

# Peritoneal irrigation vs suction alone during pediatric appendectomy for perforated appendicitis

## A meta-analysis

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### Abstract

**Background:** There currently exists no substantial evidence reporting the efficacy of peritoneal irrigation in reducing the incidence of postoperative intra-abdominal abscess in pediatric patients. The purpose of our study was to perform a meta-analysis to compare rates of intra-abdominal abscess after appendectomy between irrigation and suction alone groups.

**Methods:** We identified studies by a systematic search in EMBASE, PubMed, Web of Science, and the Cochrane Library to recognize randomized controlled trials and case control studies from the 1950 to May 2019. We limited the English language studies. We checked the reference list of studies to recognize other potentially qualified trials. We analyzed the merged data with use of the Review Manager 5.3.

**Results:** We identified 6 eligible papers enrolling a total of 1633 participants. We found no significant difference in the incidence of postoperative intraabdominal abscess, wound infection, and the length of hospitalization between 2 group, but duration of surgery is longer in irrigation group (MD=6.76, 95% CI=4.64 to 8.87,  $P < .001$ ; heterogeneity,  $I^2 = 25\%$ ,  $P = .26$ ).

**Conclusion:** Our meta-analysis did not provide strong evidence allowing definite conclusions to be drawn, but suggested that peritoneal irrigation during appendectomy did not decrease the incidence of postoperative IAA. This meta-analysis also indicated the need for more high-quality trials to identify methods to decrease the incidence of postoperative IAA in pediatric perforated appendicitis patients.

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**Abbreviations:** CCS = case control study, CI = confidence intervals, IAA = intra-abdominal abscess, MD = mean difference, NOS = Newcastle-Ottawa Quality Assessment Scale, OR = odds ratio, PI = peritoneal irrigation, RCT = randomized controlled trial, SA = suction alone.

**Keywords:** meta-analysis, peritoneal irrigation, pediatric, suction

## 1. Introduction

In recent years, the incidence of perforated appendicitis in the general pediatric population has been reported to range from 15% to 20%.<sup>[1]</sup> Perforated appendicitis is a major risk factor for

postoperative intra-abdominal abscess (IAA) formation, and approximately 5% to 10% of children with perforated appendicitis develop a postoperative IAA.<sup>[2–10]</sup> Postoperative IAA formation results in abdominal discomfort and may necessitate a drainage procedure or secondary surgery. In order to decrease the incidence of postoperative IAA, many surgeons have attempted to improve the surgical technique and perioperative management of pediatric appendectomy.

In 1906, Torek and his colleagues performed peritoneal irrigation (PI) with saline solution in pediatric patients with perforated appendicitis to decrease the incidence of postoperative IAA. Ever since, the use of PI has been accepted by the majority of surgeons.<sup>[11]</sup> Several articles have shown that the use of PI decreases the rate of postoperative IAA in adult perforated appendicitis patients. However, there currently exists no substantial evidence reporting the efficacy of PI in reducing the incidence of postoperative IAA in pediatric patients.<sup>[12,13]</sup> Rather, the use of PI is supported by its hypothesized underlying mechanism: if the bacterial load is diluted, the patient is less likely to develop peritonitis and the postoperative course will be milder. More recently, however, studies have suggested that the use of PI during appendectomy does not decrease the rate of postoperative IAA.<sup>[14–19]</sup> Indeed, recent meta-analyses have reported a similar incidence of postoperative IAA between PI and suction alone (SA)

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LWB and BLY contributed equally to this work.

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during appendectomy in both adult and pediatric patients.<sup>[20–22]</sup> PI may not wash off bacteria from the mesothelial surfaces, so the effect of reducing the population density of bacteria may be temporary.<sup>[14]</sup> Given this finding, it is important to identify whether it is clinically significant to perform PI during appendectomy in pediatric perforated appendicitis patients.

Thus, we performed this meta-analysis to compare the incidence of postoperative IAA in pediatric patients following appendectomy with PI and appendectomy with SA.

