Research Article

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Comparison of conservative treatment with appendectomy for acute uncomplicated pediatric appendicitis: a meta-analysis

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Aim: We aimed to compare conservative treatment with surgery for uncomplicated pediatric appendicitis to estimate effectiveness and safety. **Methods:** Data recorded until September 2018 were searched, and relevant academic articles from PubMed, EMBASE, the Cochrane Library and other libraries were selected. STATA version 13.0 (Stata Corporation, TX, USA) was used for statistical analysis. **Results:** We identified nine eligible papers. The study reported a significant difference in the success rate of treatment in 1 month and in 1 year, and no difference in the incidence of complications. The patients with fecaliths showed low treatment efficacy in conservative treatment group ($p < 0.05$). **Conclusion:** Standardized conservative treatment as inpatients for pediatric appendicitis is safe and feasible. Appendectomy was the better choice for patients with fecaliths.

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Keywords: appendectomy • conservative treatment • fecaliths • meta-analysis • pediatric appendicitis

In children, acute appendicitis is the most prevalent gastrointestinal disease [1]. Approximately 1–4 children in 1000 undergo appendectomy per year [2]. Although surgery has been the gold standard in the treatment of pediatric appendicitis, it is an intra-abdominal intervention that requires general anesthesia. The incidence rate of complications of surgery or anesthesia is about 10% within 30 postoperative days [3]. In addition, even with current imaging methods, a normal appendix may be found during appendectomy.

Conservative treatment of appendicitis can be a viable alternative. Several clinical trials and meta-analyses in adults have demonstrated conservative management to be an effective treatment for acute uncomplicated appendicitis [4–10]. However, the conclusions reached in the case of adults may not be applicable to pediatric patients owing to the difference in the clinical scenario as well as development of acute appendicitis in them. There are some studies on the conservative treatment of acute simple appendicitis in children. Recent studies have shown a 75–80% success rate for conservative management in simple pediatric appendicitis [11–19]. However, the treatment of the uncomplicated appendicitis is still a debatable point.

The purpose of our study was to perform meta-analysis comparing conservative treatment with surgery for uncomplicated pediatric appendicitis to estimate the effectiveness and safety of conservative treatment.

Materials & methods

We conducted a meta-analysis according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement standards.

Literature & search strategy

Two independent researchers performed a systematic search of the electronic databases including EMBASE, PubMed and the Cochrane Library, and in other databases to identify randomized controlled trials (RCTs) and randomized cohort studies (RCS) on conservative treatment for acute uncomplicated appendicitis recorded from the initial establishment of electronic databases to September 2018. We used a structured search strategy in combination with

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Boolean logic: (child OR children OR pediatric patients) AND (uncomplicated appendicitis) AND (nonoperation OR conservative treatment OR antibiotic treatment) AND (appendectomy OR operation). In addition, we checked the reference list of the studies to identify other trials that might potentially qualify for inclusion in the meta-analysis. The process was completed when no further studies could be determined. In case of more than one publication available for a study, we used either the most recent publication or the one with the most relevant information.

Inclusion & exclusion criteria

We included all RCTs and RCS which matched the following inclusion criteria: population: children with acute uncomplicated appendicitis; intervention: conservative treatment; comparison intervention: appendectomy; and outcomes, including more than one of the following outcomes. Exclusion criteria were as follows: non-English language studies; animal studies; studies including complicated appendicitis (abscess, perforation); studies that involved adults and patients with other diseases such as appendix tumor. Two independent authors evaluated all the articles of all recognized studies according to the criteria.

Data extraction & risk of bias assessment

We created an electronic data extraction spreadsheet that included the following information: general trial parameters, demographic characteristics, diagnostic measurements, treatment regimens and outcomes. Two independent authors conducted data collection and disagreements were resolved by discussion. We have presented all the data in Table 1.

Two independent authors evaluated the methodological quality and risk of bias of the included RCTs and RCS, respectively, using the Cochrane Tools and the methodological index for nonrandomized studies (MINORS).

Outcomes

The first outcome of interest in the treatment was the success rate of the initial intervention, which we defined as improvement of symptoms with no need for appendectomy and without recurrence within 1 month to 1 year. Efficacy of surgery was considered as an operation without negative appendectomy findings and/or reoperation. If an interval surgery was performed because of parental wish instead of recurrence, we considered the intervention to be successful. On the contrary, if surgery was performed because of recurrence, even in the case of a normal appendix, we considered the intervention to have failed.

The secondary outcomes relating to the treatment were the rate of associated fecaliths, length of hospital stay, total cost, Health-Related Quality of Life (HRQOL) and complications including perforation, abscess, gangrene and/or postoperative complications after the appendectomy.

Data synthesis & analysis

The results of continuous data (length of hospital stay, length of disability, total cost) were calculated as the MD with 95% CIs. For dichotomous outcome variables, we used an odds ratio (OR) with 95% CIs. All analyses were performed using Stata V13. The difference was considered as statistically significant if $p < 0.05$. When there was evidence of significant heterogeneity ($I^2 > 50\%$), random-effects models were used; otherwise, fixed-effects models were used for analysis in accordance with the *Cochrane Handbook for Systematic Reviews of Interventions* (version 5.1.0).

Results

Results of search

We obtained 248 records from the three databases (PubMed n = 132, EMBASE n = 92 and Cochrane Library n = 92) for the first screening (Figure 1). Glancing over titles and abstracts of the articles, we excluded 235 articles which were clearly not relevant to our criteria. We excluded another four articles after reading the full-text for various reasons (data unavailable, article from the same trial or patients with other relevant disease). Finally, we included nine trials in the meta-analysis [14,17–24].

We summarized the characteristics of the nine included studies as follows: eight studies were performed in hospitals [14,17–23] and one in an emergency department (ED) [24] and 64,540 individuals were incorporated into our trial of whom 61,853 underwent an appendectomy and 2687 underwent conservative treatment. The general trial parameters, demographic characteristics, diagnostic measurements, treatment regimens and outcomes are shown in Table 1. The two RCTs were implemented by Svensson *et al.* and Hall *et al.* [17,23].

Table 1. Characteristics of the nine included studies.

