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Review

Contralateral processus closure to prevent metachronous inguinal hernia: A systematic review

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ABSTRACT

Background: Inguinal hernia repair is one of the most frequent operations in pediatric surgery and is increasingly performed laparoscopically. The latter introduced new momentum in the debate on the necessity of contralateral exploration, as the rates of contralateral patent processus vaginales and metachronous inguinal hernias determine whether a routine closure would be overtreatment or useful prevention.

Materials and methods: We searched MEDLINE via PubMed, Web of Science and Scopus at the 6th of September 2017; reference lists and CrossRef were snowballed for reports citing identified studies. Eligibility criteria were age < 18 years, preoperative diagnosis of unilateral hernia, laparoscopic evaluation, and publication since January 2012. Studies using hernioscopy (transinguinal laparoscopy) were excluded. We reported our systematic review following PRISMA criteria.

Results: We included 32 reports consisting of 19,188 pediatric patients diagnosed with unilateral inguinal hernia. Of these, 38.5% (95% confidence interval: 34%–43.1%) had a contralateral open processus vaginalis concomitantly found during laparoscopic inguinal hernia repair. A secondary analysis using nine studies that compared open and laparoscopic approaches found that prophylactic closure of contralateral patent processus vaginales resulted in a risk difference of 5.7% (95% confidence interval: 3.6%–7.7%; $P < 0.001$) following 2691 (42.8%) procedures (nine studies: Ten of 6282 patients operated laparoscopically had a metachronous hernia, versus 286 of 5764 with open hernia repair).

Conclusions: Prophylactic closure of a contralateral patent processus vaginalis reduces the number of metachronous inguinal hernias, but about 18 procedures must be performed to prevent one metachronous inguinal hernia, indicating that the indication should be based on personal circumstances of the patient.

1. Introduction

Indirect inguinal hernia repairs are one of the most frequent operations performed by pediatric surgeons [1]. For the last two decades, laparoscopic inguinal hernia repair has become increasingly popular in many centers, among other reasons because it allows the surgeon to inspect the contralateral side for a patent processus vaginalis that may then be prophylactically closed. Consequently, a wide spectrum of laparoscopic techniques for indirect inguinal hernias has been described [2]. Since the last systematic review on this issue only included studies published before 2012 [3], and laparoscopic inguinal hernia repair has become more prevalent in recent years, we performed a new systematic review and meta-analysis on the above questions based on the pertinent literature published since 2012. While the previous systematic review and meta-analysis characterizes simultaneous closure of the contralateral PPV as overtreatment [3], other authors of narrative reviews find it justified [4]. Considering this dichotomy, we feel that a reappraisal of the current literature in a new systematic review is in timely order.

The primary objective of our study was to calculate the relative risk of developing a contralateral metachronous hernia depending on closure of an incidentally discovered patent processus vaginalis peritonei during laparoscopic inguinal hernia repair in children, based on the most recent literature. Secondary goals were to describe the current reported methods of inguinal hernia repair and the overall incidence of an open contralateral processus peritonei.

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2. Materials and Methods

2.1. Search strategy and literature selection

We conducted a systematic literature search in MEDLINE via the PubMed interface, the Web of Science, and Scopus database, using the search strategy laid out in the appendix, at the 6th of September 2017. The systematic review was performed according to PRISMA criteria. Only studies published in English were included.

The results were exported to JabRef 3.8.2 (http://www.jabref.org). The records were screened for eligibility by title in a first step; this included an assessment of publication date and implementation of the restriction that the study had to be published since the 1st of January 2012, followed by screening of the abstracts in a second step. One researcher assessed the search results and extracted data from the included reports. The entire process and its results were reviewed by a second researcher for consistency to ensure an adequate quality control of the results. Deviations in the assessment of the studies did not occur.

2.2. Inclusion criteria, study population, and endpoints

Study participants were defined as children with the preoperative diagnosis of a unilateral inguinal hernia. Prerequisite for inclusion was the evaluation of the contralateral side by laparoscopy in the laparoscopy group. Studies using hernioscopy (laparoscopy through the contralateral hernia sac) were excluded. Primary outcome was the proportion of children diagnosed with a contralateral open processus vaginalis during unilateral inguinal hernia repair. The numbers presented by the authors were double-checked in the same way: If the study population was not inherently limited to unilateral hernia, we subtracted all preoperatively diagnosed unilateral inguinal hernias from the study population to achieve the correct population as a denominator. This population was the basis the percentage of contralateral patent processus vaginales relate to.

The included reports were assessed for a control group treated by conventional open inguinal hernia repair. If a control group was present, it was eligible for the calculation of the secondary endpoint: Absolute risk reduction for a metachronous inguinal hernia in cohorts with prophylactic closure of a contralateral patent processus vaginalis compared to a cohort who received an open inguinal hernia repair.