## 2. Methods

We conducted a meta-analysis according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement standards.<sup>[23]</sup>

### 2.1. Literature search strategy

Two researchers independently performed a systematic search of electronic databases including EMBASE, PubMed, Web of Science, and the Cochrane Library to identify randomized controlled trials (RCTs) and case control studies (CCSs) on the use of PI in appendectomy for pediatric perforated appendicitis published from 1950 to May 2019. A structured search strategy in combination with Boolean logic was employed: (children OR child OR pediatric) AND (ruptured appendicitis OR perforated appendicitis) AND (peritoneal irrigation OR peritoneal lavage). In addition, the reference list of each included study was reviewed to identify other relevant trials. The process was completed when no further studies could be identified. In cases where a study had multiple publications, the most recently published or most relevant study was included in this meta-analysis.

### 2.2. Inclusion and exclusion criteria

We included all RCTs and CCSs which met the following inclusion criteria:

- (1) population: children with acute perforated appendicitis who underwent appendectomy;
- (2) intervention: PI in appendectomy;
- (3) comparison intervention: SA in appendectomy;
- (4) outcomes (studies were required to include more than one of these): IAA incidence, wound infection incidence, length of hospitalization, and duration of surgery.

The following exclusion criteria were applied:

- (1) studies not published in English;
- (2) animal studies;
- (3) studies that involved adults and patients with other diseases, such as appendix tumors.

Two authors independently evaluated all the articles of all identified studies which met these criteria. The ethics committee review is not required.

### 2.3. Data extraction and risk of bias assessment

Two authors independently reviewed the full texts of all included studies. The following necessary information was extracted from each study: the first author's name, publication year, study design, and sample size. The other extracted information included demographic characteristics, diagnostic measurements,

and treatment regimens. A standardized table was constructed, into which the extracted data were input. Two authors independently conducted data collection and disagreements were resolved by discussion. All extracted data are presented in Table 1.

Two authors independently evaluated the methodological quality and risk of bias of the included RCTs and CCSs, using the Cochrane Tool<sup>[24]</sup> and the Newcastle-Ottawa Quality Assessment Scale (NOS),<sup>[25]</sup> respectively. The maximum total score of the NOS was 9 stars. Studies that scored 4 stars or less were considered low-quality, whereas those scoring 5 stars or more were considered high-quality. Any disagreements between the 2 authors were resolved by discussion.

### 2.4. Outcomes

The first treatment-related outcome of interest was the incidence of IAA, which we defined as the detection of an IAA by an abdominal ultrasound scan. Wound infection was defined by purulent discharge from the incision and the growth of microorganisms from the wound discharge.<sup>[26]</sup> The other treatment-related outcomes were length of hospital stay and duration of surgery.

### 2.5. Data synthesis and analysis

For continuous data (length of hospitalization and duration of surgery), mean differences (MDs) and 95% confidence interval (CIs) were calculated. For dichotomous outcome variables (IAA and wound infection incidences), odds ratios (ORs) and 95% CIs were calculated. All analyses were conducted using Review Manager 5.3. A *P* value <.05 was considered statistically significant. In accordance with the Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0),<sup>[27]</sup> when there was evidence of significant heterogeneity ( $I^2 > 50\%$ ), random-effects models were used; otherwise, fixed-effects models were used for analysis.

## 3. Results

### 3.1. Search results

We obtained a total of 199 records from the four databases (PubMed, *n* = 79; EMBASE, *n* = 47; Web of Science, *n* = 42; and the Cochrane Library, *n* = 31) for the first screening (Fig. 1). After screening the titles and abstracts of these articles, 13 articles fitting our criteria were identified. After the full texts of these 13 articles were reviewed, another 7 articles were excluded for various reasons (data unavailable, duplicate article, or patients with other relevant diseases). Finally, 6 trials were included in this meta-analysis.<sup>[16,28–32]</sup> These trials included a total of 1633 individuals: 944 underwent appendectomy with PI and 689 underwent appendectomy with SA. The general trial parameters, demographic characteristics, diagnostic measurements, treatment regimens, and outcomes of the included trials are shown in Table 1.

