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ORIGINAL ARTICLE

Laparoscopic versus open inguinal hernia repair in children: which is the true gold-standard? A systematic review and meta-analysis

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Abstract

Purpose Hernia repair is one of the most common operations performed in children. Traditionally, an open surgical approach has been utilized; however, laparoscopic repair has been gaining favour within the surgical community. We aimed to determine whether open or laparoscopic hernia repair is optimal for pediatric patients by comparing recurrence rates and other outcomes.

Methods We searched CENTRAL, MEDLINE, and EMBASE from 1980 onwards, including studies that compared laparoscopic and open repair for pediatric inguinal hernia.

Results Our initial search yielded 345 unique citations. Of these, we reviewed the full text of 28, and included 21 in meta-analysis. The results showed that patients who underwent laparoscopic surgery were more likely to experience wound infection ($p=0.003$), but less likely to experience ascending testis ($p=0.05$) and metachronous hernia ($p=0.0002$). There were no differences in recurrence rates ($p=0.95$), surgical time ($p=0.55$), length of hospitalization ($p=0.50$), intra-operative injury, bleeding, testicular atrophy, or hydrocele.

Conclusion Laparoscopic and open surgeries are equivalent in terms of recurrence rates, surgical time, and length of hospitalization. Laparoscopic repair is associated with increased risk of wound infection, but decreased risk of ascending testis. Laparoscopic surgery allows the opportunity to explore and repair the contralateral side, preventing metachronous hernia.

Level of Evidence III.

Keywords Inguinal · Hernia · Laparoscopic · Meta-analysis

Introduction

Pediatric inguinal hernia (PIH) is discovered in between 0.8 and 4.4% of children annually [1]. The majority of these hernias are indirect in nature, with the abdominal contents herniating into the inguinal canal through a patent processus vaginalis. Surgical repair, which generally involves dissecting the hernia sac at the level of the internal ring followed by high ligation of the sac [2], is the universally accepted definitive management. Taking into consideration the condition's high incidence rate, it follows that hernia repair is one of the most common operations performed in children.

Traditionally, an open surgical approach has been utilized, with high success rates and low risk of complications [1]. However, ever since the first laparoscopic repairs performed in 1993 and 1994 (for girls and boys, respectively) [3, 4], the minimally invasive approach has been gaining favour within the surgical community. Advantages of laparoscopic repair (LR) as reported by retrospective studies include better cosmesis, shorter length of stay (LOS), faster recovery, and—probably most importantly—a greater ability to visualize and repair a contralateral hernia, if present [1, 3–5].

Despite the described advantages of LR for PIH, open repair (OR) remains the gold standard in most centres [1], and the literature has thus far not shown sufficient evidence to change that. The most recent systematic review (SR) and meta-analysis (MA) concluded that although LR did indeed prove advantageous over OR in some respects, more

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randomized controlled trials (RCT) were needed to make a definitive recommendation [5].

Considering that 7 years have passed since that SR/MA was published, we conducted an up-to-date SR/MA to compare the outcomes of OR versus LR in PIH.

Methods

Eligibility criteria

We included studies if they were published in English, French, or Arabic, and compared LR with OR for PIH. We did not include editorials or case studies, but all other comparative study designs were considered.

Literature search

We performed a search of CENTRAL, EMBASE (1980 onwards), and MEDLINE up to Sept. 22, 2017 (supplementary material 1). We identified additional publications by hand-searching the reference sections of all relevant articles.

Screening

Two reviewers (NK and CW) independently assessed all citations identified by the literature search for relevance. At a title and abstract level, we used the liberal accelerated method [6]. For assessments at the full-text level, the reviewers reached consensus on which articles should be included in the final analysis. We resolved disagreements by discussion or third party consultation (AN) when necessary. Where articles had potential to satisfy inclusion criteria but were missing some important data, we attempted to contact the authors for clarification and retrieval of these data.

Data extraction

We extracted the following information from all included studies: citation details including title and year of publication; study details including design, country/region and sample size; participant details including age at surgery, sex, type of hernia (e.g. direct vs. indirect), comorbid conditions, and length of follow-up; and surgical details including procedure used, and whether it was performed emergently or electively. Clinical outcomes extracted included: rates of recurrence (primary outcome), length of surgical time, length of hospital stay, intra- and post-operative complications (including wound infection), rates of postoperative metachronous inguinal hernia (PMIH), pain, and cosmesis. Two reviewers (NK, NT) extracted all data and a second reviewer (CW) verified the extracted data. We resolved all discrepancies through discussion or third party consultation (AN) if necessary.

Quality assessment

We assessed methodological quality of RCTs using the Cochrane Risk of Bias tool [7]. Non-randomized studies were assessed using the MINORS tool [8]. Two reviewers (NK and CW) independently performed quality assessment of each publication and compared scores to reach a consensus. When consensus could not be reached, we consulted a third researcher (AN). We used these quality assessments to inform interpretations of the data, and to help identify studies for which the results may have been influenced by the study design.

Synthesis

We used tables to summarize the characteristics of included studies. MA was performed where possible, with data being pooled using inverse variance random effects models. Count and dichotomous data were expressed as risk difference (RD) with 95% confidence interval (CI), while continuous data were expressed as mean difference (MD) with 95% CI. We utilized forest plots to visualize the data. We assessed statistical heterogeneity of the included studies using the I^2 test with 95% confidence intervals, and estimated publication bias using a funnel plot. We summarized qualitative data in a narrative manner.