In the case of overlapping cohorts, the larger one was included. A deviation from this preplanned decision-scheme was necessary to include another study in the secondary analysis of metachronous inguinal hernias as only the excluded smaller cohort of the same group consisted of a control group treated by open hernia repair [5].

2.3. Assessment of bias and heterogeneity

Bias was assessed using the quality assessment tool for quantitative studies [6] (Thomas' tool in the assessment of quality assessment tools by *Deeks* et al. [7]). All included studies were rated weak. For retrospective studies quality assessment included an assessment of the ten major methodological aspects described by *Vassar & Holzmann* [8].

While 23 studies were retrospective chart reviews, eight were prospectively conducted observational studies [9–15], and one study design remained unclear [16]. Only eight studies provided a definition of a contralateral patent processus vaginalis [9,14,17–22] and none of the retrospective studies specified a pathway of patient identification and inclusion. Measures of quality control, e.g. structured training of the chart abstractors, a regularly monitoring or an implemented double-checking by a second investigator were assessed in the retrospective chart reviews.

Bias on the outcome level was objectified. Some reports used the terminology of a hernia and a contralateral patent processus vaginalis interchangeably [10,11,13,16,23]. Only one study [24] reported a median follow-up, whereas the majority of studies reported the mean follow-up [5,25–28]. Only a range without a measure of centrality of follow-up could be found in two studies [29,30] and one report did not report on follow-up at all [31]. Another source of bias in follow-up might be introduced by longer periods of follow-up in groups operated via the open approach, which was present in three reports [5,26,27]. These factors were accounted for in the analysis.

The source studies were assessed descriptively for potential heterogeneity and for publication bias using Egger's test as recommended elsewhere [32]. It was calculated using R [33] (version 3.5.1) with the metafor-package [34] (version 2.0) as was the corresponding Funnel plot.

2.4. Data synthesis

Data were synthesized using OpenMeta-Analyst [35]. We used the Random-Effects Model 'Restricted Maximum Likelihood' in light of the heterogeneity between the studies ($I^2 = 98\%$; $P < 0.001$ for the synthesis of the rates of a contralateral patent processus vaginalis and $I^2 = 88\%$; $P < 0.001$ for the calculation of an absolute risk reduction between prophylactic closure of a contralateral patent processus vaginalis during laparoscopic inguinal hernia repair compared to conventional open repair) as suggested elsewhere [36]. Using the absolute risk reduction by a prophylactic closure of the contralateral patent processus vaginalis was the appropriate measure due to the already low baseline rate of metachronous inguinal hernias following an open inguinal hernia repair and a relative difference would exaggerate the effect. The number of interventions necessary to prevent one metachronous inguinal hernia was calculated for descriptive purposes. This measure was calculated by dividing the number of closed contralateral patent processus vaginales by all cases in the laparoscopy group in a first step. In the second step, number of metachronous inguinal hernias in the unilateral open repair group was divided by all cases in the open repair group. The final step then was to divide the result the first step by that of the second. This descriptive method has been used by the largest study in our meta-analysis, too [25].

This study was reported in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses [68]) and AMSTAR (Assessing the methodological quality of systematic reviews [69]) Guidelines.

3. Results

The systematic literature search identified 634 records, of which 324 were duplicates, and 100 had been published since the 1st January 2012. Following title screening, 60 were left for abstract screening and 49 reports were subject to full-text evaluation. Subsequently, 35 studies were included and used for data synthesis with the exception of three studies [42–44] which evaluated contralateral patent processus vaginales in conditions other than pediatric inguinal hernias (Fig. 1). The 32 studies reported on 19,188 patients who had a unilateral pediatric hernia repaired by laparoscopy (Table 1). A contralateral patent processus vaginalis was found in 8292 patients: Thus, the percentage of children diagnosed with a contralateral patent processus vaginalis was 38.5% (95% confidence interval: 34–43.1%) (Fig. 2). In contrast, the three studies evaluating the presence of an open processus vaginalis in the absence of an inguinal hernia found an open processus vaginalis in around the half of this number, with the exception of a small study dealing with infants operated for hypertrophic pyloric stenosis (Table 2) [25].

Based on the studies identified for the primary outcome, those with a control group operated by the open approach were eligible to calculate the secondary outcome of the absolute risk reduction by prophylactic closure of a contralateral patent processus vaginalis. Nine studies were included in this secondary analysis with 6282 patients treated by laparoscopy and 5764 operated in a conventional open approach. In the open group (without contralateral open processus closure), 286

