Laparoscopic versus open inguinal hernia repair in children: A systematic review

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Abstract

Purpose: Considerable debates exist regarding the preferable technique to repair a paediatric inguinal hernia (PIH). This systematic review aims to compare the efficacy and safety of laparoscopic herniorrhaphy (LH) and open herniorrhaphy (OH) in PIH.

Methods: The randomised controlled trials (RCTs) that compared the outcomes of LH and OH in PIH without region and language restrictions searched from the following databases: PubMed, Web of Science Database, Cochrane Library, SciELO Citation Index, Russian Science Citation Index, China National Knowledge Infrastructure, WanFang Data and China Science and Technology Journal Database.

Results: A total of 13 RCTs that involving 1207 patients included in the review. The LH displayed a shorter operative time for bilateral hernia repair (weighted mean difference = −8.23, 95% confidence interval [CI]: −11.22 − −5.23, P < 0.00001), a lower complication rate (odds ratio [OR] = 0.32, 95% CI: 0.13–0.83, P = 0.02) along with a lower wound infection (OR = 0.14, 95% CI: 0.04–0.55, P = 0.005) and major male-specific post-operative complications (OR = 0.10, 95% CI: 0.04–0.24, P < 0.00001) and a less contralateral metachronous inguinal hernia (CMIH) incidence rate (OR = 0.09, 95% CI: 0.02–0.42, P = 0.002). No significant difference was found for unilateral operative time, time to full recovery, length of hospital stay, recurrence and hydrocele rates between the two techniques.

Conclusion: The present review reiterates that both the LH and OH techniques for the PIH repair are comparable. However, in some aspects, the LH is superior to the OH in terms of operative time for bilateral hernias, post-operative complications rate and CMIH incidence rate. Rigorously designed RCTs are anticipated to confirm the clinical effects of both LH and OH.

Keywords: Inguinal hernia repair, laparoscopic herniorrhaphy, laparoscopy, open herniorrhaphy, paediatric inguinal hernia

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INTRODUCTION

Paediatric inguinal hernia (PIH) is one of the most common diseases in children and has an incidence rate of approximately 0.8%–4.4%. It is an inguinoscrotal abnormality that occurs chiefly because of the failed natural closing of the processus vaginalis. Due to the risk of incarceration and serious consequences such as bowel necrosis as well as testicular/ovarian dysfunction or mortification, surgical intervention is indicated in all children who have been diagnosed with inguinal hernia. Open herniorrhaphy (OH), which primarily involves the high ligation and excision of the hernia sac, has been accepted as a gold standard for PIH repair since its introduction over five decades, due to its high procedural success and low complication rate.\(^5\)

Laparoscopic herniorrhaphy (LH) was first described as an alternative technique to the traditional OH by Montupet in 1993 as noted by Schier et al., 1998.\(^3\) Recently, with the advancement of technology and instrumentation, LH was reported to have advantages of improved post-operative pain, short surgery time for bilateral cases, reduced tissue trauma to the delicate inguinal cord structures, quick identification of a contralateral (the clinically unaffected side) patent processus vaginalis and improved cosmesis.\(^4\) However, controversies still exist whether LH is better over OH because of the potentially high recurrence rate, injury to the testicular vessels during the surgical site closure, resulting in testicular atrophy, and harm to the intra-abdominal structures due to a breached peritoneal cavity.\(^4\)

In the 2014 survey on the management of PIH, 83% of respondents preferred an open approach in the management of PIH.\(^3\) Previous systematic reviews which compared LH and OH in the treatment for PIH did not reach a consensus about the superiority of one technique over the other.\(^6\)–\(^11\) Since the evidence in this area has increased, the investigators of this study reviewed the present literature and accomplished a systematic review of randomised controlled trials (RCTs) to evaluate and compare the clinical outcomes after the two herniorrhaphy techniques.

METHODS

Protocol and registration
The study was registered in the PROSPERO (Registration ID: CRD42019119149) and conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines.\(^12\)

Eligibility criteria
The following eligibility criteria were applied: (a) population: paediatric patients with inguinal indirect hernias; (b) intervention: LH; (c) comparator: OH; (d) outcomes: overall success rate, operative time, time to resume to full activity, length of hospital stay, complications, identification of contralateral patent processus vaginalis (CPPV) and incidence of contralateral metachronous inguinal hernia (CMIH); (e) study design: RCTs.