Results

Studies included

Our electronic search yielded 345 records after removing duplicates. After applying our exclusion criteria to titles and abstracts, 28 studies remained. We included 21 of these studies in quantitative synthesis following full-text review. Studies were excluded at the full-text level for several reasons, including: having an ineligible study design, no outcome of interest, unclear reporting of data, not comparative, or not pediatric (Fig. 1).

Study characteristics

The majority of studies were retrospective in nature; four were prospective or had a prospective component; five were RCTs (Table 1). Studies were published between 2004 and 2017 and were conducted in over 10 different countries. All were published in English. The MINORS scores for our included non-randomized studies ranged from 12 to 18

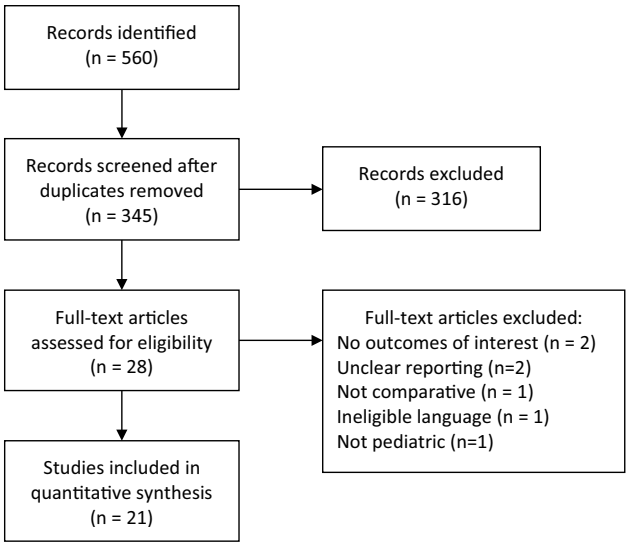


Fig. 1 PRISMA flow-diagram

(Table 1). Risk of bias of included RCTs was generally low, and full details are provided in supplementary material 2.

Patient characteristics

Altogether, the 21 included studies consisted of 3477 patients undergoing LR (1891 males, 1528 females, 58 unspecified) and 2569 undergoing traditional OR (1775 males, 631 females, 163 unspecified). All patients were diagnosed with either an "inguinal hernia", "indirect inguinal hernia", or communicating "hydrocele". A minority underwent emergent surgery for incarcerated hernia, though most studies did not differentiate between emergent vs. elective surgery. Age at surgery varied considerably between studies, and ranged from the first weeks of life to early adolescence. With regard to surgical technique, patients undergoing OR underwent standard high ligation of the hernia sac, while the technique varied somewhat between studies for LR. Length of follow-up for patients was quite variable; it ranged from 1 month to several years, with both within- and between-study variability. Since many studies only included ranges of follow-up periods and no individual values, we were unable to calculate a median follow-up length (Table 1).

Laparoscopic versus open repair

For our primary outcome of recurrence, the results of our MA of 21 studies revealed no difference between OR and LR (RD 0.00, 95% CI −0.00 to 0.00, $p=0.91$; Fig. 2). Heterogeneity for this comparison was very low ($I^2=0\%$) and visual analysis of the funnel plot suggests low risk of publication bias (Fig. 3).

Regarding secondary outcomes, our results showed that patients who underwent LR were more likely to experience wound infection (RD −0.01, 95% CI −0.02 to 0.00, $p=0.003$), but less likely to experience ascending testis (RD 0.01, 95% CI 0.00 to 0.01, $p=0.05$) and metachronous hernia (RD 0.05, 95% CI 0.03 to 0.08, $p=0.0002$) compared to those who underwent OR. There were no significant differences between groups in surgical time (MD 1.64, 95% CI −3.79 to 7.07, $p=0.58$), length of hospitalization (MD 14.32, 95% CI −27.75 to 56.38, $p=0.51$), intra-operative injury (RD 0.00, 95% CI −0.01 to 0.01, $p=0.66$), bleeding (OR −0.01, 95% CI −0.05 to 0.02, $p=0.46$), testicular atrophy (OR 0.00, 95% CI −0.00 to 0.01, $p=0.67$), or hydrocele (RD 0.10, 95% CI −0.17 to 0.37, $p=0.46$) (Fig. 2, supplementary material 3).

When we analyzed the difference in surgical time for unilateral and bilateral repair separately, unilateral repair remained non-significantly different between groups (MD 2.04, 95% CI −5.24 to 9.33, $p=0.58$); however, with bilateral repair, LR took on average 9 fewer minutes to perform compared to OR (MD 9.09, 95% CI 4.10 to 14.07, $p=0.0004$) (Fig. 2).

In addition to the above data, six studies also reported on either pain experienced, analgesic doses required, or both [25, 28], but the data were not suitable for MA (Table 2). Celebi et al. determined that LR of inguinal hernia resulted in a lower postoperative pain score in the first hour using the visual analog scale (OR 6.78, LR 3.88; $p<0.05$) [25]. Three other studies assessed pain using subjective methods such as CHIPPS [30] and CHEOPS [31], OPS [32], verbal response scores, or rating systems of mild, moderate, and severe [21, 24, 28]. Similarly, Chan et al. found that patients undergoing LR required significantly less acetaminophen post-operatively than those undergoing OR ($p=0.032$) [26]. Conversely, Koivusalo et al. determined that LR patients required more postoperative rescue analgesia than OR patients, and had significantly higher OPS 2 days post-operatively ($p<0.05$) [28]. No other studies found significant differences for either pain scores or analgesia doses between OR and LR (Table 2).