Study (year)	Design	Setting	Simple size	No. of NOM	Patients	Gender (M)	Ref.
Svensson *et al.* (2015)	Randomized pilot trial	Single center	50	24	Age 5–15 y, diagnosis of acute nonperforated appendicitis, diagnosis made by history, inflammatory markers (WBC count and CRP level) and imaging	26	[17]
Minneci *et al.* (2016)	Prospective nonrandomized controlled trial	Single center	102	37	Age 7–17 y, diagnosis of acute uncomplicated appendicitis, diagnosis made by history, inflammatory markers (WBC count), and imaging; without appendicolith	69	[18]
Mudri *et al.* (2017)	Retrospective choice cohort	Multicenter	52	26	Mean age 6–17 y, diagnosis of acute uncomplicated appendicitis, diagnosis made by history, and imaging (US)	25	[20]
Hartwich *et al.* (2016)	Prospective nonrandomized controlled trial	Single center	74	24	Aged 5–18 y; diagnosis of acute uncomplicated appendicitis, diagnosis made by history, physical examination, inflammatory markers and imaging (US or/and MRI) findings	34	[14]
Tanaka *et al.* (2015)	Prospective nonrandomized controlled trial	Single center	164	78	Aged 6–15 y; diagnosis of acute uncomplicated appendicitis, diagnosis made by physical examination, blood test and imaging findings	113	[19]
Mahida *et al.* (2016)	Prospective nonrandomized controlled trial	Single center	14	5	Aged 9–15 y; diagnosis of acute uncomplicated appendicitis with appendicolith, diagnosis made by clinical history and examination (US, CT and blood test) findings	6	[21]
Gorter *et al.* (2017)	Prospective cohort study	Multicenter	44	25	Aged 7–17 y; diagnosis of acute uncomplicated appendicitis; excluded signs of severe general illness, faecalith, complex appendicitis, significant co-morbidity, allergy for the antibiotics	29	[22]
Hall *et al.* (2017)	Randomized pilot trial	Multicenter	102	52	Aged 3–15 y, acute appendicitis and an appendix mass, successfully treated nonoperatively during the acute stage of the illness; excluded coexisting gastrointestinal disease, a substantial coexisting medical condition or immune defect	51	[23]
Bachur *et al.* (2017)	Retrospective study	Multicenter	63938	2416	Aged <19 y, diagnosis of acute uncomplicated appendicitis; excluded chronic comorbidities	NR	[24]

Intervention	Comparator	Outcomes	Follow-up (average)
Intravenous meropenem (10 mg/kg × 3 per 24 h) and metronidazole (20 mg/kg × 1 per 24 h) for at least 48 h; keep nil by mouth for the first 24 h	Preoperative antibiotic prophylaxis with 20 mg/kg of metronidazole then appendectomy	Time to discharge; complications; recurrent appendicitis within 1 year	12 m
Intravenous piperacillin sodium–tazobactam sodium ≥24 h, keep nil by mouth for the first 12 h	Prompt initiation of intravenous antibiotics and laparoscopic appendectomy within 12 h	Not having undergone an appendectomy; complicated appendicitis; disability days for the child and parents; appendicitis-related total health care costs; HRQOL	12 m
Received IV ceftriaxone and Flagyl in hospital; within a 7 days of amoxicillin/Clavulin	1 preop dose of IV ceftriaxone and Flagyl and appendectomy	Interval appendectomy; readmitted to hospital	12 m
A dose of intravenous piperacillin–tazobactam at 100 mg/kg; intravenous pain medication; diet was advanced ad libitum; ampicillin–clavulanate at 50 mg/kg/d TID with a 1-week course	Appendectomy	Initial success/failure of the treatment; recurrence; interval appendectomy	14 m
Cefmetazole 100 mg/kg/d for 48 h, then sulbactam/ampicillin, 200 mg/kg/g + ceftazidime, 150 mg/kg/d	Appendectomy and prophylactic antibiotics until 48 h after surgery	Interval appendectomy; readmitted to hospital	4.3 y
Intravenous piperacillin–tazobactam with 24 h and amoxicillin–clavulanate with 7 days; keep nil by mouth for the first 12 h	Intravenous piperacillin–tazobactam and underwent urgent appendectomy	Not undergoing appendectomy by 1 year after discharge; complicated appendicitis	4.7 m

CT: Computed tomography; ED: Emergence department; HRQOL: Health-related quality of life; IV: Intravenous; NOM: No-operative management; NR: No reported; TID: Three-times per day; US: Ultrasonography; WBC: White blood cell.

Table 1. Characteristics of the nine included studies (cont.).

Intervention	Comparator	Outcomes	Follow-up (average)
intravenous antibiotics; diet restriction; pain medication	Pre-, peri- and postoperative care and appendectomy	Allergy to antibiotics, recurrent appendicitis and other complications related appendicitis, appendectomy, fecalith	25 m
NR	NR	The proportion of recurrent acute appendicitis; hospital admission, days off school or normal daily activities, cost	12 m
NR	NR	ED visits, subsequent hospitalizations, advanced imaging studies, complicated appendicitis perforation; recurrent appendectomy	12 m

CT: Computed tomography; ED: Emergence department; HRQOL: Health-related quality of life; IV: Intravenous; NOM: No-operative management; NR: No reported; TID: Three-times per day; US: Ultrasonography; WBC: White blood cell.