The publications with the possibility of overlap/duplication were excluded. The initial literature search and the final inclusion were performed without any region and language restrictions.

Information source and search strategy
An extensive literature search was performed in March 2020 using PubMed, Web of Science Database, Cochrane Library, SciELO Citation Index, Russian Science Citation Index, China National Knowledge Infrastructure, WanFang Data and China Science and Technology Journal Database. The following were all the possible combinations of MeSH terms and keywords used to search the databases mentioned above: ((Children OR Pediatrics OR (Pediatric patients)) AND ((Hernias, Inguinal) OR (Inguinal Hernia)) AND ((herniorrhaphy OR (hernia repair))) AND ((Laparoscopy OR laparoscopic OR Celioscopy OR Peritoneoscopy) OR (open OR conventional OR traditional))). After identifying the coherent titles, the abstracts were reviewed to determine whether the study was eligible. If the information obtained from the title and/or abstract appeared to match the eligibility criteria, the full articles were retrieved. Furthermore, the reference lists of the retrieved articles and relevant reviews were manually checked. The work was independently completed by two reviewers, and any disagreements were settled by discussion and consensus.

Data extraction
Two authors independently reviewed each article and extracted the data into a pre-established electronic data extraction table. The following data were abstracted: first author, publication year, study type, patient characteristics, intervention features, follow-up and outcome parameters. The extracted data were checked by another investigator, and any disagreements were settled by discussion and consensus.

Quality assessment
The Cochrane Risk of Bias tool for RCTs (random sequence generation, allocation concealment, blinding, incomplete outcome data, selective reporting and other bias) was used to appraise the methodological quality of the included articles, which was performed by two independent reviewers. Any disagreements between the reviewers were settled by discussion and consensus.
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Statistical analysis
Weighted mean differences (WMDs) with 95% confidence interval (CI) and odds ratios (ORs) were utilised for the analysis of continuous and dichotomous variables, respectively. Studies without adequate data to obtain the mean values and standard deviations (SDs) for continuous variables or studies without sufficient data for the analysis of relevant indices, such as OR and 95% CI, were excluded from the relevant calculations. A \( P < 0.05 \) was considered statistically significant. Statistical heterogeneity was assessed based on the summary data using the \( I^2 \) statistic, and an \( I^2 \)-value of >50% was considered as significant heterogeneity. Pooled effect sizes were calculated using a random-effects model. Subgroup analysis was performed according to the suturing approach used for LH (intracorporeal or extracorporeal laparoscopic suturing) if the outcome was regarded potentially affected. All statistical analyses were performed using the Review Manager version 5.3 (Cochrane Collaboration, Oxford, United Kingdom).

Results

Study selection
Among the 1463 records initially screened, 468 records were excluded due to duplication, and 958 were excluded based on the titles and abstracts [Figure 1]. The full text of the remaining 37 citations were retrieved and reviewed for more detailed information. Finally, 13 RCTs\(^{[13-25]}\) focussed on the comparison between LH and OH for PIH and reported that predefined outcomes were included for the analysis after the independent review.

Study characteristics
A summary of the included studies is presented in Table 1. The majority of the studies were published in English, four were in Chinese, and one was in Turkish. This systematic review included a total of 1207 children who underwent LH (612, 50.7%) or OH (595, 49.3%) from 13 selected RCTs. All the studies included both boys and girls, except the three studies\(^{[13,17,19]}\) that included only boys. Patients’ age at the surgery and follow-up time varied considerably both within and across the studies.