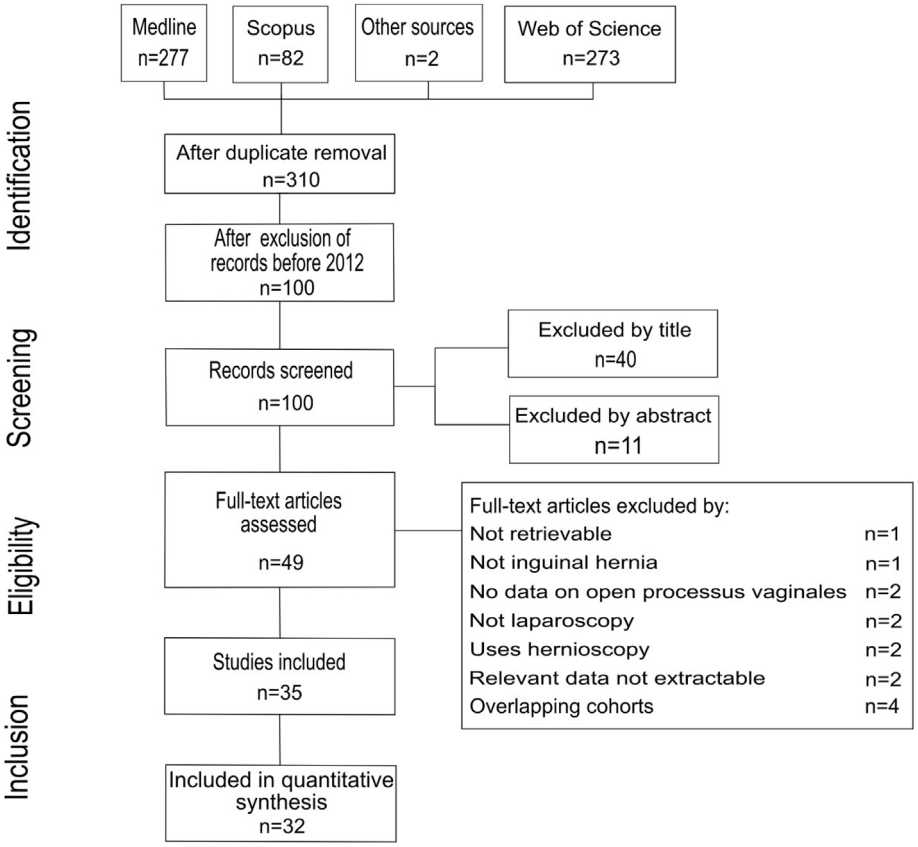

Fig. 1. PRISMA flow diagram of the literature identification and selection process.

metachronous inguinal hernias occurred, whereas ten were to be found in the laparoscopic group despite 2691 (42.8%) prophylactic closures of a contralateral patent processus vaginalis (Table 3). Prophylactic closure of a contralateral patent processus vaginalis achieved an absolute risk reduction of 5.7% (95% confidence interval: 3.6–7.7%; $P < 0.001$) starting from a calculated baseline risk of 5.96% (95% confidence interval: 3.9–8%) (Fig. 3).

The source studies were found to exhibit a degree of heterogeneity in terms of design (retrospective versus prospective), outcome definition, reported length of follow-up. Egger's test in the mixed-effects version and corresponding Funnel plots neither revealed publication bias for the percentage of contralateral patent processus vaginales ($z = -0.023$; $P = 0.98$) (Fig. 4A) nor for the absolute risk difference between the laparoscopically operated and the group with an open repair ($z = -1.559$; $P = 0.119$) (Fig. 4B).

4. Discussion

Laparoscopic pediatric inguinal hernia repair was introduced by *Schier,* who also introduced the concept of simultaneous closure of an open processus vaginalis [45]. Traditionally, our staff performs nearly all pediatric inguinal hernias laparoscopically and closes contralateral patent processus vaginales if present.

In an effort to critically reflect upon our standard operating procedures, we aimed to investigate whether a contralateral patent processus vaginalis is diagnosed more often than in earlier studies conducted up to 2011 that have been included in a previously published meta-analysis and was 30% (95% confidence interval: 26–34%) [3]. Despite the relatively long history of pediatric inguinal hernia repair, the open approach is still favored by 83% of the respondents in a recent survey, of which 79% routinely perform unilateral inguinal hernia repair without contralateral exploration [46]. General surgeons who provide surgical care to children also favor the open approach [47,48]. To judge the potential merits of a prophylactic closure of a contralateral patent processus vaginalis, it is necessary to consider risks and benefits: In particular the absolute risk reduction in comparison to patients operated by the traditional open approach.

According to our findings, the pooled prevalence of a contralateral patent processus was 38.5% with a 95% confidence interval between 34% and 43.1%. It exceeded those calculated for transabdominal laparoscopic evaluation in a previous meta-analysis by 7% (31%, 95% confidence interval: 26–37%) [3]. Compared to the results of a transinguinal laparoscopic evaluation presented there (27%, 95% confidence interval: 23–32%) [3], even the 95% confidence intervals did not overlap anymore, suggesting a higher sensitivity of transabdominal laparoscopy if a similar prevalence of a contralateral patent processus vaginalis would be assumed. Of note, the results of *Kokorowski* et al. were largely hampered by high heterogeneity between studies.