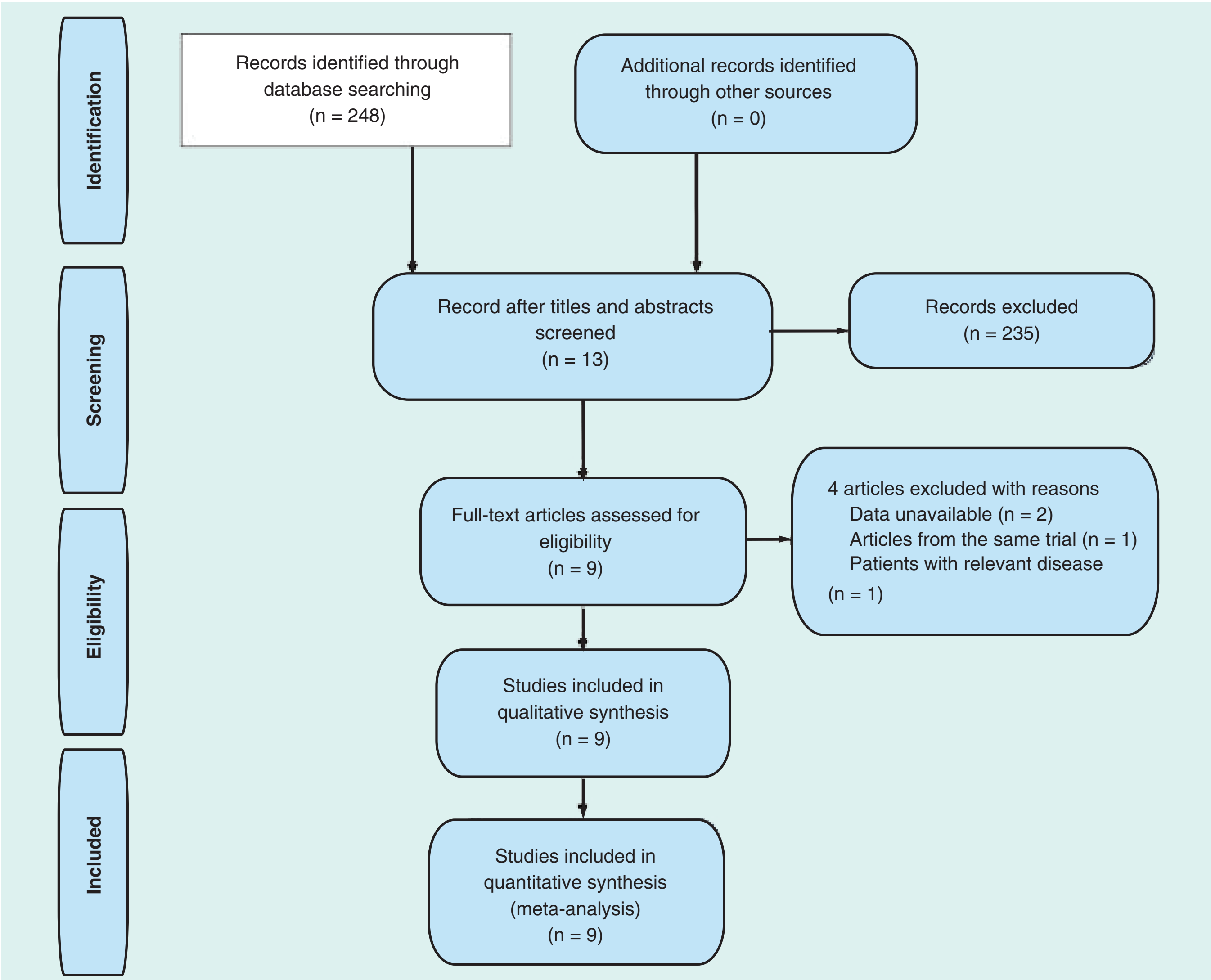

Figure 1. Flowchart of the study selection process.

Study quality & risk of bias

The quality of the included RCTs was evaluated by the scale of Cochrane Tools. The details are showed in Figure 2. The scores of the RCS accessed by MINOR were 18. The details of the quality assessment are summarized in Table 2. Only one study utilized blinded outcome assessment [23].

Outcomes synthesis

Success rate of treatment at 1 month

The success rate of treatment at 1-month follow-up was assessed in six studies [14,17–21]. We found a significant heterogeneity (I^2 = 0%; p = 0.959), so that a fixed-effect model was used in the analysis. The success rate was 99% (260/262) in the appendectomy group and 90% (175/194) in the conservative management group (OR: 0.122; 95% CI: 0.041–0.376; $p < 0.001$, Figure 3). The study by Gorter *et al.* reported the success rate of treatment at 8-week follow-up, and suggested that it was 100% at 8-week postsurgery in the conservative treatment group [22]. The other two studies did not report the success rate of treatment after the 1-month follow-up [23,24].

In the conservative treatment group, 19 of 194 patients (10%) presented with initial failure of conservative treatment; and 16 patients were diagnosed with appendicitis following histopathological examination, with three of them having perforated appendicitis [14,17–19,21]. Mudri *et al.* could not explain the recurrence of symptoms

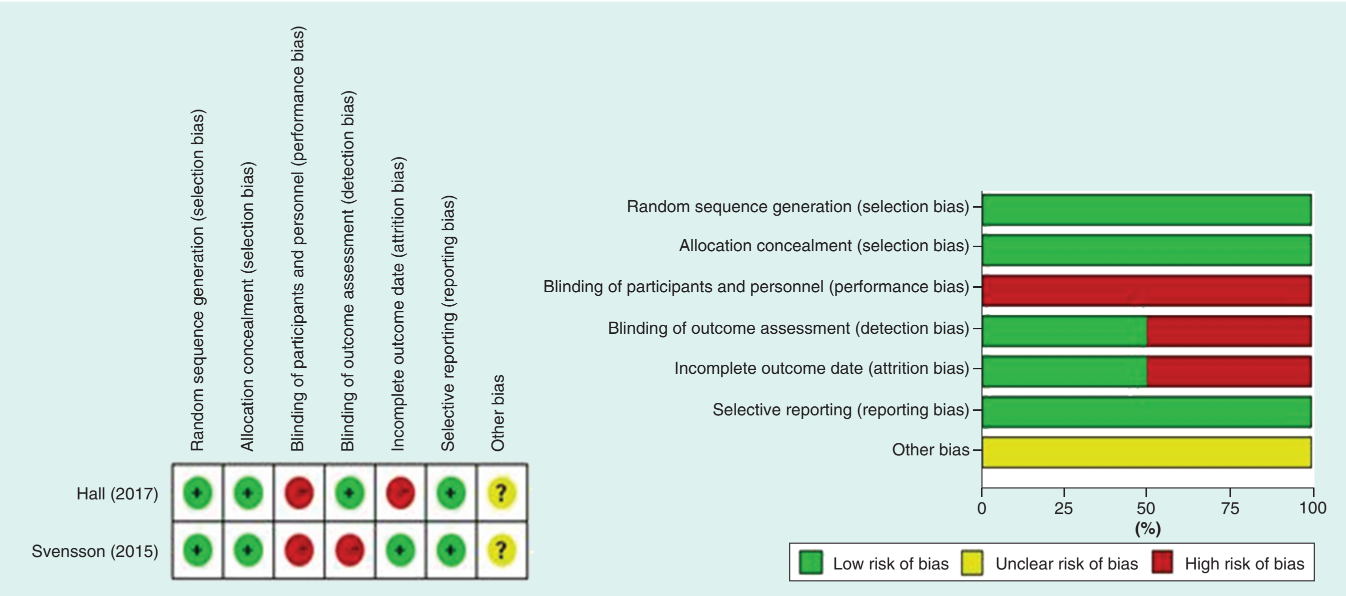

Figure 2. Risk of bias summary and graph for randomized controlled trials.