Finally, eight studies recorded either scar visibility, cosmetic satisfaction, or both (Amano et al.) [9, 11, 13, 15, 21, 25–29]. When assessing scar visibility, only Amano et al. provided a scale [9]. Two studies (Jun et al. and Shalaby et al.) used the term "ugly scar" to describe defects in patients, with one (Shalaby et al.) finding significantly better scar healing after LR ($p=0.024$) [13, 29]. Three studies found LR to be superior in providing better overall cosmetic results ($p<0.05$; $p=0.000$; OR 100% good cosmesis, LR 100% excellent cosmesis) [21, 25, 26], while two found no significant difference ($p=0.11$ in unilateral repair; $p=$ ns) [27, 28] (Table 3). Three other studies described the cosmetic results despite not having a formal ranking system or

Table 1 Characteristics of studies included in systematic review and meta-analysis

Study (year, country)	Study design	*N* (m, f)	Age at surgery	Follow-up	Surgical details	Quality
Randomized controlled trials						RoB
Celebi et al. (2014, Turkey) [25]	RCT, single-blinded	OR (32, 0) LR (30, 0)	OR—7.83 ± 1.58 years, range 6–14 years) LR—8.24 ± 2.60 years, range 6–13 years)	3 months–2 years	OR—standard high ligation LR—closure of the hernial defect by closing periorificial peritoneum with purse-string suture at level of the internal ring with 3/0 nonabsorbable suture	5 low 3 unclear
Chan et al. (2005, Hong Kong) [26]	RCT, single-blinded	OR (33, 9) LR (34, 7)	OR—46 ± 34.2 months LR—56 ± 45.67 months	OR—11.79 ± 2.55 months LR—12.21 ± 2.83 months	OR—standard high ligation, modification was made on double-ligation of the proximal end of the sac without it being twisted LR—purse-string stitch placed around internal inguinal ring	6 low 1 high 1 unclear
Gause et al. (2017, USA) [27]	RCT, single-blinded	OR (12, 3) LR (19, 7)	OR—*Uni*—199.8 (139.74 SD), *Bi*—93.2 (66.66 SD) days LR—*Uni*—376.29 (225.15 SD), *Bi*—288.67 (335.56 SD) days	2 years (2.7 SD)	OR—standard high ligation LR—was performed via subcutaneous endoscopically assisted ligation of the internal ring (SEAL technique)	4 low 2 high 2 unclear
Koivusalo et al. (2009, Finland) [28]	RCT, single-blinded	OR (30, 12) LR (36, 11)	OR—6.1 years (median), range 1.6-15 years LR—6.0 years (median), range 0.65–15 years	6 months–2 years	OR—standard high ligation LR—internal inguinal orifice was closed using unabsorbable suture (Ti-Cron)	5 low 1 high 3 unclear
Shalaby et al. (2012, Egypt) [29]	RCT, non-blinded	OR (92, 33) LR (38, 87)	OR—50 1–12 months, 55 12–24 months, 20 > 24 months LR—58 1–12 months, 45 12–24 months, 22 > 24 months	24 months (mean), range 16–30 months	OR—standard high ligation LR—purse-string stitch around internal inguinal ring	5 low 1 high 3 unclear
Non-randomized studies—comparative						MINORS
Amano et al. (2017, Japan) [9]	Retrospective cohort	OR (632, 363) LR (488, 545)	OR—48.8 ± 36.0 months LR—49.0 ± 36.2 months	OR—49.3 ± 50.5 months LR—29.1 ± 24.3 months	OR—standard high ligation LR—SILPEC, using the LPEC needle, the hernial sac was closed extraperitoneally with circuit suturing around the internal inguinal ring. The circuit suturing was tied extracorporeally, and the hernial sac was completely closed. Double ligation was introduced for cases over 5 years old and cases with hydrocele since July 2012	17

Table 1 (continued)

Study (year, country)	Study design	*N* (m, f)	Age at surgery	Follow-up	Surgical details	Quality
Antao et al. (2004, UK) [10]	Mixed retrospective and prospective review	OR (169, 26) LR (37, 7)	OR—37 ± 3 days (< 32 weeks GA), 49 ± 5 days (> 32 weeks GA) LR—35 ± 3 days (< 32 weeks GA), 74 ± 4 days (> 32 weeks GA)	OR—37 ± 23 months LR—7 ± 4 months	OR—standard high ligation LR—purse string suture closed the internal ring	16
Endo et al. (2009, Japan) [11]	Retrospective case series	OR (226, 82) LR (694, 563)	OR—3.7 ± 3.2 years, range 1 month-22 years) LR—3.8 ± 2.9 years, range 1 month-24 years)	1–11 years	OR—standard high ligation LR—2–0 suture achieving completely extraperitoneal ligation of the ring. For infants younger than aged 1 year 6 months, the IIR was closed with double ligation	17
Hassan et al. (2007, UAE) [12]	Retrospective cohort	OR (18, 0) LR (15, 0)	OR—44 months (mean) LR—39 months (mean)	3 months	OR—standard high ligation LR—flip-flap technique, an incision over the peritoneum alongside the anterior and lateral edge of the hernia entry side was made; a peritoneal flap big enough to cover the hernia opening was raised. The anterior and lateral half circumference of the sac was detached from the surrounding soft tissue and the opening of the hernia sac spontaneously collapsed. The peritoneal flap was flipped medially and anchored with the stitch. The suture was tied intracorporeally	12
Jun et al. (2016, China) [13]	Retrospective review	OR (20, 22) LRS (27, 21) LRT (21, 15)	OR—2 years (median), range 1 month-3.5 years LRS—1.9 years (median), range 2 months-4 years LRT—1.8 years (median), range 1 month–4 years	3–9 months	OR—standard high ligation LRS—single-port repair LRT—trans-umbilical conventional two-port laparoscopic repair	16
Koivusalo et al. (2007, Finland) [14]	Retrospective review	OR (14, 1) LR (17, 1)	OR—9.1 months (median), range 1–61.1 months LR—15.1 months (median), range 1–81.1 months	26 months (median), range 4-49 months	OR—standard high ligation LR—inner orifice of the inguinal canal was closed with one or two purse-string stitches	17