### 3.2. Study quality and risk of bias

The quality of the included RCTs was evaluated by the Cochrane Tool, and the results are shown in Fig. 2. The CCSs were assessed by the NOS, and the calculated scores are summarized in Table 2.

**Table 1**  
Baseline characteristics of included studies and included population.

Study	Design	Simple size	No. of irrigation	Participant	Age (mean)	Gender (M)	LA [N (%)]	Postoperative Antibiotic	Drain Use	Minimum lavage volume (ml)
Peter et al <sup>[28]</sup> , 2012	RCT	220	110	Perforated appendicitis with appendectomy	Irrigation: 10.4 Suction: 9.7	Irrigation: 52% Suction: 59%	220 (100)	Irrigation: 100% Suction: 100%	Irrigation: 40% Suction: 52%	500
Hartwich et al <sup>[16]</sup> , 2013	A retrospective review	237	139	Perforated appendicitis with appendectomy	Irrigation: 10.2 Suction: 10.4	Irrigation: 55% Suction: 50%	123 (51.7)	Irrigation: 100% Suction: 100%	NR	NR
Akkoyuna et al <sup>[29]</sup> , 2012	A retrospective review	234	61	Perforated appendicitis with appendectomy	Irrigation: 8.8 Suction: 9.1	all: 64%	0 (0)	Irrigation: 100% Suction: 100%	Irrigation: 100% Suction: 0%	NR
Escolino et al <sup>[32]</sup> , 2018	A retrospective review	699	488	Perforated appendicitis with appendectomy	Irrigation: 10.2 Suction: 9.7	Irrigation: 69% Suction: 56%	699 (100)	Irrigation: 100% Suction: 100%	Irrigation: 100% Suction: 100%	1000
Tokl <sup>[30]</sup> , 1995	A retrospective review	53	29	Perforated appendicitis with appendectomy	Irrigation: 8 Suction: 8	Irrigation: 38% Suction: 63%	0 (0)	Irrigation: 100% Suction: 100%	Irrigation: 0% Suction: 100%	1000
Stewart and Matheson <sup>[31]</sup> , 1978	A retrospective review	189	117	Perforated appendicitis with appendectomy	NR	NR	0 (0)	NR	NR	500

RCT = randomized control trial, LA = laparoscopic appendectomy, NR = not reported.

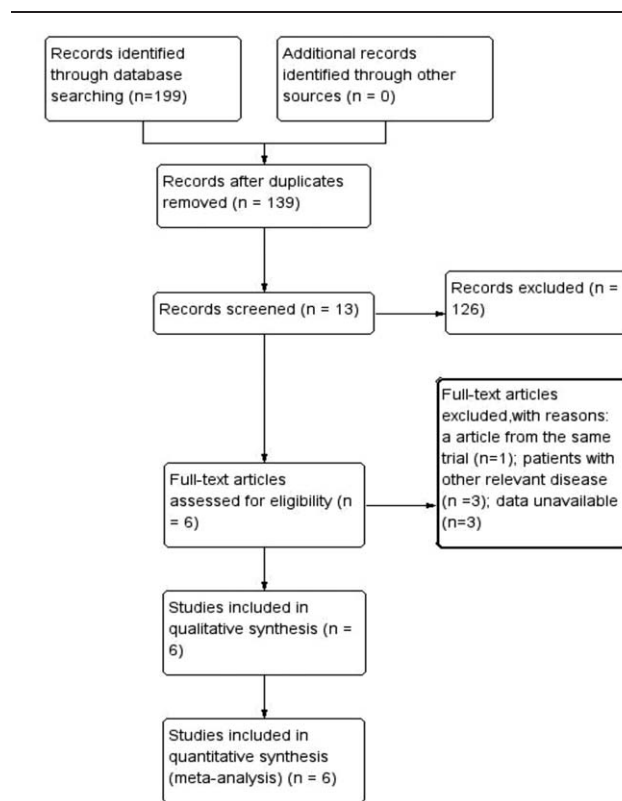


Figure 1. Flowchart of the study selection process.