Table 2. Quality assessment score of the included studies.

Quality assessment for nonrandomized trials	Minneci *et al.* (2016)†	Mudri *et al.* (2017)†	Hartwich *et al.* (2016)†	Tanaka *et al.* (2015)†	Mahida *et al.* (2016)†	Gorter *et al.* (2017)†	Bachur *et al.* (2017)†
A clearly stated aim	2	2	2	2	2	2	2
Inclusion of consecutive patients	2	2	2	2	2	2	2
Prospective data collection	1	1	2	0	1	2	0
End points appropriate to the aim of the study	2	2	2	2	2	2	2
Unbiased assessment of the study end point	2	2	2	2	2	2	2
A follow-up period appropriate to the aim of study	2	2	2	2	2	2	2
Less than 5% loss to follow-up	1	0	0	2	0	0	1
Prospective calculation of the sample size	0	0	0	0	2	0	0
An adequate control group	2	2	2	2	2	2	2
Contemporary groups	2	2	2	2	2	2	2
Baseline equivalence of groups	2	2	2	2	2	2	2
Adequate statistical analyses	2	2	2	2	2	2	2

†Minneci *et al.* (2016) [18]; Mudri *et al.* (2017) [20]; Hartwich *et al.* (2016) [14]; Tanaka *et al.* (2015) [19]; Mahida *et al.* (2016) [21]; Gorter *et al.* (2017) [22]; Bachur *et al.* (2017) [24].

within 48 h in the three patients who were diagnosed on pathological examination as appendicitis [20]. In their study, nine patients had a recurrence in the 1-year follow-up, of whom only five were diagnosed on pathological examination as appendicitis and four were normal [20]. No one was confirmed to have perforated appendicitis [20]. In the appendectomy group, negative appendectomy findings were observed, except for one (one of 262) patient who experienced a major complication that needed reoperation.

Success rate of treatment within 1 year

Of the 2498 patients allocated to the conservative treatment group, 1098 patients (44.0%) underwent appendectomy within the 1-year follow-up. A significant heterogeneity was observed (I^2 = 95.6%; $p < 0.001$), and we used a randomized-effect model. There was a significant difference in the success rate between the conservative treatment (1400/2498) and appendectomy groups (61,829/61,847; OR: 0.028, 95% CI: 0.001–0.980; p = 0.049,

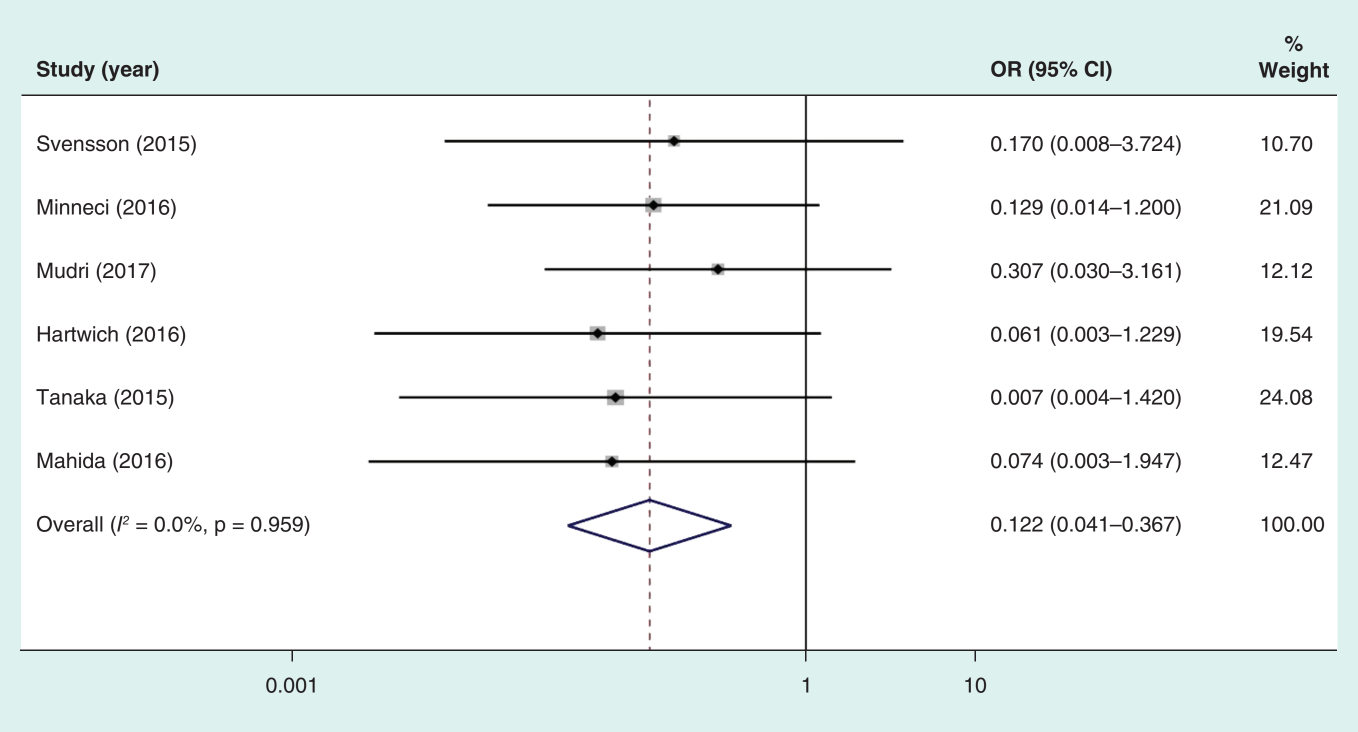

Figure 3. Forest plot showing odds ratio of the success rate in 1 month in the conservative treatment versus appendectomy groups.
OR: Odds ratio.

Figure 4) for children with acute uncomplicated appendicitis. Using histopathalogic findings, 43 patients (78.1%, 43/55) were diagnosed with appendicitis in six studies [14,18–20,23,24] and 315 patients (29.5%, 315/1067) were diagnosed with complicated appendicitis in four studies [18–20,24]. Svensson *et al.* and Hartwich *et al.* did not report their findings on histological examination [17,21]. Moreover, eight of 46 patients were diagnosed as having a normal appendix based on histopathologic findings.

As Bachur *et al.* had included patients seen in the ED [24], we performed the meta-analysis using the other studies. Conservative treatment was successful in 205 of 271 (75.6%) patients (OR: 0.087; 95% CI: 0.015–0.493; p = 0.006; heterogeneity, I^2 = 78.9%; p < 0.001).