Methodological quality of included studies
The Cochrane Risk of Bias tool was used to assess the risk of bias in the included studies [Figure 2]. Ten studies showed a low risk for random sequence generation, where pseudorandom number generator, balloting, coin flipping or random number table methods were used, and two studies mentioned randomisation without the description of randomisation method. Saranga Bharathi et al.’s study\(^{[22]}\) was considered at a high risk of bias for random sequence generation and allocation concealment where surgical options were based on days of presentation to the outpatient department. Six studies mentioned sealed/
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Table 1: Summary of study characteristics

| Study design | Male | Female | Unilateral | Bilateral | LH (n) | OH (n) | Age range | Tumors in LH | Laparoscopic suturing approaches | Intraperitoneal | Extraperitoneal |
|--------------|------|--------|------------|-----------|--------|--------|-----------|------------|-------------------------------|----------------|---------------|
| Celebi et al. | 59 (28,31) | 0 | 59 | 0 | 0 | 0 | ≤3 months | Two 3 mm, one 5 mm | Infraperitoneal | 3/24 |
| Chan et al. | 83 (41,42) | 67 | 16 | 80 | 0 | 0 | 3–18 months | Two 3 mm, one 5 mm | Infraperitoneal | 3/24 |
| Gause et al. | 41 (26,15) | 33 | 10 | 73 | 0 | 0 | <3 years | One 3 mm | Extrapertoneal | 3/24 |
| Igwe et al. | 64 (32,32) | 40 | 20 | 0 | 3 | 2 | 2 months–14 years | One 5 mm | Extrapertoneal | 3/24 |
| Jiang et al. | 40 (20,20) | 25 | 0 | 15 | 0 | 0 | 2 months | One 3 mm, one 5 mm | Infraperitoneal | 3/24 |
| Jukic et al. | 224 (112,112) | 80 | 40 | 0 | 3 | 0 | 2 months–14 years | Two 5 mm, two 3 mm | Infraperitoneal | 3/24 |
| Koivusalo et al. | 250 (125,125) | 125 | 125 | 0 | 3 | 0 | 2 months–14 years | Three 5 mm | Infraperitoneal | 3/24 |
| Saranga et al. | 89 (47,42) | 0 | 92 | 4 | 10 | 0 | <1 year | One 5 mm, one 3 mm | Extrapertoneal | 3/24 |
| Shalaby et al. | 61 (30,31) | 0 | 0 | 60 | 0 | 0 | 3–18 years | One 5 mm | Extrapertoneal | 3/24 |
| Shum et al. | 2008 (1008,1008) | 0 | 0 | 0 | 0 | 0 | 3–18 years | One 3 mm | Extrapertoneal | 3/24 |
| Zhu et al. | 102 (53,49) | 0 | 0 | 0 | 0 | 0 | 3–18 years | One 5 mm | Extrapertoneal | 3/24 |

*Laterality of the inguinal hernia was unclear in 105 children: (i) Unilateral in obese child 53 (25, 28); (ii) Bilateral 92 (44, 48); (iii) Recurrent inguinal hernia 27 (12, 15); (iv) Inguinal hernia with umbilical hernia 40 (18, 22); (v) Inguinal hernia with questionable other side 38 (26, 12).

Operative time

Nine of the included studies[14,17,19,23] compared the unilateral operative time, and the analysis revealed no significant difference between the two techniques (WMD = −0.92, 95% CI: −7.36–5.52, P = 0.78), with a considerable statistical heterogeneity (I² = 96%). This effect existed even after the analysis considered only studies that performed intracorporeal suturing (WMD = 6.60, 95% CI: −2.05–5.25, P = 0.13; F = 94%). Although it was shorter when only studies performed extracorporeal suturing were considered (WMD = −6.75, 95% CI: −12.75–−0.76, P = 0.03; F = 92%), this difference disappeared (WMD = −5.55, 95% CI: −11.62–0.52, P = 0.07; F = 94%) in sensitivity analysis, where the study[21] that detected the contralateral in open surgery was excluded from the extracorporeal subgroup.

Six trials[13,15,16,22,23] reported the mean operation time for hernia repair and the analysis for overall effect showed that the LH group had a shorter bilateral operative time than that of OH (WMD = −8.23, 95% CI: −11.22–−5.23, P < 0.00001; F = 57%). Similar results were found in both subgroups with limited heterogeneity (intracorporeal suturing: WMD = −5.88, 95% CI: −7.48–−4.29, P < 0.00001; F = 0%; extracorporeal suturing: WMD = −10.29, 95% CI: −12.32–−8.26, P < 0.00001; F = 0%).