In order to assess possible sources of heterogeneity in our data, we tested whether heterogeneity would be reduced if we only included those studies that provided a definition of a contralateral patent processus vaginalis [9,14,17–22], but heterogeneity remained high with $I^2 = 75\%$. We also assessed statistical heterogeneity using Galbraith-plots, which detected only one study [31] outside the confidence band for the number of contralateral patent processus vaginales (not shown), but its omission was without effect in leave-one-out cross-validation. Therefore, clinical heterogeneity between the studies is likely.

There was considerable variation in the male-to-female ratio between studies: Four studies include more girls than boys [14,21,26,31], whereas the majority includes more boys than girls, two studies only include boys [11,49], and one did not report gender at all [22]. One might argue that gender has been demonstrated to be irrelevant in a previous systematic review [46] – it is not a meta-analysis, because it used statistical methods of primary studies (Fisher's exact test) instead of those designed for meta-analyses – but due to this methodological shortcoming its results are questionable in this issue. Therefore, gender

Table 1
Reported percentages of contralateral patent processus vaginalis diagnosed during a laparoscopic hernia repair.

Cases	% CPPV	Definition of CPPV	Closure by SOP	Study type	Ref
2855	51.5	No	yes	retrospective	[25]
2111	66.6	No	yes	retrospective	[66]
1747	43.2	Yes	no	prospective observational	[14]
1407	47.3	No	yes	retrospective	[54]
1300	41	No	yes	retrospective	[67]
1232	45.8	Yes	yes	retrospective	[21]
1.036	21.3	No	yes	retrospective	[52]
959	39.6	No	yes	retrospective	[26]
904	15.8	No	yes	retrospective	[27]
857	39.3	Yes	yes	retrospective	[20]
720	24.4	No	yes	unclear	[16]
564	36.5	Yes	yes	retrospective	[17]
454	43	No	yes	retrospective	[55]
437	34.3	No	yes	prospective observational	[15]
409	47.9	No	yes	retrospective	[23]
331	48.3	Yes	yes	retrospective	[19]
289	46.4	Yes	yes	retrospective	[22]
285	59.6	No	yes	retrospective	[31]
219	38.8	No	yes	retrospective	[56]
189	39.2	No	yes	prospective observational	[12]
153	43.8	No	yes	retrospective	[29]
145	17.2	No	yes	retrospective	[49]
120	16.7	No	yes	retrospective	[53]
106	43.4	No	yes	retrospective	[28]
91	40.7	No	yes	retrospective	[57]
85	30.6	No	yes	retrospective	[24]
56	39.3	Yes	yes	prospective observational	[9]
32	28.1	No	yes	prospective observational	[13]
30	16.7	No	yes	prospective observational	[10]
25	44	No	yes	retrospective	[30]
21	19	No	yes	prospective observational	[11]
19	63.2	Yes	yes	retrospective	[18]

CPPV = contralateral patent processus vaginalis. SOP = standard operating procedure.

disparities between the studies might have influenced the results. In general there are many limitations when using data from the present literature and the variability may be high depending on the population analyzed.

Another important source of clinical heterogeneity is age and prematurity in particular [50,51]. The vast majority of included studies reported mean ages, one did not mention age at all [29], another did not provide a measure of centrality [23], and seven studies reported median ages [14,19–21,52,53]. Two studies that reported both median and mean age indicate age as a relevant source of clinical heterogeneity as one had a median age that was more than doubled compared to the mean age [27] whereas the other had an almost halved median age compared to the mean age [15]. Consequently, an exploratory analysis limited to all studies with a mean age between 36 and 48 months [10,12,13,28,54–57] did in fact reduce heterogeneity to 72%, but it still remained high. Thus, age is likely to influence the results. Support for this can be drawn from the studies that investigated a contralateral patent processus vaginalis in surgery unrelated to inguinal hernia repair: In a cohort of 416 patients with a median age of 12.4 years only 9.1% had a patent processus vaginalis [42], whereas it was 19.9% in a group of 1548 children with a median age of 4.8 months [43], and even 41.7% in 103 children operated for hypertrophic pyloric stenosis at a median age of 37 days [44].

Calculating a formal number needed to treat for the pooled estimate – as done by two previous syntheses of the literature [37,38] – is formally not possible if the source studies are heterogeneous [39–41]: Both preceding syntheses derived the number needed to treat from the pooled estimate of the risk difference, which introduces bias due to differing baseline risks between included studies [39,40]. It has been argued that a single number needed to treat might be calculated from relative measurements such as relative risk reduction and odds ratio as they account for differing baseline risks. However, this still requires the baseline risk to be similar between the two groups that were compared in the primary study. This is assumed for randomized-controlled trials and – with reservations – for propensity-score matched studies, but is unlikely for those included in our analysis. In order to better visualize the importance and effects of differences in baseline risk for descriptive purposes, we used the formula presented by Zhao et al. [25].