Incidence rate of complications

We found no significant difference in the incidence of complications between the conservative treatment group (18/265) and the appendicectomy group (25/316; OR: 0.567; 95% CI: 0.273–1.176; p = 0.127, Figure 5) [14,17–20,22,23]. A low level of heterogeneity existed (I^2 = 24.9%; p = 0.239) and we used a fixed-effect model. However, in the operation group, there was a patient who developed laryngospasm during extubation and required reintubation and ICU admission for 4 days [22].

Success rate of appendicolith

We performed a subgroup analysis to show that the success rate of treatment differs in the presence of fecaliths. Of the 11 included studies, six reported the presence of fecaliths [14,17,19–21,23], it was excluded in two [18,22], and Bachur *et al.* did not report the presence of fecaliths [24]. Compared with that of conservative treatment (25/45), appendectomy (29/29) showed a higher success rate in patients with an appendicolith (OR: 0.073; 95% CI: 0.013–0.400; p = 0.003; heterogeneity, I^2 = 0%; p = 0.778, Figure 6). However, we found no statistically significant difference in treatment efficacy between conservative treatment (131/164) and appendectomy (195/212) in patients without a fecalith (OR: 0.475, 95% CI: 0.015–1.699; p = 0.128; heterogeneity, I^2 = 82.5%; p < 0.001, Figure 7).

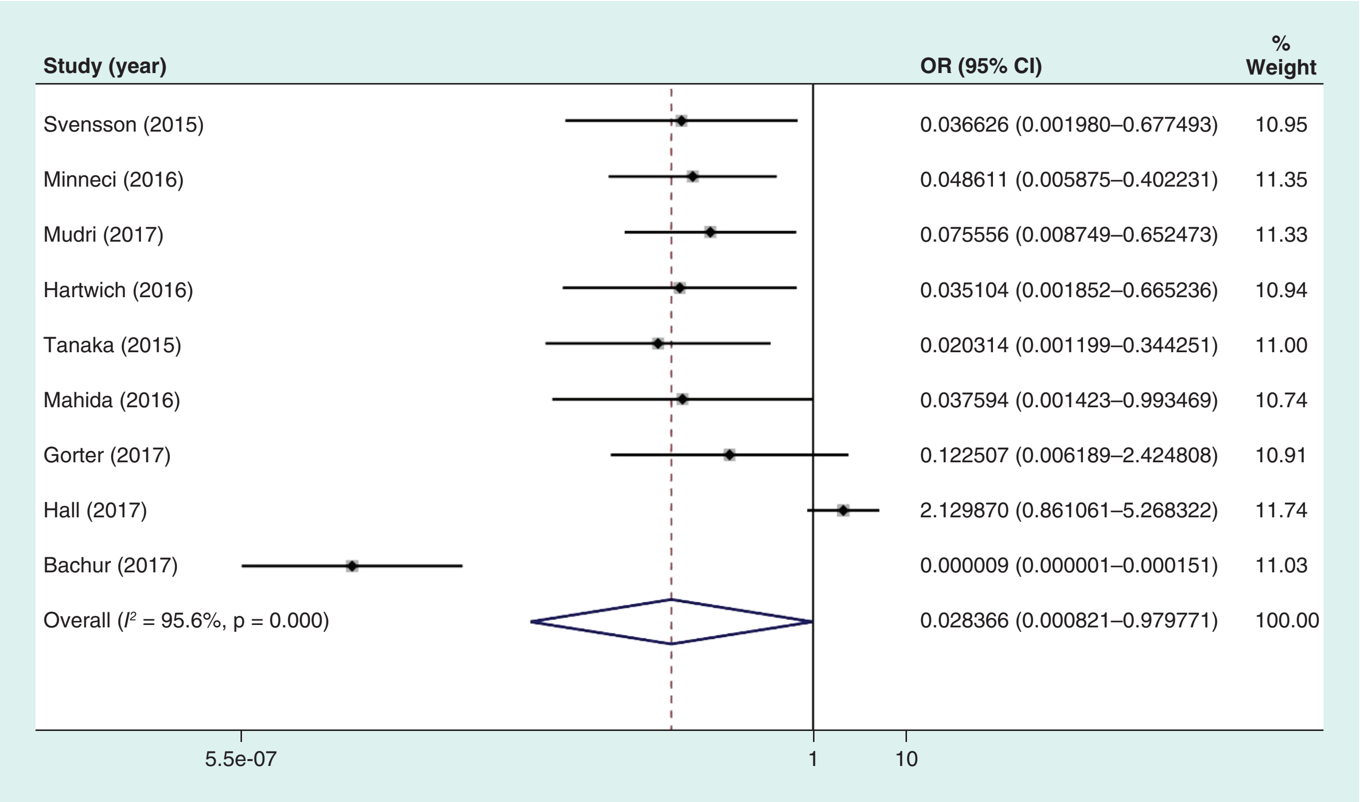

Figure 4. Forest plot showing odds ratio of success rate in 1 year in the conservative treatment versus appendectomy groups.
OR: Odds ratio.