Each CCS scored more than 5 stars, so all CCSs included in this meta-analysis were considered to be of high quality.

**3.3. Outcomes**

**3.3.1. Intraabdominal abscess incidence.** All of the included publications reported outcomes related to the incidence of IAA (Fig. 3). Therefore, the incidence of IAA was compared between 944 patients in the PI group and 689 in the SA group. We found no statistical difference in the incidence of IAA between the 2 groups (PI:93/944, OA:77/689; OR = 1.03, 95% CI = 0.41–2.58, P = .96). High heterogeneity was noted, so a random-effects model was used (I<sup>2</sup> = 80%, P < .05).

**3.3.2. Wound infection incidence.** Five of the included publications reported outcomes related to the incidence of wound infection (Fig. 4).<sup>[16,29–32]</sup> Therefore, the incidence of wound infection was compared between 834 patients in the PI group and 579 in the SA group. We found no statistical difference in the incidence of wound infection between the 2 groups (PI:44/834, SA:35/579; OR = 0.97, 95% CI = 0.30–3.16, P = .96). High heterogeneity was noted, so a random-effects model was used (I<sup>2</sup> = 71%, P < .05).

**3.3.3. Length of hospital stay.** Five of the included publications reported outcomes related to length of hospital stay (Fig. 5).<sup>[28–32]</sup> There was no statistical difference in the length of hospitalization between the 2 groups (MD = -0.90, 95% CI = -3.28 to 1.48, P = .46). Significant heterogeneity was noted, so a random-effects model was used (I<sup>2</sup> = 93%, P < .05).

**3.3.4. Duration of surgery.** Three of the included publications reported outcomes related to duration of surgery (Fig. 6).<sup>[28,29,32]</sup> Duration of surgery was found to be significantly longer in the PI

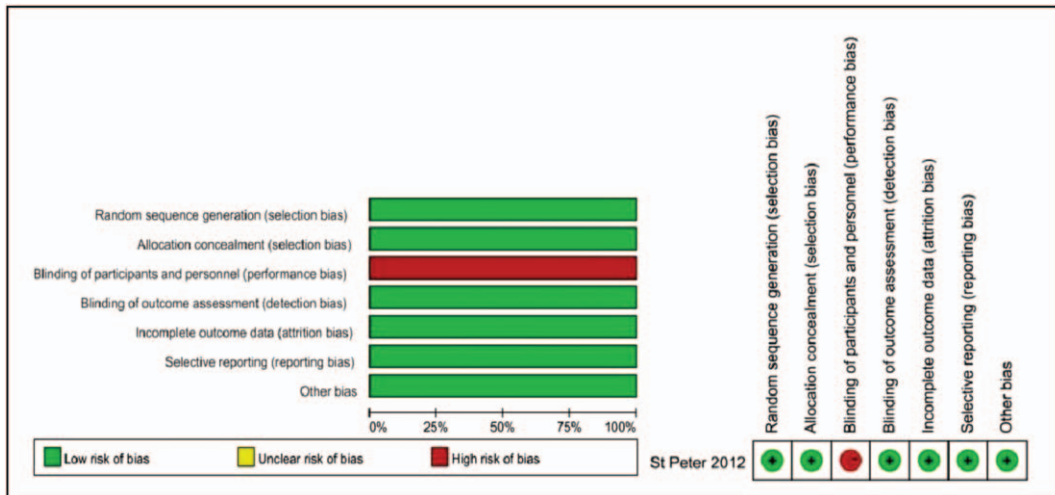


Figure 2. Risk of bias summary and graph for showing each risk of bias item for the randomization trial.