Table 1 (continued)

Study (year, country)	Study design	*N* (m, f)	Age at surgery	Follow-up	Surgical details	Quality
Da Lin et al. (2011, Taiwan) [15]	Retrospective review	OR (25, 6) LR (20, 4)	OR—5.39 ± 4.11 months LR—7.17 ± 4.21 months	OR—20.2 ± 10.5 months LR—22.9 ± 10.5 months	OR—standard high ligation LR—mini Laparoscopic technique, the procedure is carried out using 3 trocar ports of 3 mm. The peritoneal defect is closed using an intracorporeal suture technique	16
Mishra et al. (2014, UK) [16]	Retrospective review	OR (40, 5) LR (24, 3)	nr	OR—4 weeks–2 years LR—4 weeks–3 years	OR—standard high ligation, 13/45 had hernioscopy performed LR—hernia orifice was closed with purse-string polypropylene 4/0 suture on a round body needle in patients under 3 years and 3/0 suture if the child was older than 3 years	15
Nah et al. (2011, UK) [17]	Retrospective review	OR (31, 4) LR (23, 5)	OR—5.39 ± 4.11 months LR—3.1 months (median), range 0.7–39.8 months	OR—4 months (median), range 1-36 months LR—3 months (median), range 2-24 months	OR—standard high ligation LR—open internal ring on the same side of the hernia is closed with a purse-string or Z-type suture	15
Niyogi et al. (2010, UK) [18]	Retrospective review	OR 164 LR 58	12% of the patients were neonates, 57% were infants under 1 year	8 months (median), range 6 weeks–1 year)	OR—standard high ligation, 77 had OR with hernioscopic evaluation of the contralateral side, 164 had OR with no contralateral exploration LR—conventional two-port laparoscopic repair	15
Saha et al. (2013, Bangladesh) [19]	Prospective series	OR (28, 4) LR (26, 4)	OR—6.63 ± 2.67 months LR—5.92 ± 2.11 months	OR—22.5 ± 10.5 months LR—24.5 ± 10.5 months	OR—standard high ligation LR—conventional two-port laparoscopic repair	17

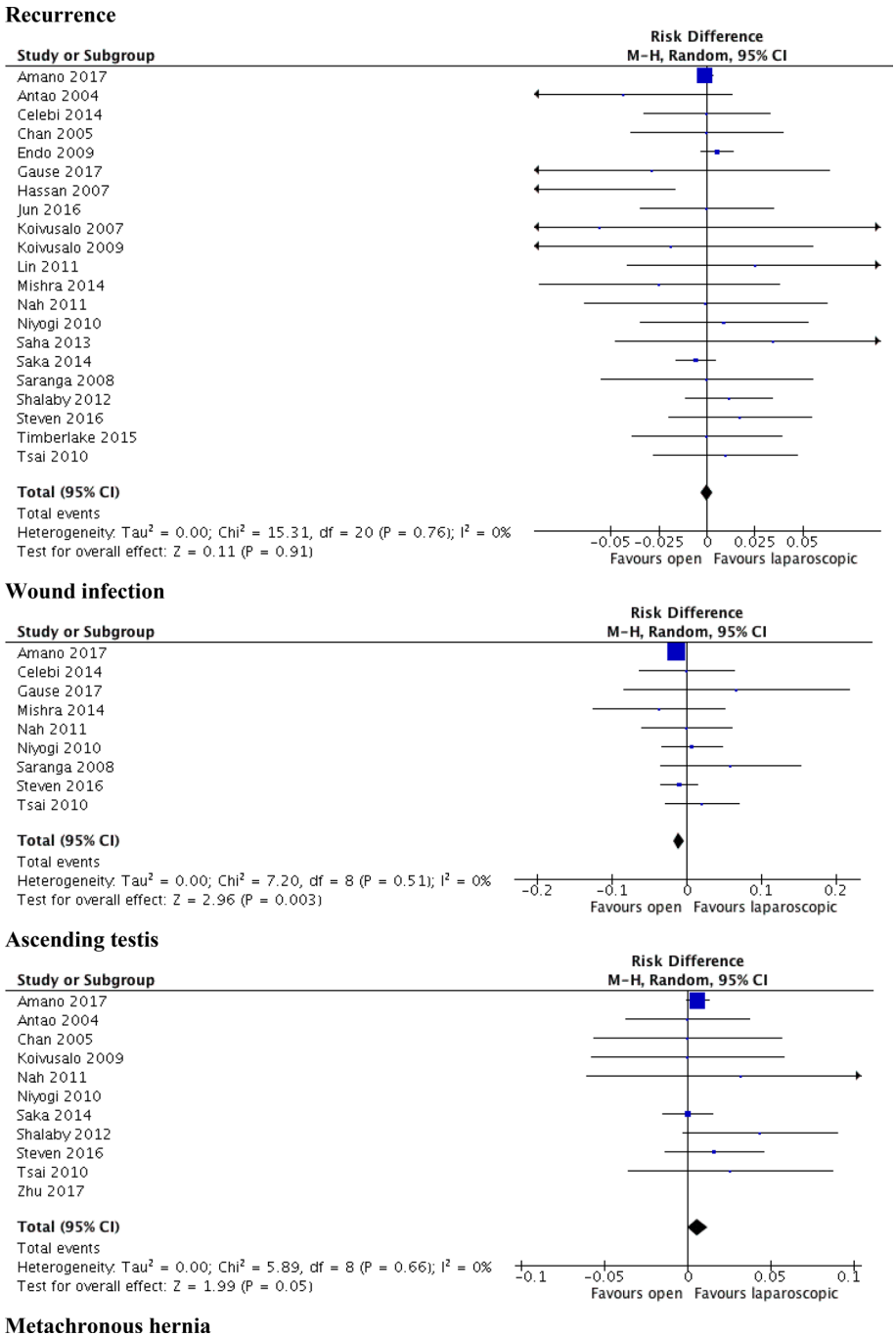
Table 1 (continued)