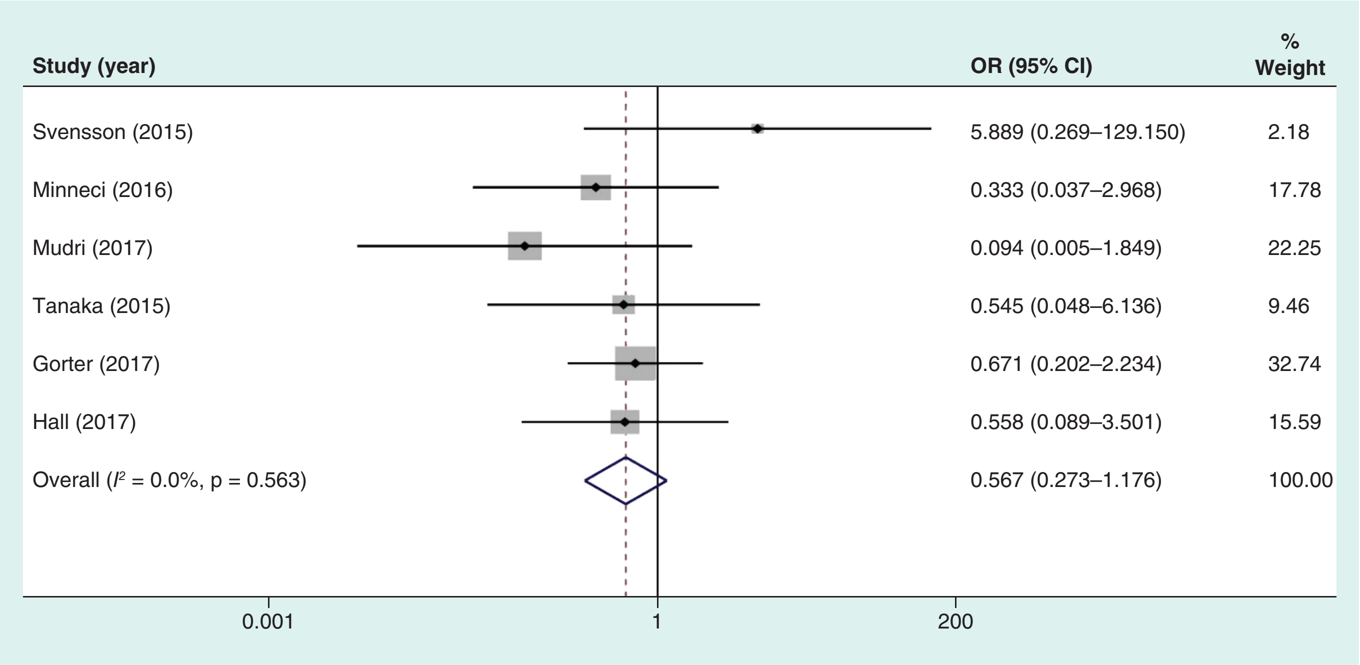

Figure 5. Forest plot showing odds ratio for incidence rate of complications in the conservative treatment versus appendectomy groups.
OR: Odds ratio.

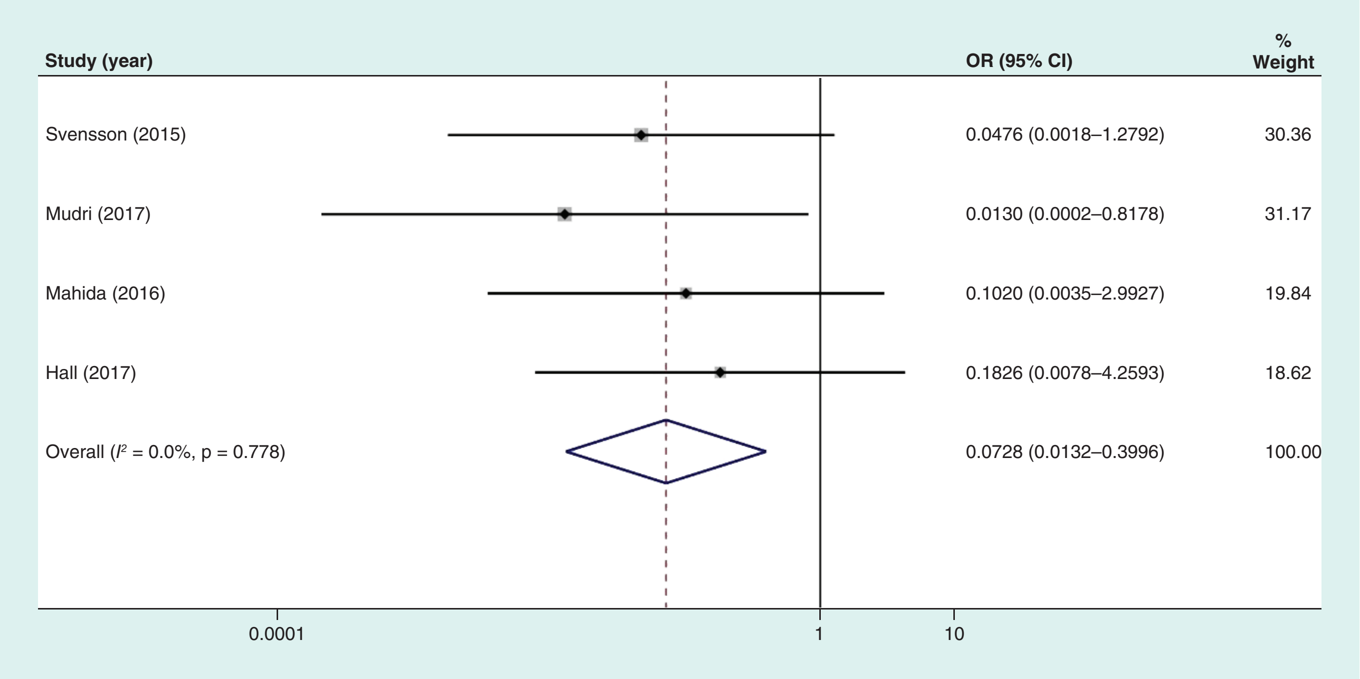

Figure 6. Subgroup forest plot showing odds ratio of the success rate in patients with fecaliths in the conservative treatment versus appendectomy groups.
OR: Odds ratio.