Time to full recovery

Five[13–15,20,21] of the included studies reported the time to resume full activity or time to return to normal daily activities. Shalaby et al.'s study[21] was excluded from the calculation as they reported the time to full recovery only within a specific time (LH: <6 h; OH: <10 h). In addition,
Yang et al.'s study assessed the time to leaving bed after surgery and Inal et al.'s study assessed the time to first walking were also excluded from the data synthesis. The analysis revealed similar results after the two techniques (WMD = −1.46, 95% CI = −15.72–12.81; P = 0.84) with a high heterogeneity ($I^2 = 71\%$). The subgroup analysis of laparoscopic herniorrhaphy did not change the result (intracorporeal suturing: WMD = 1.50, 95% CI: −14.89–17.89; P = 0.86; $F = 83\%$; extracorporeal suturing: WMD = −15.49, 95% CI: −44.08–13.10, $P = 0.29$; $F = 0\%$).

**Length of hospital stay**

Eleven studies reported the length of hospital stay for both the techniques; however, mean values and standard deviations were available only for six studies. Analysis of the limited data revealed no significant differences between the two groups (WMD = −11.8, 95% CI: −26.90–4.74, $P = 0.17$), with a high heterogeneity ($I^2 = 100\%$). The subgroup analysis of studies that used the extracorporeal suturing technique did not change the result (WMD = −15.45, 95% CI: −47.46–16.57, $P = 0.34$) with a high heterogeneity ($I^2 = 99\%$). However, sensitivity analysis by excluding the Jiang et al.'s study altered the outcome (WMD = −5.69, 95% CI: −8.36–3.02, $P = 0.0001$) with an improved heterogeneity ($I^2 = 0\%$). The subgroup analysis of studies that used the intracorporeal suturing technique also revealed a shorter length of hospital stay in the OH group (WMD = 1.10, 95% CI: 0.48–1.72, $F = 0\%$, $P = 0.0005$).

**Complications**

The included studies recorded varying complications after the inguinal hernia repair. The overall complication rate was lower in the LH group (OR = 0.32, 95% CI: 013–0.83, $P = 0.02$; $F = 59\%$). A comparable complication rate for the two techniques was observed after the subgroup analysis of the studies that performed the intracorporeal suturing (OR = 0.86, 95% CI: 0.15–5.10, $P = 0.87$; $F = 69\%$). A lower complication rate was found for LH after the subgroup analysis of studies that performed extracorporeal suturing (OR = 0.15, 95% CI: 0.07–0.35, $P < 0.00001$; $F = 20\%$).

Analysis revealed that LH resulted in a lower incidence of major male-specific post-operative complications (iatrogenic testicular ascent, testicular atrophy and scrotal oedema/haematoma) when compared to OH (OR = 0.10, 95% CI: 0.04–0.24, $P < 0.00001$; $F = 0\%$). Besides, a lower incidence of wound infection was also observed in LH (OR = 0.14, 95% CI: 0.04–0.55, $P = 0.005$; $F = 0\%$). These differences between two techniques existed in subgroup on extracorporeal suturing, while disappeared in subgroup on intracorporeal suturing.

There was no significant difference between LH and OH in the incidence of hydrocele (OR = 1.15, 95% CI: 0.41–3.24, $P = 0.79$; $F = 7\%$) and ipsilateral recurrence after the surgery (OR = 0.49, 95% CI: 0.14–1.66, $P = 0.25$; $F = 0\%$). Similar results were found after the subgroup analysis.

**Contralateral metachronous inguinal hernia**

Six studies reported the identification of CPPV in unilateral-affected cases, with an incidence ranging from 7.7% to 30.0%, and five studies reported the occurrence of CMIH. The analysis after excluding the study that did not repair the CPPV in the primary surgery showed that the LH group had a lower CMIH incidence rate (OR = 0.09, 95% CI: 0.02–0.42, $P = 0.002$, $F = 0\%$).

**DISCUSSION**

The current systematic review was performed to hopefully provide the surgeons and the parents with added information and suggestions and help select between the two techniques of PIH.