In order to weigh risks and benefits of contralateral patent processus vaginalis closure, potential complications must be considered. Unfortunately, the studies we included do not specifically report complications associated with contralateral patent processus vaginalis closure, only general complications resulting from inguinal hernia repair. Presuming that general complications such as bleeding and wound infection of inguinal hernia repair are negligible, the focus should be placed on long-term effects. In two larger studies with a six-month follow-up, laparoscopic inguinal hernia repair did not influence testicular perfusion [58,59]. Testicular perfusion is only one aspect. Another one certainly is fertility: A recent study evaluated 300 men seen at a fertility clinic and concluded inguinal hernia repair was without effects on fertility [60].

A study from 1991 that compared 288 adult patients that had inguinal hernia surgery to a control group of 105 men found open inguinal hernia repair to possibly affect sperm concentration per se, particularly if it led to testicular atrophy [61]. It is important to note that these studies were performed on adult patients who mostly underwent hernia repair for direct hernias, which represents a completely different entity compared to the high ligation procedure performed in children. To date, there is no conclusive evidence that inguinal hernia repair in children, particularly performed laparoscopically, has negatively impacts on later infertility.

Nevertheless, a well-documented fact is the prevention of metachronous inguinal hernias by closure of contralateral patent processus vaginales [5,24,26,27]. However, some authors consider routine prophylactic closure overtreatment due to a relatively high number of procedures necessary to prevent a metachronous inguinal hernia [3,37,38,51]. An opinion shared by the largest primary study included in the present analysis [25]. In our study, the pooled estimate of the absolute risk reduction was 5.7% (95% confidence interval: 3.6–7.7%); put descriptively this equals 18 closures of a contralateral patent processus vaginalis to prevent one metachronous inguinal hernia. As mentioned before, a formal number needed to treat requires the baseline characteristics of all studies to be similar as demonstrated by *Altman & Deeks* [60] and can thus strictly not be calculated based on the available studies.

It is also important to understand that the rate of metachronous hernias seems highly variable in different populations: A nationwide study from Taiwan found the rate to be 12.3% [62] after a follow-up of 17 years, whereas 0.0004% of all children included in the nationwide Danish register had a metachronous inguinal hernia after 12 months of follow-up [47], when 41.6% of all metachronous inguinal hernias should have occurred within this time frame according to the Kaplan-Meier analysis from the aforementioned Taiwanese study [62]. Some of this may be due to ethnicity, which may be suspected due to the highly different results. In a French cohort consisting exclusively of prematurely born infants, who have the highest risk for an inguinal hernia, the rate of subsequent metachronous inguinal hernias was 11% [51]. A previous meta-analysis calculated the pooled estimate of 7.3% (95% confidence interval: 6.5–8.1%) for metachronous inguinal hernias [3]. However, the cumulative incidence of a metachronous inguinal hernia