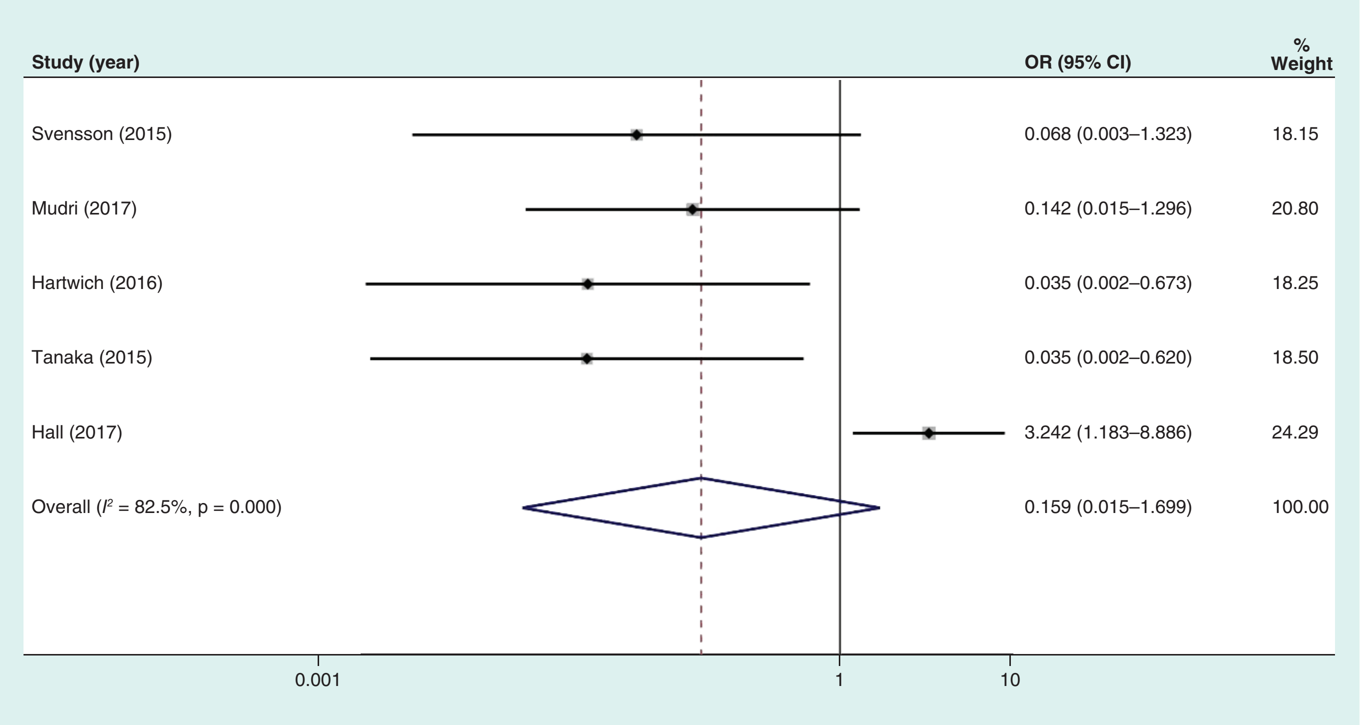

Figure 7. Subgroup forest plot showing odds ratio of the success rate in patients without fecaliths in the conservative treatment versus appendectomy groups.
OR: Odds ratio.

Length of hospital stay

The mean length of hospital stay for conservative treatment of uncomplicated appendicitis ranged from 4.4 to 13.4 h in six studies [17–20,23,24]. However, Mudri *et al.* only reported the mean of the total length, which was excluded from the meta-analysis [20]. The forest plot showed a longer hospital stay in the conservative treatment group than in the appendectomy group, with a mean difference of 3.293 h, but did not show statistical significance (95% CI: -23.569–16.983 h; p = 0.75; heterogeneity, I^2 = 97.4%; $p < 0.001$).

Furthermore, the mean difference between the two groups in length of disability was 6.767 days with the conservative treatment group having a longer disability period (95% CI: -19.496–5.962 days; p = 0.297; heterogeneity, I^2 = 94.7%; $p < 0.001$). There was no statistical difference.

Cost

The difference in total appendicitis-associated costs was reported in five studies [14,17,18,20,23], of which four could be included in the meta-analysis. The meta-analysis including the four studies showed that total appendicitis-associated costs increased by US$1.744 in the appendectomy group (95% CI: US$-6.976 to US$3.488; p = 0.514; heterogeneity, I^2 = 97.6%; $p < 0.001$). There was no statistical difference.

Health-related quality of life

Three studies reported on the HRQOL between conservative treatment group and appendectomy group [18,19,22]. However, we could not include them in our meta-analysis owing to some problems with the results, such as strong subjectivity, low follow-up rate and inconsistent assessment methods. Minneci *et al.* reported on similar quality of life following both treatments by using Quality of Life Inventory instruments in both patients and parents [18]. Conversely, Tanaka *et al.* found higher patient satisfaction in the appendectomy group [19]. Unfortunately, Gorter *et al.* failed to obtain the responses to the HRQOL questionnaire in the appendectomy group [22].

Discussion

Surgery has been the standard treatment in acute simple appendicitis owing to concerns of perforation. However, recent trials reveal that conservative treatment might help avoid appendectomy in 83–99% patients with uncomplicated appendicitis in the short-term [11–14,17–19,25,26]. Successful conservative management of acute simple appendicitis helps avoid general anesthesia as well as appendectomy.

We performed a meta-analysis of the reported outcomes between conservative treatment and appendectomy in children with acute uncomplicated appendicitis. Our results revealed no statistical difference between conservative treatment and appendectomy in the incidence of complications, length of hospital stay and total cost associated with appendicitis.

Our study reported the initial success rate of conservative treatment as 90%, whereas the success rate was only 56% in the 1-year follow-up. It should be noted that Bachur *et al.* included patients with appendicitis from the ED in their study [24]. Bachur *et al.* reported that differences in patient selection at the onset of treatment, inadequate antibiotic treatment regimens, patient noncompliance or limitations in measuring treatment outcomes by using administrative data led to the increase in the reported fail rate [24]. On excluding the data from the study by Bachur *et al.*, the success rate of conservative treatment was 75.6%, which was similar to the success rate of nonoperative treatment for uncomplicated appendicitis (68–95%) within 1 year according to a meta-analysis in adults [4–10,27]. In addition, although the success rate of treatment in the appendectomy group was 94.5%, it is desirable that the incidence of normal appendix should be lower than the present 4–5% [24,28–31]. Moreover, the consequence of treating a patient with suspected (but unproven) appendicitis with antibiotics would likely be considered more acceptable than undergoing a needless surgery.

We found the incidence rate of complications to be similar with both conservative treatment and appendectomy. Postappendectomy complications have been reported in up to 17% of cases with acute uncomplicated pediatric appendicitis [4,5,7,32]. Gorter *et al.* reported that one patient experienced a serious complication (re-intubation and ICU admission) after appendectomy [22,31,33,34]. On the contrary, the incidence of complications with conservative management ranges from 0 to -8% in uncomplicated pediatric appendicitis [11–14,17–19,26]. Moreover, all complications were not serious. Furthermore, recent articles have reported no differences in the incidence of perforated appendicitis between those who had undergone surgery following the failure of conservative treatment and those who underwent appendectomy at the outset, which means that appendectomy did not become a more difficult procedure following conservative management for simple pediatric appendicitis [18,35]. There were different pathophysiological characteristics and a lack of linear relationship between simple appendicitis and complex appendicitis, and the delay in surgery was not related to the increased incidence of perforations in children [36–38]. Simple appendicitis can be regarded as an emergency disease different from complex appendicitis. Emergency surgery is not the best way to prevent perforation of the appendix, and an individual management plan should be made according to the clinical characteristics [39–41].