Study (year, country)	Study design	*N* (m, f)	Age at surgery	Follow-up	Surgical details	Quality
Saka et al. (2014, Japan) [20]	Retrospective review	OR (140, 22) LR (125, 201)	OR—38.3 ± 39.1 months LR—55.8 ± 38.6 months	1 month	OR—standard high ligation LR—the extraperitoneal circuit suturing of the internal ring was performed with a 19-gauge LPEC needle, we used 2-0 nonabsorbable suture material. If the wall of the hydrocele was confirmed laparoscopically, it was treated electrically with a grasping forceps, and if it was not, the hydrocele was punctured from the scrotum. A rectus sheath block was performed at the end of the laparoscopic procedure to relieve the postoperative pain of the umbilicus	15
Saranga et al. (2008, India) [21]	Prospective series	OR (32, 2) LR (30, 5)	OR—3.14 ± 0.92 years LR—5.58 ± 3.52 years	3.5 months (mean)	OR—standard high ligation LR—internal ring was obliterated by Z-suture purse string suture	17
Steven et al. (2016, UK) [22]	Retrospective review	OR (126, 25) LR (80, 23)	OR—0.52 years (median), range 0.04–13.47 years LR—0.56 years (median), range 0.04–14.7 years	Unclear	OR—standard high ligation LR—simple purse string technique	14
Timberlake et al. (2015, USA) [23]	Retrospective review	OR (36, 2) LR (34, 4)	OR—23 months (median), range 1–92 months LR—21.5 months (median), range 2–103 months	OR—47 days (median), range 21–146 days LR—51 days (median), range 37–113 days	OR—standard high ligation LR—a 1–2 mm stab incision is made over the ipsilateral internal inguinal ring. The needle is manipulated externally. No intracorporeal suturing is necessary	15
Tsai et al. (2010, Taiwan) [24]	Prospective series	OR (39, 10) LR (75, 15)	OR—4.9 years (mean) LR—5.4 years (mean)	OR—24.3 months (mean) LR—21.2 months (mean)	OR—standard high ligation LR—peritoneum defect of the internal ring was closed with 3–0 Vicryl sutures using an intracorporeal suture technique	18

Summary of study design, number of participants with sex differentiation, age at surgery, length of follow-up, surgical details, and quality rating for each study

N number of participants, *m* males, *f* females, *RCT* randomized controlled trial, *OR* open repair; *LR* laparoscopic repair, *RoB* 'Risk of bias', *SD* standard deviation, *LRS* single-port laparoscopic repair, *LRT* two-port laparoscopic repair, *nr* not recorded

