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Evaluation of the Contralateral Inguinal Ring in Clinically Unilateral Inguinal Hernia: A Systematic Review and Meta-analysis

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Abstract

Purpose—The management of the contralateral inguinal canal in children with clinical unilateral inguinal hernia is controversial. Our objective was to systematically review the literature regarding management of the contralateral inguinal canal.

Methods—We searched MEDLINE, EMBASE, and Cochrane databases (1940–2011) using 'hernia' and 'inguinal' and either 'pediatric,' 'infant,' or 'child,' to identify studies of pediatric (age 21 yrs) patients with inguinal hernia. Among clinical unilateral hernia patients, we assessed the number of cases with contralateral patent processus (CPP) and incidence of subsequent clinical metachronous contralateral hernia (MCH). We evaluated three strategies for contralateral management: expectant management, laparoscopic evaluation or pre-operative ultrasound. Pooled estimates of MCH or CPP were generated with random effects by study when heterogeneity was found ($I^2 > 50\%$, or Cochrane's $Q p < 0.10$).

Results—We identified 2,477 non-duplicated studies, 129 of which met our inclusion criteria and had sufficient information for quantitative analysis. The pooled incidence of MCH after open unilateral repair was 7.3% (95% CI 6.5%–8.1%). Laparoscopic examination identified CPP in 30% (95% CI 26%–34%). Lower age was associated with higher incidence of CPP ($p < 0.01$). The incidence of MCH after a negative laparoscopic evaluation was 0.9% (95% CI 0.5%–1.3%). Significant heterogeneity was found in studies and pooled estimates should be interpreted with caution.

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Conclusions—The literature suggests that laparoscopically identified CPP is a poor indicator of future contralateral hernia. Almost a third of patients will have a CPP, while less than one in 10 will develop MCH when managed expectantly. Performing contralateral hernia repair in patients with CPP results in overtreatment in roughly 2 out of 3 patients.

Keywords

Inguinal; Hernia; Pediatric; Laparoscopy

Introduction

Inguinal hernia is an important cause of morbidity in the pediatric population with an incidence of 1–4%. [1] It has long been recognized that children with clinical unilateral inguinal hernias are at risk for subsequently developing a contralateral inguinal hernia. The incidence of metachronous contralateral hernia (MCH) as determined in several reviews is 7–10%, [2–4] with higher incidence if the initial hernia was on the left, and among younger patients. Gender does not appear to be a consistently significant predictor. A MCH is typically related to a contralateral patent processus vaginalis (CPP). The processus vaginalis is a finger-like projection of peritoneum that typically closes between the 36th and 40th week of gestation. It is thought that 40% close in the first few months after birth and an additional 20% by age 2 years. [5]

More recently, laparoscopic techniques have been used at the time of unilateral hernia repair, to evaluate the contralateral inguinal canal in an attempt to identify children who are likely to subsequently develop a contralateral hernia. Preoperative imaging (e.g. inguinal ultrasound) has also been utilized to this end. When a CPP is identified, simultaneous repair can be performed, preventing later contralateral hernia development and obviating the need for subsequent inguinal surgery. However, the use of these techniques may lead to both false positive and false negative findings, and the balance of risks and benefits of such strategies are uncertain.

The purpose of this systematic review is to examine contemporary management strategies in terms of the incidence of MCH (as would occur with expectant management) as well as the incidence of CPP with laparoscopic or ultrasound evaluation.