However, we found in our meta-analysis that the success rate of conservative treatment was lower than that for appendectomy in patients with appendicoliths; the success rate of conservative treatment was similar to that of appendectomy in patients without appendicoliths. Similarly, recent articles have reported that the presence of a fecaliths was a risk factor for failure of conservative treatment of simple pediatric appendicitis. The investigative trial had to be terminated in the study by Mahida *et al.* because the failure rate of the conservative treatment for appendicitis with fecaliths in children was so high that it was unacceptable to both the patients and surgeons [21]. Taken together, it is obviously unreasonable to use conservative treatment for patients with fecaliths. The success rate of conservative management may increase on excluding patients with fecaliths. Therefore, imaging for the presence of appendicoliths is crucial.

No significant difference was noted in the total length of hospital stay in our study. Svensson *et al.* reported the total length of hospital stay to be longer in the conservative management group than that in the surgery group [17]. A reasonable explanation could be that Svensson *et al.* requested a minimum of 48 h of intravenous antibiotics [17]. However, Mudri *et al.* have suggested that the total length of stay in the conservative treatment group is longer than that in the appendectomy group because the conservative treatment group had a high readmission rate due to recurrence [20].

In addition, surgeons differed in their suggestions about the number days required to recuperate, and this might lead to differences in the number of disability days.

We also did not find a significant difference between the two groups for total cost associated with the treatment of appendicitis. Mudri *et al.* reported that the initial cost of treatment incurred by the appendectomy group was almost double that incurred by the conservative treatment group, but the high recurrence rates led to similar total costs finally [20]. On the contrary, Hartwich *et al.* found that even considering recurrence and secondary surgery, attempted conservative management of simple appendicitis was still more than US$1000 cheaper than the cost of initial surgery, not considering the surgeon's and anesthetist's fees [14]. Similarly, Wu *et al.* established a model to demonstrate that conservative treatment was more cost-effective than appendectomy for acute simple appendicitis in children [42]. The difference in the results may be explained by the different treatment strategies and charging standards in different centers or regions.

In addition to the defined outcomes, we also evaluated the HRQOL after both treatments as we considered these real-life concerns to be important in establishing the true effectiveness of a treatment. The HRQOL was influenced by several factors. On the one hand, in the conservative management group, HRQOL might be influenced by fear of recurrence, while in the appendectomy group, a few children might suffer from postoperative pain or complications [40]. Tanaka *et al.* reported that children who underwent appendectomy were more satisfied than the children who received conservative therapy [19]. However, Gorter *et al.* noted low response rates for HRQOL in the pediatric population [22]. Moreover, the study requires further examination to explore whether there is a statistical difference in the HRQOL between both the treatments because the present satisfaction survey is not a standardized tool and the missing data for 30% of the patients can limit the results.

Huang *et al.* performed a recent meta-analysis of the related topic and reported similar results of antibiotic therapy being recommended in pediatric patients with uncomplicated appendicitis [43]. However, according to Kessler *et al.*, conservative treatment was not superior to appendectomy because conservative treatment had a higher readmission rate [44]. They explained that many parents tended to opt for interval appendectomy due to worry of relapse. Gorter *et al.* also reported in their systematic review that conservative treatment could help avoid appendectomy in children, and those who needed a delayed appendectomy had no more postoperative complications than those who underwent an immediate appendectomy [45]. In a systematic review that focused on complicated appendicitis [46], the risk for recurrence in patients who did not undergo interval appendectomy was similar to the risk for morbidity associated with interval appendectomy. Therefore, the key point to be noted from the studies is that uncomplicated appendicitis must be accurately diagnosed, because the development and treatment of the two diseases (uncomplicated appendicitis and complicated appendicitis) are different. Further studies should focus on patient characteristics (such as biomarkers and imaging) to accurately identify uncomplicated appendicitis and predict the failure of conservative management of early uncomplicated appendicitis.

Limitations

The limitations of our study are mentioned in the following points: the follow-up period was only 1 year, while the risk of recurrence is for lifetime; Mahida *et al.* ended their study within only 4.7 months of the follow-up period; and the included studies were short of some data.

Conclusion

This review provides a detailed and systematically analyzed comparison between conservative treatment and appendectomy for pediatric patients with uncomplicated appendicitis. Standardized conservative treatment as an inpatient for pediatric appendicitis has a high rate of success with a risk for complications comparable to that for appendectomy so it is feasible and effective. However, for patients with appendicoliths, appendectomy is the better choice. We should interpret the quantitative effects with caution because of the large heterogeneity.

Future perspective

Further studies should focus on patient characteristics (such as biomarkers and imaging) to accurately identify uncomplicated appendicitis and predict the failure of conservative management of early uncomplicated appendicitis.

Summary points

- In children, acute appendicitis is the most prevalent gastrointestinal disease. Approximately, 1–4 children in 1000 undergo appendectomy per year.
- Surgery requires general anesthesia and intra-abdominal intervention, and the incidence rate of complications is as high as 10% within 30 postoperative days.
- It is important to identify whether conservative treatment is effective and safe for acute uncomplicated pediatric appendicitis.
- The purpose of our study was to perform meta-analysis comparing conservative treatment with surgery for uncomplicated pediatric appendicitis to estimate the effectiveness and safety of conservative treatment.
- There were no statistically significant differences in the length of stay, total cost and health-related quality of life on comparing the two groups. The study reported a significant difference in the initial success rate of treatment (odds ratio [OR]: 0.122; 95% CI: 0.041–0.367; $p < 0.05$) and in 1 year (OR: 0.087; 95% CI: 0.015–0.493; $p < 0.05$).
- The patients with fecaliths showed low treatment efficacy in the conservative treatment group with a significant difference (OR: 0.073; 95% CI: 0.013–0.004; $p < 0.05$). For the patients with appendicoliths, appendectomy is the better choice.
- Conservative treatment was found to be safe and feasible and many patients with acute uncomplicated appendicitis can avoid the risks of the operation and general anesthesia.
- Our meta-analysis, depending on the existing data, does not provide strong evidence for definite conclusions, while may hint that conservative treatment may be an effective way to treat acute simple appendicitis in children.

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Author contributions

LW Bi contributed the most to the study and should be considered first author. BL Yan contributed the same as the first author. LW Bi and BL Yan had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis; study concept and design: all authors. Acquisition, analysis or interpretation of data: LW Bi. Drafting of the manuscript: LW Bi and BL Yan. Critical revision of the manuscript for important intellectual content: QY Yang, HL Cui; statistical analysis: LW Bi; obtained funding: HL Cui; administrative, technical or material support: all authors.

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