Fig. 2 Forest plots

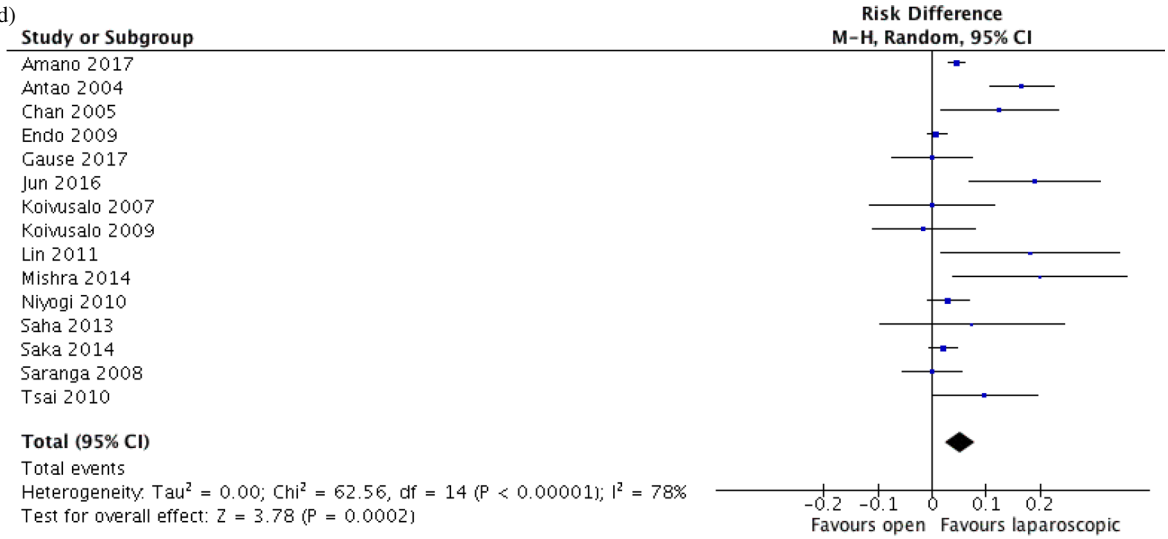


numerical data, indicating that the patients who underwent laparoscopic repair were very satisfied with the repair [11, 15, 29].

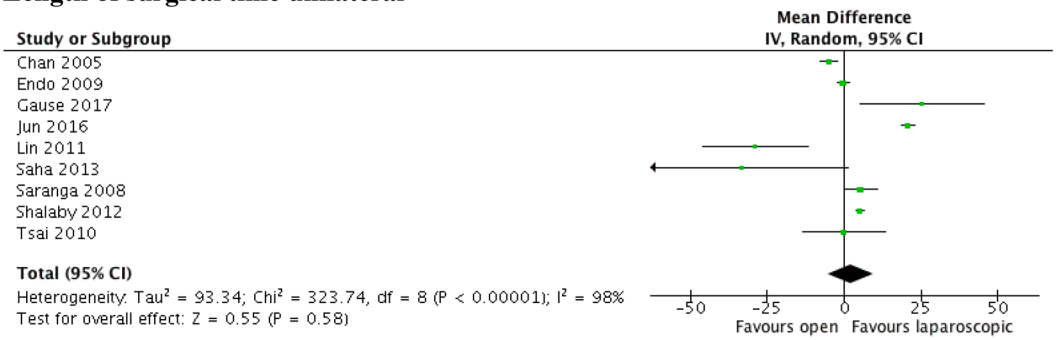
Discussion

As inguinal hernia repair is one of the most common operations performed on children [4, 33], we examined the current literature to provide pediatric surgeons with a more conclusive understanding of the risks and benefits associated with both methods of repair, and to assess whether either approach could result in superior outcomes. To our knowledge, our review encompasses all relevant scientific papers comparing laparoscopic and open repair of PIH.

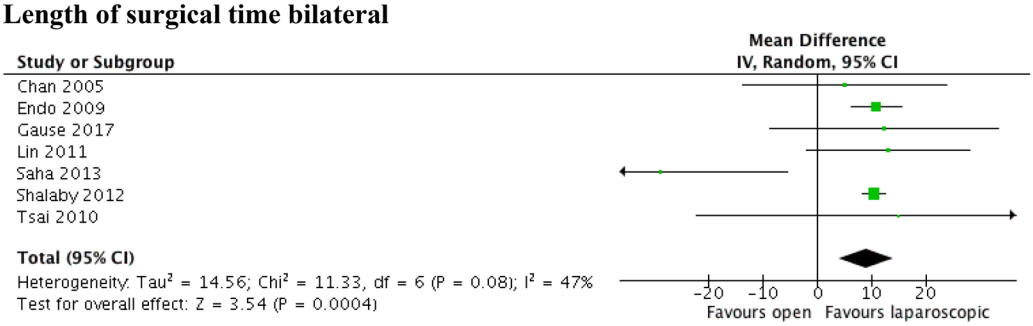
Fig. 2 (continued)



Length of surgical time unilateral



Length of surgical time bilateral



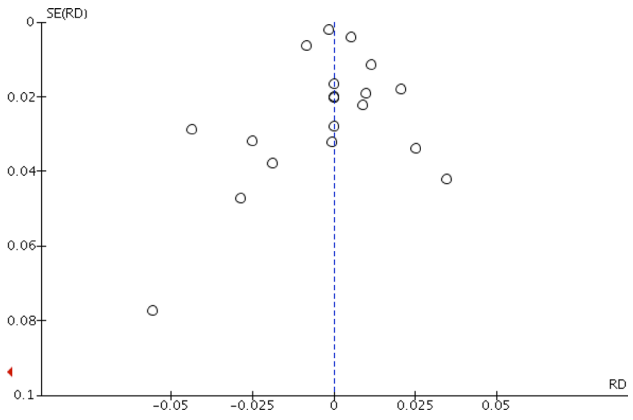


Fig. 3 Funnel plot (recurrence)

Summary of findings and relation to the current literature

Recurrence

A concern among surgeons surrounds the rate of recurrence after PIH repair. We found there to be no significant difference between OR and LR in terms of hernia recurrence on the initially affected side, reinforcing the findings and opinions of existing literature in adult populations [34, 35]. In the OR and LR groups, the ranges of recurrence were approximately 0–6.3% and 0–5.7%, respectively, excluding the study by Hassan et al. that found an outlying recurrence rate of 26.7% in the LR group [12]. The variation may be

Table 2 Concise findings of pain and dosage differences experienced by patients undergoing both open and laparoscopic herniotomy, as reported by each study