Methods

We performed a systematic review of the literature from 1940 to 2011. Medline, Embase, and the Cochrane Library were queried for the key terms of Inguinal, Hernia or Hydrocele and (infant or child* or neonat* or pediatric* or paediatric*) (Figure 1). Secondary searches of reference lists of selected articles and reviews were performed. Full text sources were available for most titles, however some data was derived from abstracts alone or previously-performed systematic reviews when sufficient detail was provided. [6,3,4] For inclusion in this review, reports were required to have cohorts of clinically unilateral inguinal hernias, have an adequate description of technique used to evaluate the contralateral inguinal ring (either expectant management, ultrasound evaluation, transinguinal or transabdominal laparoscopy) and data on the number of CPP found on evaluation (ultrasound or

laparoscopic) and/or the number of MCH. Studies were excluded if the number of clinically unilateral hernias that were found to have contralateral abnormalities was unclear. Studies where the primary hernia was only associated with undescended testis were excluded, however three studies where a small proportion of hernias (20%, 1%, and 7% of the cohorts, respectively)[7–9] were related to undescended testes were included. Information regarding follow-up, age, sex, and laterality at presentation was recorded where available. Two reviewers independently performed the initial literature search, selection of titles, and data abstraction. Article lists and abstracted data were compared and inconsistencies settled by joint re-review of relevant primary sources.

Pooled estimates of the incidence of MCH and CPP were generated from studies with relevant data and weighted with inverse variance methods (Peto).[10] Odds ratios for the relative risk of outcomes compared incidence by gender or laterality at presentation, where data were available. Random effects estimation (DerSimonian-Laird)[10] was used if significant heterogeneity ($I^2 > 50\%$ or Cochrane's $Q p < 0.10$) was encountered. Egger plots were used to examine for publication bias. Significant ($p < 0.01$) publication bias on Egger plots are characterized by a regression line intercept and associated 95% confidence interval that does not overlap with zero on the y-axis.[11] Data management was performed with Microsoft Excel (2011, Microsoft Corporation, Redmond, WA). Analyses of primary outcomes were performed using Stata Statistical Software (*Release 11*. College Station, TX: StataCorp LP.). Mixed effect regression models with random effects for each study were used to test for significant effects of age on CPP and incidence of MCH, or length of follow-up on incidence of MCH. We assumed a linear effect of age or length of follow-up on the incidence of MCH and a linear effect of log(age) on the presence of CPP.

Results

After a complete search of 2,477 titles, data from 129 studies were included in the analysis. Most studies were retrospective reviews of local experience ($n=76$), however there were some prospective ($n=20$) and randomized ($n=4$) studies as well. Specific study design could not be deduced from the available information in 29 papers. Eleven studies included multiple strategies.

Data on the incidence of MCH after unilateral open surgical repair with expectant management were available from 66 sources with a sum total of 32,432 patients. The pooled incidence of MCH after unilateral hernia repair was 7.3% (95% CI 6.5%–8.1%; Figure 2). Egger plots demonstrated evidence for potentially significant publication bias ($p < 0.01$) for the risk of MCH after open repair. After stratifying by study type the incidence of MCH was 8.2% (95% CI 4.8%–8.0%, $I^2=0\%$), 6.0% (95% CI 4.1%–8.0%, $I^2=76\%$), 6.3% (95% CI 5.3%–7.2%, $I^2=83\%$), 9.5% (95% CI 7.8%–11.3%, $I^2=89\%$) for randomized trials, prospective cohorts, retrospective cohorts, and unknown/unclear studies respectively. There was no significantly increased risk in males versus females (OR 1.18; 95% CI 0.91–1.54, $I^2=0\%$, $n=13$ studies). There was a significantly increased odds of MCH when the initial presenting side was Left (OR 1.71; 95% CI 1.21–2.41, $I^2=51\%$, $n=20$ studies). This represents a risk difference in the range of 3–4% (absolute increase in risk for MCH) when the presenting side is left as compared to right.