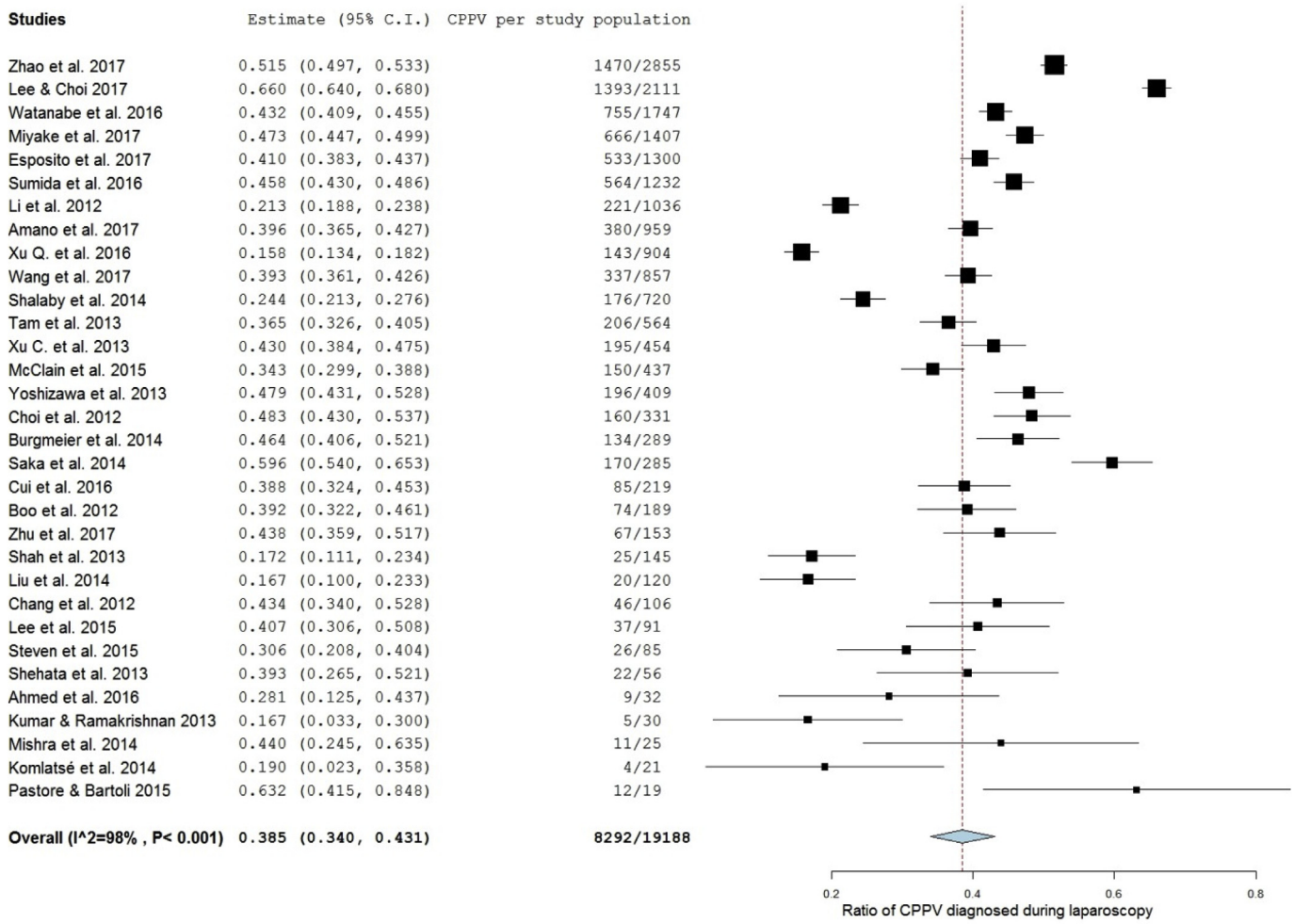

Fig. 2. Forest plot of the included studies from Table 1 for the rates of a contralateral patent processus vaginalis diagnosed during laparoscopy.

Table 2
Reported percentages of patent processus vaginales diagnosed during laparoscopy for a condition other than inguinal hernia.

Cases	%PPV	Definition of CPPV	Closure by SOP	Study type	Ref
1548	19.9	No	no	retrospective	[43]
416	9.1	No	no	retrospective	[42]
103	41.7	No	yes	retrospective	[44]

PPV = patent processus vaginalis. SOP = standard operating procedure.

is closely linked to follow-up as demonstrated not only by a previous systematic review [46], but also by recent primary data from the Taiwanese register data [62]. This highlights another limitation of our included studies: The insufficient follow-up data to estimate the true rate of metachronous inguinal hernia as described in the bias assessment in the methods.

Some authors argued for a lifelong follow-up of a contralateral patent processus vaginalis [46], which may be supported by the fact that in Swedish register data more than 50% of adult inguinal hernias are indirect [63] and a patent processus vaginalis is a *condicio sine qua non* for an indirect inguinal hernia [50]. However, after a follow-up of ten years, the cumulative incidence of a metachronous inguinal hernia asymptotically approaches 100% as 99.3% of all metachronous inguinal hernias were detected within this follow-up duration [62]. The highest

Table 3
Number of contralateral patent processus vaginales that need to be closed to prevent one metachronous inguinal hernia.

Cases LR	CPPVs closed	MIH LR	Cases OR	MIH OR	cCPPVs to prevent a MIH	Ref
2855	1469	3	2538	62	21.1 (95% CI: 16.4–27)	[25]
959	380	3	901	44	8.1 (95% CI: 6–10.9)	[26]
908	379	3	879	57	6.4 (95% CI: 5–8.4)	[5]
904	143	0	327	27	1.9 (95% CI: 1.3–2.8)	[27]
285	170	0	130	3	25.8 (95% CI: 8.4–79.4)	[31]
153	67	0	732	74	4.3 (95% CI: 3.3–5.7)	[29]
106	46	0	80	6	5.8 (95% CI: 2.6–12.9)	[28]
85	26	1	132	6	8.1 (95% CI: 3.2–20.2)	[24]
27	11	0	45	7	2.6 (95% CI: 1.2–5.9)	[30]

LR = laparoscopic repair. OR = open repair. MIH = metachronous inguinal hernia. cCPPV = closed contralateral patent processus vaginalis. CI = confidence interval.