The present analysis revealed no significance in unilateral hernia operative time between LH and OH. Subgroup analysis showed that the extraperitoneal approaches of LH required a shorter unilateral operative time when compared to the open group. However, after the sensitivity analysis excluding a study that performed OH with practice to inspect contralateral side by using a laparoscope which probably prolonged the operative time, the difference disappeared. Therefore, it remained to confirm whether laparoscopic repair performed with the extracorporeal suturing could shorten the operative time in unilateral cases. What has been confirmed was that the operative time of bilateral hernia under the LH is superior to OH. This was mainly because the ligation of the contralateral hernia sac can be directly performed after the LH of the first side, while an open surgery requires the complete repetition of the procedures. However, it should be noted that the definitions of the operative time were not exactly the same. For example, the time from skin incision to wound closure was probably different from the time from the first incision to wound dressings were applied. Besides, the operative time greatly varied with the surgical technique and partly depended on the expertise of the surgical team. We believe that with the growing experience and use of refinements, the operative time will come down.

The time to full recovery did not differ statistically between LH and OH, suggesting that post-operative recovery after
two techniques was comparable. Again, it should be noticed that the definitions of a full recovery were different among the studies, which made an objective comparison difficult. Koivusalo et al. reported that post-operative restoration of activities in patients aged <6 years was faster than that in patients aged 6 years or more, both in LH and OH. It would be useful to detect the association between the age and post-operative recovery, but no more details were found in existing studies. Future research in this aspect may provide hints on the timing of surgery.

A similar length of hospital stay between LH and OH was found in the present study. However, the heterogeneity could not be ignored. The data varied greatly among studies as different discharge criteria were used and different periods were measured. To be specific, patients were discharged when they were stable and feeding well or when the pain could be adequately controlled with oral acetaminophen. Koivusalo et al. recorded the duration from the moment when patients arrived in the operating room to discharge, while Yang et al. recorded the length of post-operative hospital duration. A standard definition should be identified in future studies. In sensitivity analysis, the length of hospital stay was reduced significantly in the LH. It is considered that the change may be an implication of the single-port LH. Studies with a more precise design and larger sample size are needed to confirm this conjecture. Besides, we need to point out the limitation that the length of hospital stay depends on the country and time of the day the surgery performed. In most countries, such patients are operated in the day wards nowadays; however, the procedure was often performed in the hospitals in the past.

The complications are the major concerns of both the surgeons and parents. The common reported complications after inguinal hernia repair included recurrence, hydrocele, wound infection, bleeding, scrotal haematoma, scrotal oedema, injury of the vas deferens or spermatic vessels, iatrogenic testicular ascent and testicular atrophy. In the present review, LH is superior to OH in terms of overall post-operative complication rates. Consistent with the expectation that minimally invasive surgery reduces the risk of infection at the surgical site, we found that the patients who underwent laparoscopic repair were less likely to experience wound infection. Esposito et al. explained this as the LH incisions may be in a more sterile environment, compared to the inguinal incisions, which are inside the diaper area.

The reason behind the lower incidence of major male-specific post-operative complications (such as iatrogenic testicular ascent, testicular atrophy and scrotal oedema/haematoma) in the LH is probably due to the clarity of the laparoscopic images that allow the surgeons to effectively avoid injury to these structures, and the laparoscopic approach does not dissect the inguinal region and separate the cremaster muscle to avoid disrupting the collateral circulation of the spermatic vessels.

The incidence of recurrence and post-operative hydrocele was similar in the two groups. Some studies reported a higher recurrence incidence and hydrocele after laparoscopic surgery. This was attributed to the technique-derived limitations, in which the hernia sac was not transected or was not completely ligated. With the advancement of laparoscopic techniques and skills, the recurrence rate of LH has been gradually reduced. If both the procedures performed by the specialists in their respective sub-specialities, the clinical difference becomes minimum.

What calls for special attention is that the incidence of the long-term complications such as recurrence and testicular atrophy may have been underestimated due to the limitation of varying length of follow-up time. As only 50% recurrence appeared within 6 months, 76% within 2 years, and 96% within 5 years, the long-term follow-up is strongly needed to prove the current results.