Data on laparoscopic evaluation of the contralateral internal ring was available from 71 studies with a sum total of 11,386 patients. The pooled incidence of CPP when using either transabdominal or transinguinal laparoscopy to evaluate the contralateral inguinal ring was 30% (95% CI 26%–34%; Figure 3). Egger plots demonstrated evidence for significant publication bias ($p<0.01$) for the prevalence of CPP during laparoscopic evaluation. Using a subgroup of only transabdominal laparoscopy the pooled incidence of CPP was 31% (95% CI 26%–37%, $I^2=97\%$) as compared to the transinguinal laparoscopy group where the incidence of CPP was 27% (95% CI 23%–32%, $I^2=89\%$). After stratifying by study type the pooled incidence of CPP was 25% (95% CI 18%–32%, $I^2=0\%$), 34% (95% CI 26%–42%, $I^2=79\%$), 30% (95% CI 25%–34%, $I^2=97\%$), 25% (95% CI 11%–38%, $I^2=82\%$) for randomized trials, prospective cohorts, retrospective cohorts, and unknown/unclear studies respectively. Males were 55% less likely to have a CPP than females (OR 0.45; 95% CI 0.25–0.79, $I^2=62\%$, $n=5$ studies), representing a 3–10% absolute risk difference. Children were 96% more likely to have a CPP when presenting side was left (OR 1.96; 95% CI 1.45–2.65, $I^2=32\%$, $n=8$ studies), representing an 11–16% absolute difference.

Among patients who underwent laparoscopic evaluation and were NOT found to have a CPP, the incidence of MCH was 0.9% (95% CI 0.5%–1.3%). However one very large study suggested a near-nil risk among this group, and may have skewed the incidence. When this one large study was removed in a sensitivity analysis, the pooled incidence of MCH after negative laparoscopic exploration became 1.8% (95% CI 1.1%–2.5%).

Additional potential sources of heterogeneity that were investigated in sensitivity/subgroup analyses include the distribution of gender, presenting side of original hernia, study type, age and the length of follow-up. When examining only studies that had stratified male/female data regarding CPP, the I^2 reduced only to 62% suggesting persistent issues. Heterogeneity improved ($I^2=32\%$) for evaluation of CPP but not for MCH ($I^2=51\%$) in presenting right versus presenting left among studies with laterality information. For study type, heterogeneity was reduced to near 0% among randomized trials for the incidence of MCH after unilateral repair ($n=3$) and for the incidence of CPP ($n=4$). Among those managed expectantly (i.e. no laparoscopic evaluation), there was no significant correlation between length of follow-up measures and incidence of MCH (by minimum follow-up $R^2=0.03$, $p=0.40$; by mean/median $R^2=0.10$, $p=0.20$; by maximum $R^2=0.04$, $p=0.31$). Age at surgery was not significantly correlated ($R^2=0.15$, $p=0.09$) with incidence of MCH. With regard to the presence of a CPP, there was a statistically significant but weak correlation ($R^2=0.43$, $p<0.01$) with the log of cohort age. Other sources of heterogeneity may exist, but could not be examined further with the existing data.

Evaluating the test characteristics of laparoscopic assessment of the contralateral ring, with presence of CPP being considered a positive test, and clinical occurrence of MCH being the gold standard, then laparoscopic examination of the contralateral internal ring has sensitivity of 91%, specificity of 74%, PPV of 26%, NPV of 99%.

Only 5 studies contributed data on the utility of preoperative ultrasound for evaluation of the contralateral inguinal canal with a sum total of 881 patients. Criterion used for a positive test were the presence of abdominal structures, fluid in the patent processus, and/or a canal

width >4mm in three[12–14] studies, the presence of a lumen >2cm from the inferior epigastric vessels in one, [15] and not described in detail in one.[16] The pooled incidence of CPP among these studies was 32% (95% CI 18.7%–45.8%). The detection rate was quite variable from 8–78% reflecting the considerable heterogeneity between studies ($I^2=96\%$). Age may have played a role in these findings since the one study limited to ages less than one year found CPP in 78% while the remaining studies with ages up to 13–15 years found CPP incidence from 8–32%. The false negative rate regarding MCH is difficult to determine since only one of the five studies reported the post-operative outcomes among those patients who were not explored, based on a negative ultrasound; no cases of MCH were observed in 6–12 month follow-up. The false negative rate of ultrasound for CPP, as determined by open or laparoscopic evaluation of the contralateral side, was 3.4–80% in the three studies with this information. Two other studies only explored those with positive ultrasound findings.