Study	Scale used	Open herniotomy		Laparoscopic herniotomy	
		n	Value	*n*	Value
Pain experienced					
Celebi et al. [25]	Visual analog scale 0 = no distress, 10 = unbearable distress mean ± SD	31	6.78 ± 3.2 at 1 h post-op	28	3.88 ± 2.39 1 h post-op
Saranga Bharathi et al. [21]	Nil, mild, and moderate pain scores using CHIPPS and CHEOPS *n* (%)	34	Nil: 0 Mild: 32 (94.1%) Moderate: 2 (5.9%)	35	Nil: 2 (5.7%) Mild: 30 (85.7%) Moderate: 3 (8.6%)
Niyogi et al. [18]	The authors mentioned that one patient had chronic pain after hernioscopy, but that laparoscopic repair had the potential to reduce pain and improve cosmesis although it was not quantitatively analyzed in this study				
Tsai et al. [24]	Chronic wound pain: intermittent or persistent pain lasting more than 6 months *n* (%)	49	1/49 (2%)	90	1/90 (1%)
Analgesic dosages required					
Celebi et al. [25]	Dosages of morphine requested (10 μg/kg/10 min) Median ± SD	31	12.5 ± 10.2	28	8.8 ± 6.6
Chan et al. [26]	Acetaminophen dose/patient based on CHIPPS and CHEOPS (15 mg/kg/dose) Mean ± SD	42	1.05 ± 1.2 doses/patient	41	0.54 ± 0.84 doses/patient
Gause et al. [27]	FLACC scale used to determine total acetaminophen dosages given in unilateral IH (15 mg/kg/dose) Mean ± SD	[a]	9 ± 9.68	[a]	5.3 ± 2.93
Koivusalo et al. [28]	Patients requiring post-operative rescue analgesia (1 μg/kg fentanyl) *n* (%)	42	20/42 (48%)	47	37/47 (79%)

[a]31/41 patients had completed pain medication data. Gause et al. did not distinguish which of these patients received OR versus LR

attributed to modified surgical techniques, as well as surgical experience and heterogeneous patient populations [36]. For example, Antao et al. conceded that their relatively high recurrence rate may be due to patient factors such as chronic lung disease and that increased intraabdominal pressure may have disrupted the closed internal ring. He proposed a two-layered purse string suture or overlapping Z-stitch to overcome this [10]. Additionally, the studies differed in their follow-up time. Grosfeld et al. determined that only 50% of recurrences develop within the first six months post-op, with 96% occurring in the first 5 years [37]. Of the studies included, the average follow-up was < 2 years, with significant variation between studies (Table 1).

Though both techniques proved similarly efficacious in terms of rates of recurrence, LR was deemed to be superior in the detection of contralateral patent processus vaginalis (cPPV), and thus also the prevention of metachronous contralateral inguinal hernia (MCIH). The percentage of patients developing MCIH was 5.9% in the OR group, which is similar to the review by Ron et al. reporting a 7.2% risk after OR [38]. With laparoscopic surgery the rate is essentially 0%, as surgeons can detect and repair any contralateral patency during the same procedure, without the need for additional access or anesthesia [9, 15, 26, 39–41].

Operative time

There were no significant differences between the two approaches for unilateral repair, although it was observed that LR led to an appreciably shorter operative time for bilateral repair. Feliu et al. has suggested that this is due in part to the ability of LR to facilitate bilateral repair from a single access point, whereas OR requires repeating the same procedure with two individual incisions [42].

Length of hospitalization

Overall, the length of admission did not significantly different between LR and OR. This logically follows our finding that overall neither pain nor intra-/post-operative complications significantly differed between the two techniques.

Table 3 Overall cosmesis and scar visibility determined by parents and hospital staff after inguinal hernia repair by either open or laparoscopic herniotomy, as reported by each study

Study	Scale used	Open herniotomy		Laparoscopic herniotomy	
		n	Value	*n*	Value
Scar visibility					
Amano et al. [9]	1 = well visible, 5 = not visible at all mean ± SD	490	4.7 ± 0.6	605	4.9 ± 0.5
Jun et al. [13]	"Ugly scar" *n* (%)	42	3/42 (7.1%)	84	0/84 (0%)
Shalaby et al. [29]	"Ugly scar" *n* (%)	125	5/125 (4%)	125	0/125 (0%)
Overall cosmetic satisfaction					
Amano et al. [9]	1 = not satisfied, 5 = very satisfied Mean ± SD	490	4.8 ± 0.5	605	4.8 ± 0.5
Celebi et al. [25]	100 = excellent, 90 = very good, 80 = good, 70 = fair Mean ± SD	31	78 ± 6.7	28	89 ± 4.23
Chan et al. [26]	100 = excellent, 90 = very good, 80 = good, 70 = fair Mean ± SD	42	84.3 ± 7.7	41	97.6 ± 5.4
Endo et al. [11]	The authors qualitatively mentioned that cosmetic results were excellent in the laparoscopic group				
Gause et al. [27]	1 = not satisfied, 5 = very satisfied in unilateral IH Mean ± SD	[a]	4.44 ± 0.82	[a]	4.86 ± 0.36
Koivusalo et al. [28]	Unsatisfactory = 0, satisfactory = 1, good = 2, excellent = 3 measured by 3 individuals (total = 9) 2 years post-op median (range)	42	9 (5–9)	47	7 (5–9)
Da Lin et al. [15]	It was stated that cosmetic results from laparoscopic repair were satisfactory to the parents				
Saranga Bharathi et al. [21]	"Excellent", "good" compared to preoperatively *n* (%)	34	Excellent: 0 Good: 34 (100%)	35	Excellent: 35 (100%) Good: 0
Shalaby et al. [29]	It was reported that overall early cosmetic results for bilateral cases was excellent in both open repair and laparoscopic repair, and additionally all parents were satisfied with the cosmetic results in the laparoscopic group				