Under the direct visualisation with a laparoscope, a CPPV can be easily detected and prophylactically closed simultaneously with the primary surgery. Our review showed a lower CMIH rate after the LH as prophylactic closure performed when a CPPV found. It should be noticed that the cumulative incidence of CMIH is closely associated with the follow-up time. A recent systematic review reported the prevalence of a contralateral patent processus vaginalis was up to 38.5%. It is certain that prophylactic closure of a CPPV detected in LH can prevent suffering from a second operation and anaesthesia. However, a patent processus vaginalis does not mean a contralateral hernia. There is a persistent controversy that a routine closure would be useful prevention or overtreatment due to the low rate of CMIH in unilateral affected cases. The aforementioned review concluded that 18 clinically asymptomatic CPPVs need to be repaired to prevent one subsequent contralateral hernia. Therefore, the decision should be made carefully and individually based on clinical characteristics of patients, considering the relevant risks such as premature, coexistence of other diseases, as well as the opinions of parents. Strong evidence to support the benefits and risks of this management is required to establish a standard for determining whether or not closing the CPPV at the same time during the primary hernia repair.
This systematic review included 13 RCTs with a small sample size of 1207 children who underwent LH or OH. Selection, performance and detection bias possibly existed in the conduct of the included studies; since the studies included children, the implementation of allocation concealment and blinding became more difficult. Furthermore, there were variations in the physical conditions of the children, surgical techniques, surgeons’ skills, outcome definitions and follow-up time. Therefore, the clinical and methodological heterogeneity among the included studies was significant. Besides, the age of surgery is a vital issue that need to address. Unfortunately, since the outcomes were assessed in different and partially overlapping age groups among the studies, the relation between the age of surgery and its influence on the outcomes cannot be concluded precisely with the current evidence. More reliable experimental results are needed to address this concern.