Among cases suggested by US, CPP was confirmed at exploration in 78% (14/18)[16], 95% (74/78)[15] and 100% (10/10)[12]. The sensitivity of US in symptomatic and asymptomatic hernias from two studies was 98%[14] (323/330) and 97%[13] (458/473).

Discussion

Inguinal hernia occurs in 0.8–4.4% of children, and are unilateral in 75–90%.[5,4] Incidence is higher in premature infants (13% of those <32wks gestation) and low birth weight infants (30% in infants <1000g).[5] Children with clinical unilateral inguinal hernia are at increased risk of developing a metachronous contralateral hernia. These may present days to years after the initial hernia, and can be frustrating for both surgeons and families. In response, a variety of strategies have been proposed for management of the contralateral inguinal canal. Such strategies seek to minimize the need for subsequent contralateral surgery, while also avoiding potential over-treatment among those children in whom MCH would never occur. However, considerable controversy persists as to the optimal approach in children with clinical unilateral hernia.

Routine contralateral open exploration was considered standard for much of the 20th century.[17] As recently as 1996, a survey of pediatric general surgeons found that 65% still performed contralateral open exploration of males less than 2 years old; laparoscopic evaluation of the contralateral side was performed by only 6% of respondents.[18] Routine contralateral exploration has been questioned, however, based on concerns over the risk of injury to the vas deferens or testicular blood supply during exploration, as well as the low overall risk of clinical metachronous contralateral hernia (meaning that contralateral treatment is unnecessary in most patients).[5] As a result of these concerns, laparoscopic evaluation of the contralateral ring has been advocated as a way to identify children with a CPP who are more likely to develop a MCH. Preoperative ultrasound has also been proposed as an even less invasive way to identify a CPP. In theory, presence of a CPP indicates a high risk for MCH, and therefore contralateral repair is performed and the need for subsequent surgery eliminated.

Unfortunately, determining the accuracy of these methods to predict contralateral clinical hernia is difficult, because few studies assessed contralateral status and then managed all or

some expectantly. It is clear that presence of a CPP does not invariably lead to subsequent contralateral clinical hernia, and regardless of the diagnostic approach used, the chance of finding a CPP is much higher than the expected rate of contralateral clinical disease. In the only study of its kind in this review, among 53 patients with CPP on laparoscopic evaluation (but left untreated), only 6 (11%) went on to develop clinical contralateral hernia during up to 82 months of follow-up.[19] It seems clear that at least some contralateral repairs do not actually prevent clinical disease.

This review of the existing literature suggests that when an expectant management or observational approach is used for children with clinical unilateral hernia, the risk of developing a MCH is less than 10%. Laterality of the presenting hernia may have some influence since the risk of MCH is around 3–4% higher when the initial clinical hernia is on the left side. However, when adjunctive diagnostic methods are used, a CPP is found in about 30% of patients. Again when the presenting side is left, there is an 11–16% increased risk of finding a CPP. Thus even assuming 100% accuracy of these methods for detection of CPP, it is likely that less than one-third of those with CPP would develop a clinical hernia if observed. This is consistent with autopsy data that suggest 20%–30% of adults live asymptotically with a CPP but without clinical hernia.[20,21] Conversely, some patients (roughly 1–2%) with a negative diagnostic test for CPP will still develop a metachronous contralateral hernia; it is unclear if this is due to inaccurate assessment for CPP, or to patients who truly have a closed ring but develop subsequent hernia despite this.

Further complicating the picture are the varying criteria that different investigators have used to define a “positive” diagnostic test. Some studies use institution specific criterion during laparoscopy for CPP: >1 cm deep (n=4 studies, mean incidence CPP=35%), >1cm diameter (n=1, incidence=24%), 2cm deep (n=3, mean 41%), >2 cm diameter (n=1, incidence=11%), gas in scrotum or crepitus (n=9, mean=28%), no visible termination to patent processus (n=7, mean=30%). Unfortunately, most studies only report subjective findings of an open or closed CPP (n=54 studies). Although this factor cannot explain the differences in the incidence of CPP, it makes sense that the threshold used would contribute to the heterogeneity among study results.