**Table 2**  
Quality assessment of case control studies.

	Akkoyun <sup>[29]</sup> 2012	Escolino <sup>[32]</sup> 2018	Hartwich <sup>[16]</sup> 2013	Stewart and Matheson <sup>[31]</sup> 1978	ToKi <sup>[30]</sup> 1995
Is the case definition adequate?	*	*	*	†	*
Representativeness of the cases	*	*	*	*	*
election of Controls	†	†	†	†	†
Definition of Controls	*	*	*	*	*
Comparability of cases and controls on basis of the design or analysis	**	**	**	†	*
Ascertainment of exposure	*	*	*	*	*
Same method of ascertainment for cases and controls	*	*	*	*	*
Non-response rate	*	†	†	†	*

\* The study is accord with requirements for this item.  
† The study is not accord with requirements for this item.

group than in the SA group (MD=6.76, 95% CI=4.64–8.87,  $P < .001$ ). Obvious heterogeneity was noted, so a fixed-effects model was used ( $I^2 = 25\%$ ,  $P = .26$ ).

**4. Discussion**

Acute perforated appendicitis is the common surgical diagnosis that may lead to peritonitis in children. There is a high incidence of postoperative IAA in perforated appendicitis which could be

influenced by differences in clinical management.<sup>[33,34]</sup> Postoperative IAA is mainly the most frequent and devastating complication.<sup>[15]</sup> It is associated with postoperative pain, slower intestinal function recovery, longer length of hospitalization and increasing cost even repeat intervention. A number of strategies are currently employed to avoid postoperative IAA formation, namely the perioperative administration of antibiotics, postoperative drainage, and intraoperative PI.

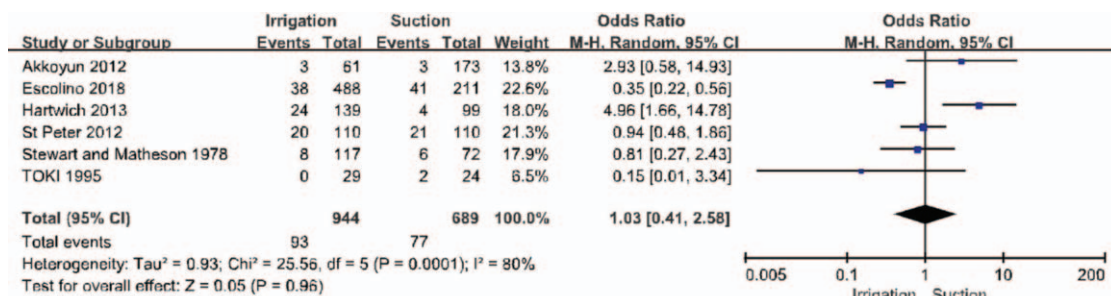


Figure 3. Forest plot regarding intra-abdominal abscess incidence among the groups of patients with irrigation and suction vs those with suction alone.

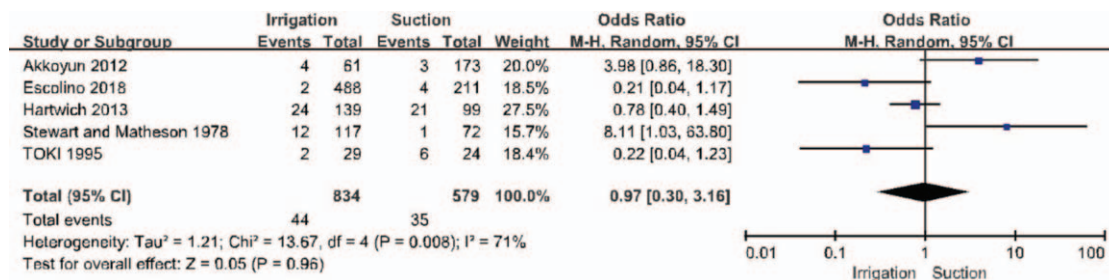


Figure 4. Forest plot regarding wound infection incidence among the groups of patients with irrigation and suctions vs those with suction alone.