[a]31/41 patients had completed post-operative cosmetic data. Gause et al. did not distinguish which of these patients received OR versus LR

Complications

Our analysis of complications arising from surgery mirrors the current debate among surgeons, as nearly all included studies demonstrated that both LR and OR resulted in similar rates of injury. Specifically, rates of bleeding, testicular atrophy, and hydrocele were noted to be similar between OR and LR. Although the literature conflicts on which technique provides fewer adverse outcomes, overall there is agreement that increased surgical experience is believed to mitigate the risk of complications from either procedure [43]. Ascension of the testis was found in our MA to occur less frequently in patients who underwent LR, although most papers individually reported that there were similar incidences of injury or no significant difference between LR and OR with regards to this outcome.

When discussing wound infection, the included papers provided sparse details with regard to the location of the infected port or incision and subsequent treatment. Saranga Bharathi et al. mentioned erythemas which were treated with oral antibiotics, suggesting wound infections in two patients who had received OR [21], and Amano et al. indicated that patients receiving laparoscopic repair required oral antibiotics for infections at the umbilicus [9]. Gause et al. saw only a single patient who had undergone OR receiving oral antibiotics [27], and Tsai et al. reported that a single patient in the OR group required medical treatment for a wound infection, but there was no elaboration on the nature of this treatment [24]. Other studies included in the MA that reported infections did not specify the intervention or location of the infection [18, 22].

Surprisingly, we found that patients undergoing LR experienced higher rates of wound infection than OR patients. This contradicts the expectation that minimally invasive procedures, on average, decrease the risk of surgical site infection [44, 45], and also counters the argument that the higher incision from LR may be in a more sterile environment as it is above the diaper [39, 46]. Of the papers reporting wound infection and included in our MA, only one of nine used a single-incision laparoscopic percutaneous extraperitoneal closure (SILPEC), which was also the only paper that reported a significantly higher infection rate for LR, treated with oral antibiotics [9]. Seven of the other studies used a three port approach with instruments of either 3 or 5 mm and one study used a single-incision SEAL technique. These did not demonstrate significant difference in infection rates

[16–18, 21, 22, 24, 25, 27]. SILPEC was a novel procedure being studied by the investigators to determine safety and feasibility, so it is possible that a lack of experience could have contributed to the elevated infection rate. Additionally, the authors mentioned that although the umbilicus was routinely cleaned before the procedure, the blot may have hindered sterility, and thus skewed the results of our MA. Despite reaching statistical significance, the overall low infection rate makes it difficult to determine whether this represents a clinically significant difference in wound infection rates between OR and LR [9].

Subjective outcomes

While we assessed pain and cosmesis data, we were not able to perform MAs due to the nature of the data reported (e.g., most studies reported medians rather than means). As the experience of pain is subjective and no consistent scale was used, we were unable to conclude whether LR reduced postoperative pain, as reported by Celebi et al. and Chan et al., or increased postoperative pain, as reported by Koivusalo et al. [25, 26, 28]. Other studies considered differences to be insignificant, but this may have resulted from small sample sizes [18, 21, 24, 27]. Additional standardized data from RCTs would help to elucidate whether there is a difference in pain between surgical approaches, despite the assumption that LR confers less pain during recovery [34, 40]. Concerning cosmesis and scar visibility, LR was found to have better wound healing after the procedure [11, 13, 21, 25, 26, 29, 47], although any visible scarring is above the underwear or diaper line, whereas the incision from OR is in a more discrete location [46].

Limitations and future directions

Though this MA includes a substantial number of patients, only five of the 21 studies included were RCTs, and not all included studies reported on all factors included in our MA. There could also be confounding variables involved, such as varying operative techniques and surgeon experience, which could have skewed each study's results. In addition, patients were not followed up indefinitely, meaning rates of recurrence could have theoretically been underestimated for both techniques. More robust RCTs with larger sample sizes and longer follow-up could either reinforce a lack of clinically significant differences between OR and LR for treating PIH, or yield further results pointing to one option as the optimal choice. Despite these limitations, this is the most up-to-date SR and MA on this topic. Although other reviews assessing LR and OR exist, many are limited by the available literature [5, 39, 40, 42], and since the publication of the most recent systematic review concerning this topic is from 2014 [39], more relevant papers have been published, including RCTs, which have been included here.

Conclusion

This SR and MA have provided further insight into the optimal surgical technique for treating PIH. Importantly, it showed that both LR and OR have similar rates of recurrence, and varied only slightly between various clinical outcomes. Specifically, it was shown that LR can shorten operative time for bilateral repair, reduce the chances of testicular ascent, and most likely also yield superior aesthetic results. On the other hand, OR appeared to reduce the chances of wound infection, though most papers showed insignificant differences in this regard, with one study's results skewing the rest. Our review reinforced the advantage conferred by LR, which is the ability to detect and simultaneously repair cPPV, reducing the chances of a contralateral hernia in the future. Overall, this paper reinforces that either technique is appropriate in clinical use. In closing, both LR and OR offer safe and effective options in treating PIH, and the decision of which to utilize should come out of a shared decision-making process between both the patient's parents and their surgeon.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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