CONCLUSION

This review showed that LH and OH are comparable in terms of recurrence after surgery. Specifically, the LH can bestow shorter operative time for bilateral hernias, lower post-operative complication rate and lower CMIH incidence rate. Moreover, less wound infection and male-specific operative complications were noted in the LH group. We consider the laparoscopic technique performed with extracorporeal suturing might be a priority in bilateral hernia repairs, especially in male patients. Overall, both the LH and OH are safe and effective for the surgical management of PIH. Further evidence is needed to give notable recommendations.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Miltenburg DM, Nuchtern JG, Jaksic T, Kozinetz C, Brandt ML. Laparoscopic evaluation of the pediatric inguinal hernia–A meta-analysis. J Pediatr Surg 1998;33:874-9.
2. International Pediatric Endosurgery Group. IPEG guidelines for inguinal hernia and hydrocele. J Laparoendosc Adv Surg Tech A 2010;20:x-xiv.
3. Schier F. Laparoscopic herniorrhaphy in girls. J Pediatr Surg 1998;33:1495-7.
4. Davies DA, Rideout DA, Clarke SA. The International Pediatric Endosurgery Group Evidence-Based Guideline on minimal access approaches to the operative management of inguinal hernia in children. J Laparoendosc Adv Surg Tech A, 2020;30:221-7.
5. Zani A, Eaton S, Hoelbelth M, Puri P, Tovar J, Fasching G, et al. Management of pediatric inguinal hernias in the era of laparoscopy: results of an international survey. Eur J Pediatr Surg 2014;24:9-13.
6. Alzahem A. Laparoscopic versus open inguinal herniotomy in infants and children: a meta-analysis. Pediatr Surg Int 2011;27:605-12.
7. Yang C, Zhang H, Pu J, Mei H, Zheng L, Tong Q. Laparoscopic vs open herniorrhaphy in the management of pediatric inguinal hernia: a systemic review and meta-analysis. J Pediatr Surg 2011;46:1824-34.
8. Esposito C, St Peter SD, Escolino M, Juang D, Settimi A, Holcomb GW 3rd. Laparoscopic versus open inguinal hernia repair in pediatric patients: A systematic review. J Laparoendosc Adv Surg Tech A 2014;24:811-8.
9. Feng S, Zhao L, Liao Z, Chen X. Open versus laparoscopic inguinal herniotomy in children: A systematic review and meta-analysis focusing on postoperative complications. Surg Laparosc Endosc Percutan Tech 2015;25:275-80.
10. Kantor N, Travis N, Wayne C, Nasr A. Laparoscopic versus open inguinal hernia repair in children: Which is the true gold-standard? A systematic review and meta-analysis. Pediatr Surg Int 2019;35:1013-26.
11. Dreuwing K, Maat S, Twisk J, van Heurn E, Derilis J. Laparoscopic versus open pediatric inguinal hernia repair: State-of-the-art comparison and future perspectives from a meta-analysis. Surg Endosc 2019;33:3177-91.
12. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ 2009;339:b2535.
13. Celebi S, Uysal AI, Inal FY, Yildiz A. A single-blinded, randomized comparison of laparoscopic versus open bilateral hernia repair in boys. J Laparoendosc Adv Surg Tech A 2014;24:117-21.
14. Chan KL, Hui WC, Tam PK. Prospective randomized single-center, single-blind comparison of laparoscopic vs open repair of pediatric inguinal hernia. Surg Endosc 2005;19:927-32.
15. Gause CD, Casamassima MG, Yang J, Hsiung G, Rhee D, Salazar JH, et al. Laparoscopic versus open inguinal hernia repair in children≤3: A randomized controlled trial. Pediatr Surg Int 2017;33:367-76.
16. Igwe AO, Talabi AO, Adisa AO, Adumah CC, Ogundele IO, Sowande OA, et al. Comparative study of laparoscopic and open inguinal herniotomy in children in Ille Ife, Nigeria: A prospective randomized trial. J Laparoendosc Adv Surg Tech A 2019;29:1609-15.
17. Inal FY, Celebi S, Uysal AI, Yilmaz Y, Topraş M, Daşkaya H. Comparison of the effects of laparoscopic and open repair techniques on postoperative pain and analgesic consumption in pediatric unilateral inguinal hernia. Haseki Tip Bulenti 2014;45:284-8.
18. Jiang XH, Yu DS, Luo JE. Analysis of clinical therapeutic effect of laparoscopic high ligation of hernial sac in children with inguinal hernia. Chin J Hernia Abdominal Wall Surg 2015;9:246-8.
19. Junkić M, Pogorelić Z, Supe-Domić D, Jerončić A. Comparison of inflammatory stress response between laparoscopic and open approach for pediatric inguinal hernia repair in children. Surg Endosc 2019;33:3243-50.
20. Koivusalo AI, Korpela R, Wirtavuori K, Piiparinen S, Rintala RJ, Holcomb GW 3rd. Laparoscopic versus open hernia repair in children: Which is the true gold-standard? A meta-analysis. J Pediatr Surg 2011;46:1824-34.
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24. Zhou ZQ. Research of application value by single-port laparoscopic surgery in the treatment of children oblique inguinal hernia. Chin Prac Med 2017;12:29-31.

25. Zhu XQ, Guan WX. Laparoscopic assisted extraperitoneal hernia sac high ligation vs traditional surgery for inguinal hernia in preschool children. World Chin J Dig 2015;23:2168-73.

26. Gandaglia G, Ghani KR, Sood A, Meyers JR, Sammon JD, Schmid M, et al. Effect of minimally invasive surgery on the risk for surgical site infections: results from the National Surgical Quality Improvement Program (NSQIP) Database. JAMA Surg 2014;149:1039-44.

27. Tsai YC, Wu CC, Yang SS. Minilaparoscopic herniorrhaphy with hernia sac transection in children and young adults: A preliminary report. Surg Endosc 2007;21:1623-5.

28. Saranga Bharathi R, Arora M, Baskaran V. Minimal access surgery of pediatric inguinal hernias: A review. Surg Endosc 2008;22:1751-62.

29. Grosfeld JL, Minnick K, Shedd F, West KW, Rescorla FJ, Vane DW. Inguinal hernia in children: Factors affecting recurrence in 62 cases. J Pediatr Surg 1991;26:283-7.

30. Lee CH, Chen Y, Cheng CF, Yao CL, Wu JC, Yin WY, et al. Incidence of and risk factors for pediatric metachronous contralateral inguinal hernia: Analysis of a 17-year nationwide database in Taiwan. PLoS One. 2016;11:e0163278.

31. Muensterer OJ, Gianicolo E. Contralateral processus closure to prevent metachronous inguinal hernia: A systematic review. Int J Surg 2019;68:11-9.