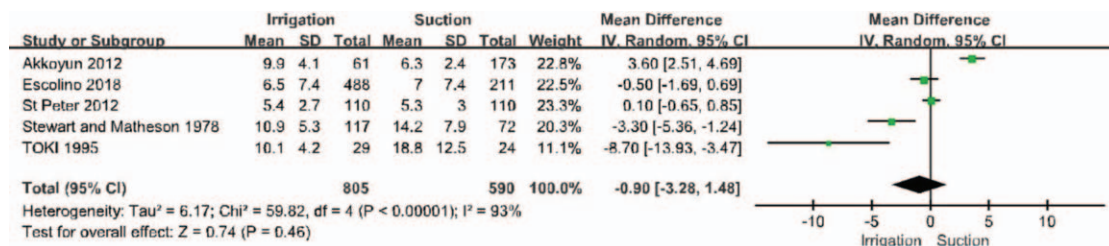


Figure 5. Forest plot regarding the length of hospital stay among the groups of patients with irrigation and suctions vs those with suction alone.

This analysis included 1 RCT and 5 retrospective observational trials involving a total of 1633 patients. This meta-analysis found no statistical differences between intraoperative PI and SA with respect to postoperative IAA incidence, postoperative wound infection incidence, or length of hospitalization. A significantly increased duration of surgery was noted in the PI group.

A similar postoperative IAA incidence was found between PI and SA in our study, consistent with articles published by Peter et al and Akkoyun et al on perforated appendicitis.<sup>[28,29]</sup> In contrast, Hartwich et al reported a postoperative IAA incidence of 17.2% in the PI group and 4% in the SA group, demonstrating a clear statistical difference.<sup>[16]</sup> In a survey of American Pediatric Surgical Association members, almost all surgeons reported that they perform intraoperative PI with saline solution during pediatric appendectomy.<sup>[35]</sup> This is because PI is cheap, easy to perform and may avoid postoperative IAA formation. However, our results suggest that in cases of perforated appendicitis, the use of PI did not decrease the incidence of postoperative IAA formation. PI may possibly spread the infected contents of the appendix and bacteria throughout the abdominal cavity, explaining our observed results. Unfortunately, the mechanisms underlying postoperative IAA formation remain unclear. In a 2013 article, Peter and Holcomb summarized why PI may not be effective:

- (1) bacteria adhere to the peritoneal mesothelial cells, so the micro-organism load on the peritoneum is not decreased by irrigation;
- (2) irrigation may cause diffuse or remote inoculation, thus spreading the pollution; and
- (3) irrigation may dilute mediators of phagocytosis (opsonic proteins and immunoglobulins).<sup>[14]</sup>

In contrast, however, in their international multicentric study, Escolino et al<sup>[32]</sup> demonstrated that the use of PI was associated with a lower incidence of IAA compared with SA in pediatric perforated appendicitis patients.

Additionally, Peter et al reported that irrigation with a moderate volume of saline did not improve the rate of postoperative IAA in perforated appendicitis patients.<sup>[28]</sup> They explained that while saline might lyse and dilute many of the intra-abdominal bacteria, it also displaces some bacteria and intestinal contents throughout the peritoneal cavity, potentially providing a nidus for future abscess development. Furthermore, Hartwich et al<sup>[16]</sup> suggested that saline could be more harmful to the patient's own defense mechanisms than to bacteria. Our results, along with those of other previously published articles, therefore cautiously suggest that the routine practice of intraoperative PI with saline should not be recommended.