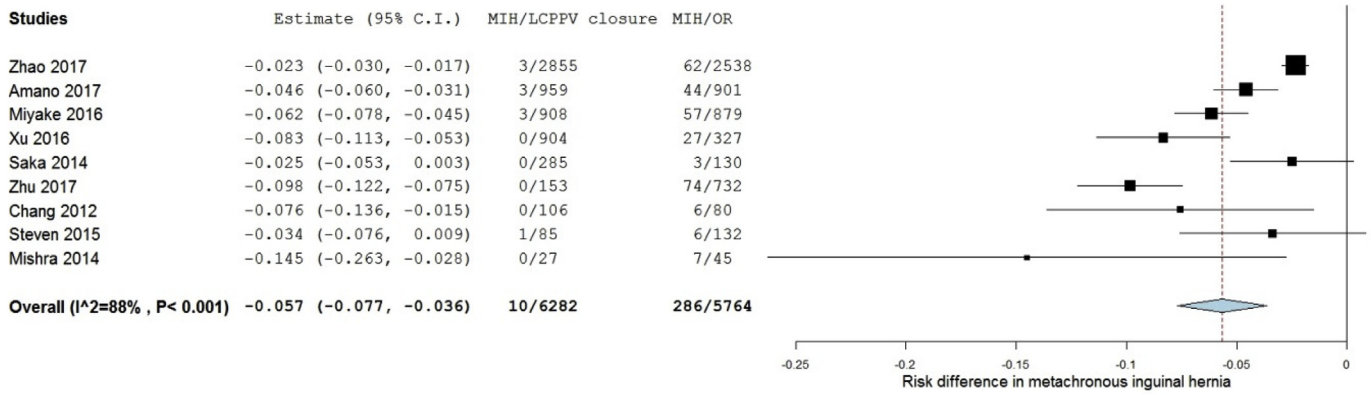

Fig. 3. Forest plot of the included studies from Table 3 for the risk difference achieved by prophylactic laparoscopic closure of a contralateral patent processus vaginalis and conventional open repair.
MIH = metachronous inguinal hernia. LCPPV = cohort with laparoscopically diagnosed and prophylactically closed contralateral patent processus vaginalis. OR = open repair.

rates for metachronous inguinal hernias in the literature are 12.3% for the Taiwanese nationwide study after 17 years of follow-up [62] and a German autopsy study found the prevalence of a patent processus vaginalis to be 29% [64], whose addition is close to the confidence interval for the overall presence of a contralateral patent processus vaginalis.

It is clear that prophylactic closure of a contralateral patent processus vaginalis will spare some children from needing a second operation and anesthesia, sometimes emergently in the setting of an incarcerated hernia and potentially suboptimal condition. Considering involved risks, one approach may be to counsel families on the possibility of contralateral repair on an individual basis, taking into account risk factors for incarceration, prematurity, other co-morbidities or the inability or unwillingness of patient's caretakers to ensure an adequate monitoring of potentially arising metachronous hernia, which has been an exclusion criteria in a currently recruiting trial on the adequate timing of inguinal hernia repair in prematures [65]. Ultimately, simultaneous closure of an intraoperatively discovered contralateral patent processus should be closed simultanously should be discussed with the parents and caregivers during the informed consent process, and their decision respected accordingly.

In our experience, when presented with the background information, most parents will opt for contralateral closure by laparoscopy. When given the choice, they usually ask us to “fix the other side while you are there”, because they prefer not to have to worry about recurrence in the future. At our institution, pediatric inguinal hernia repairs are performed by trainees under supervision of a consultant and we have so far not observed perioperative complications associated solely with the prophylactic closure of the contralateral patent processus vaginalis. Therefore, we feel that the complications resulting from laparoscopic contralateral patent processus vaginalis closure are negligible and therefore justified. However – in line with previous results [46] – this may not be the case for contralateral open exploration.

