retrospective study. These retrospective studies might be associated with a high risk of bias, and affect the reliability of pooled results. Secondly, the external stented procedures might have several different types, the combination of different external stents into one group might be inappropriate and could increase the heterogeneity of the results. The last, limited by lacking sufficient data in included studies, some important outcomes were not analyzed. This might make our evaluation incomplete and unsystematic.

5. Conclusion

In conclusion, there were no significant differences in operative time, operative success, hospital stay, improvement of renal functions, overall complications for the external stented, DJ stented and stent-less procedures in pediatric pyeloplasty. DJ stented procedure seemed to have more advantages than external stented and stent-less procedures when considering ranking results. However, due to the limitations of our analysis, additional high-quality studies are needed to further evaluate the outcomes.

Ethical approval

All analyses were based on previous published studies, thus no ethical approval and patient consent are required.

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The authors declare no sources of funding.

Author contribution

Xu Liu: Design the protocol, acquisition and interpretation of data, technical procedures, drafted the initial manuscript, and approved the final manuscript, supervised all phases of the study.

Chuiguo Huang: Design the protocol, acquisition and interpretation of data, technical procedures, drafted the initial manuscript, and approved the final manuscript, supervised all phases of the study.

Yin Guo: Design the protocol, acquisition and interpretation of data, technical procedures, drafted the initial manuscript, and approved the final manuscript.

Yiwei Yue: Revised the manuscript, modified the language issues, and approved the final manuscript.

Jiawen Hong: Acquisition and interpretation of data, drafted the initial manuscript, and approved the final manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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Data statement

The raw data of this study are derived from the included studies, which are available in public. All detailed data included in the study are available upon request by contact with the corresponding author.

Provenance and peer review

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Appendix A. Supplementary data

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