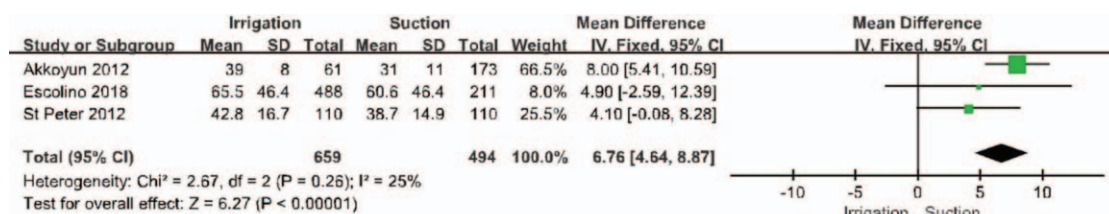


Figure 6. Forest plot regarding duration of surgery among the groups of patients with irrigation and suctions vs those with suction alone.

We also found no statistically significant differences between PI and SA with respect to wound infection incidence and length of hospitalization, consistent with the findings of Peter et al.<sup>[28]</sup>, Akkoyun et al.<sup>[29]</sup>, and Escolino et al.<sup>[32]</sup> In contrast, a trial by Hartwich et al.<sup>[16]</sup> reported that PI decreased the incidence of wound infection.

Optimizing surgery duration may have a dramatic impact on healthcare cost-effectiveness outcomes. In this meta-analysis, we reported a longer duration of surgery in patients treated by appendectomy with PI. An additional three studies have similarly reported longer operative times when PI is used in the treatment of perforated appendicitis.<sup>[28,29,32]</sup> However, a recent meta-analysis which separately analyzed pediatric patients failed to report a difference in operative time when PI was used.<sup>[20]</sup> Although the difference in operative time noted in this meta-analysis was quite small and thus has questionable clinical relevance, it may imply that the use of PI in appendectomy unnecessarily utilizes resources and increases the cost of care with no clinical benefit.

The volume of PI, drainage, and antibiotic treatment regimens are other clinical variables which may have influenced the incidence of postoperative IAA in the included studies. The volume of PI used varied greatly among the included studies, which may have influenced the results.<sup>[36]</sup> Unfortunately, we were unable to conduct a separate analysis of the data according to the volume of PI used. In addition, some of the pediatric surgeons conducted postoperative drainage, which may also have influenced the incidence of postoperative IAA. Escolino et al reported that the use of drainage was not associated with an increased incidence of postoperative IAA.<sup>[32]</sup> However, other studies reported that drainage increased the incidence of postoperative IAA.<sup>[37–40]</sup> With respect to antibiotic treatment, different surgeons exhibited differences in the number and type of antibiotics used, in addition to the length of antibiotic therapy.<sup>[41]</sup> Many pediatric surgeons tailored the antibiotic treatment regimen to the individual patient. In this meta-analysis, we failed to standardize the utilization of antibiotics, although the demographics were comparable between the two groups. Henry et al conducted a case-control study and reported that the type and timing of preoperative antibiotics and the length of postoperative antibiotics were not associated with postoperative IAA formation.<sup>[42]</sup> Similarly, Snow et al assessed the influence of peri- and postoperative antibiotics on postoperative IAA development in children, and reported that neither the number and type of antibiotics nor the length of therapy had a significant impact on the incidence of postoperative IAA.<sup>[12]</sup> If possible, however, any study into postoperative IAA should control these clinically relevant variables.

Our study has a number of limitations:

- (1) this meta-analysis included only 6 eligible studies, of which 5 were non-randomized retrospective observational studies;
- (2) the number of patients in our analysis was relatively small; and
- (3) a high level of among-study heterogeneity was noted, which may have influenced the robustness of the results.

## 5. Conclusions

Our meta-analysis did not provide strong evidence allowing definite conclusions to be drawn, but suggested that PI during appendectomy did not decrease the incidence of postoperative

IAA. This meta-analysis also indicated the need for more high-quality trials to identify methods to decrease the incidence of postoperative IAA in pediatric perforated appendicitis patients.

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**Writing – original draft:** Le-wee Bi, Bei-lei Yan.

**Writing – review & editing:** Qian-Yu Yang, Hua-lei Cui.

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