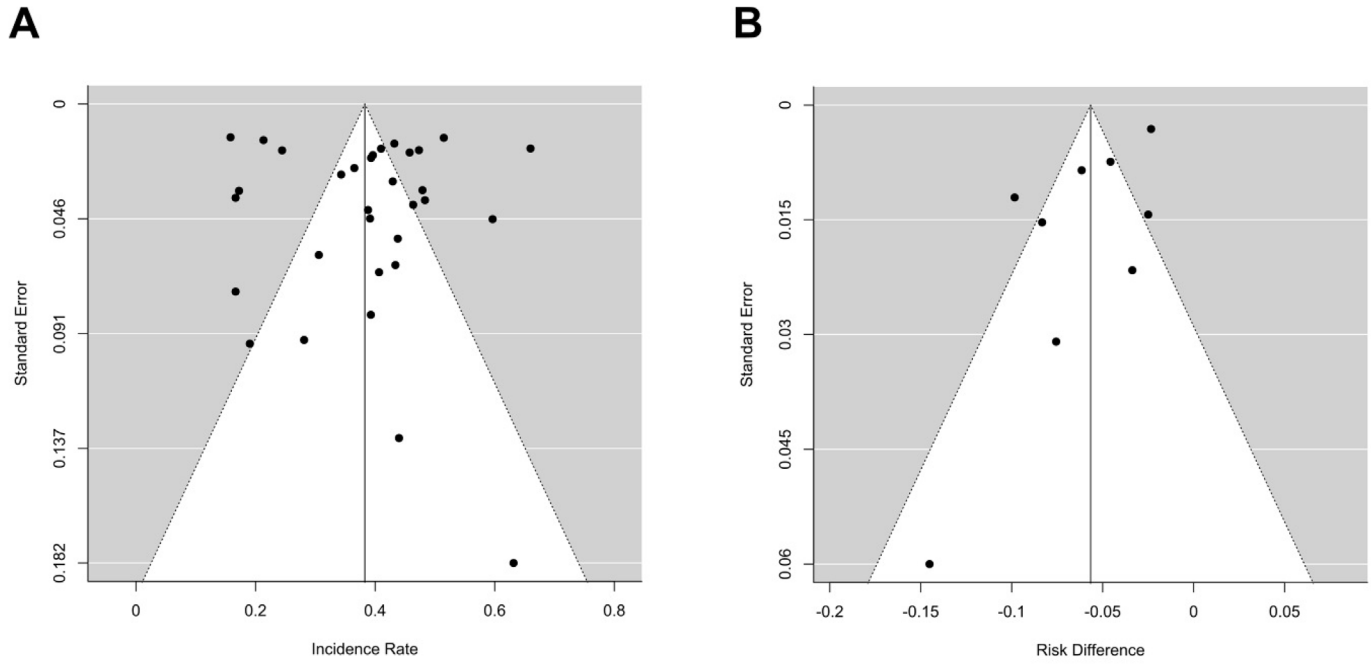

Fig. 4. Funnel plots to graphically assess potential publication bias. **A** Funnel plot for the percentage of contralateral patent processus vaginales. **B** Funnel plot for the studies that compared open and laparoscopic inguinal hernia repair.

5. Conclusions

The prevalence of a contralateral patent processus vaginalis was 38.5% (95% confidence interval: 34–42%) in the recent literature, comparable to previous meta-analyses. Likewise, the risk difference due to a prophylactic closure of a contralateral patent processus vaginalis across the most recent literature amounts to 5.7% (95% confidence interval: 3.6%–7.7%), indicating that about 18 contralateral processus have to be closed to prevent one metachronous contralateral hernia. These findings are inline with previous reports. In spite of the low quality of the current literature, the merits and possible drawbacks of a prophylactic closure of a contralateral patent processus vaginalis should be discussed preoperatively with the parents and family. Circumstances of the family, the availablility of emergency care, the anxiety level of the parents, and their decision after informed consent, must me considered to determine if a contralateral patent processus should be closed during the primary procedure. Finally, a potential benefit or harm may only be judged based on future randomized-controlled trials with a sufficiently long median follow-up. Given the low incidence of morbidity, such studies will have to be conducted in a multicenter fashion to reach sufficient power.

Disclosure

O.J.M. and EG declare no conflict of interest.

The present work was conducted without external funding.

Data statement

The data on which this systematic review was based and all data concerning the analysis is freely available anytime by contacting the author.

Ethical approval

Since this is a systematic review of published articles, no ethics approval was required by law.

Sources of funding

Internal (departmental) funding only.

Author contribution

OM designed the study, performed the systematic review and wrote the manuscript in its current form. EG assisted with the statistical analysis.

Conflicts of interest

None.

Research registry number

reviewregistry668.

Guarantor

(OM) Oliver J Muensterer, MD, PhD.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Appendix

Literature search strategy

***MEDLINE** via PubMed*

#1 hernia, abdominal[mh] NOT gastroschisis[mh]
#2 ″inguinal hernia*"[tw] OR “groin hernia*"[tw]
#3 ″processus vaginalis"[tw] OR “processus vaginales"[tw]
#4 (#1 OR #2) AND #3.
#5 child[mh]
#6 child, preschool[mh]
#7 infant[mh]
#8 (child*[tw] OR children[tw])
#9 infant*[tw]
#10 (pediatr*[tw] OR paediatr*[tw])
#11 toddler*[tw]
#12 teenager*[tw]
#13 (#5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12)
#14 #4 AND #13.

***Web of Science** via Clarivate Analytics*

#1 TS = (“inguinal hernia*” OR “groin hernia*” OR “processus vaginal$s” OR (hernia near/5 processus))
#2 TS = (child* OR infant* OR p$diat* OR toddler* OR youth* OR juvenile* OR “young people*” OR adolescent* OR preschool* OR teenager*)
#3 #1 AND #2.

***Scopus** via Elsevier*

#1 TITLE-ABS-KEY({inguinal hernia*} OR {groin hernia*} OR {processus vaginal?s}) OR TITLE-ABS-KEY(hernia* W/5 processus)
#2 TITLE-ABS-KEY(child* OR infant* OR pediat* OR paediat* OR toddler* OR youth* OR juvenile* OR {young people*} OR adolescent* OR preschool* OR teenager*)
#3 #1 AND #2.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.06.001.

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