It does seem likely that use of diagnostic techniques to evaluate the contralateral inguinal canal reduces the number of subsequent MCH repairs. Additionally, the small number of patients with MCH who present with incarceration could be reduced as well. Avoidance of the potential cost and inconvenience of having their child undergo additional surgery – not to mention that additional anesthetic risks associated with subsequent surgery – may be significant drivers of parental preference for contralateral evaluation and repair.[22] The question is whether the overtreatment that appears intrinsic to these approaches is justified by the benefits. Furthermore, there are significant concerns regarding the surgical risks of contralateral repair. The risks of surgical site infection, testicular injury, bladder injury and vas injury may be low, [23] [24] [25] but are difficult to justify for patients who would never have developed a clinical contralateral hernia.

This analysis should be interpreted in light of its limitations. Much of the included data comes from retrospective reviews that are subject to the inherent problems with this study

design. There are very few prospective, randomized trials in this field from which data could be collected. Furthermore, although we attempted to exclude series that dealt with hernias associated with undescended testis, some patients may have been included due to incomplete reporting. Hernia associated with UDT may have a different natural history than that of isolated hernia, and inclusion of such cases may dilute the validity of the findings. Our analysis suggests that publication bias may have influenced the available data. However, the asymmetry observed on the Egger's plots may also be related to heterogeneity within the various studied populations, search related biases, data irregularities, or may simply be artifactual.[11] Our point estimates for MCH and CPP risk may be imprecise, especially for the false negative rate for laparoscopic evaluation since many of the series assumed that the findings were definitive and did not include follow-up. Differences in the populations with regard to potentially measureable (age, gender, laterality) and immeasurable factors may have contributed to the significant degree of heterogeneity encountered in our pooled estimates. Sensitivity analyses on most of the measured factors could not eliminate heterogeneity, though the study design and information regarding the laterality of the presenting clinical hernia do appear to be important sources of statistical heterogeneity among studies. Because of limited available data we did not consider birthweight and prematurity in our analysis, which are known to be associated with overall incidence of inguinal hernia (although how these factors relate to the risk of contralateral hernia is unknown). Similarly, there was insufficient information in most cases for categorization of hernia severity or determining the presence of incarceration.

Conclusions

The pooled incidence of metachronous contralateral hernia after unilateral inguinal hernia repair is 7.3%. If the contralateral side is evaluated with laparoscopy or ultrasound, a CPP is found in about 30% of patients. Although contralateral repair in patients with CPP may reduce the incidence of MCH, such a strategy will result in significant overtreatment since a majority of these patients will not develop clinical MCH.

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Figure 1.
Flow diagram of search strategy.

Figure 2.
Pooled incidence of Metachronous Hernia after open primary repair and expectant management.

Figure 3.
Pooled incidence of CPP with laparoscopic examination of the contralateral inguinal canal.

Table 1

Studies with quantitative information used in the calculation of pooled estimates.

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparos copy
1	Chang, et al. 2011. J Laparoendo sc Adv Surg Tech A 21:277- 82	Unclear/Un known	Laparoscopy	186	64.4 %	-	0 mo to 21 yr	-	39. 8%	-
		Retrospective	Expectant/Obs ervation	22	-	-	"Infants"	18. 2%	-	-
2	Lin, et al. 2011. Journal of Urology 185:1071-6	Retrospective	Laparoscopy	20	-	-	"Infants"	-	65. 0%	-
3	Montupet, et al. 2011. Surg Endosc 25:450-3	Retrospective	Laparoscopy	596	100.0%	1 yr	6 mo to 15 yr	-	15. 9%	-
4	Giseke, et al. 2010. Journal of Laparoendo scopic and Advanced Surgical Techniques 20:191-4	Retrospective	Laparoscopy	346	-	1 mo to 0 yr	2 mo to 17 yr	-	29. 2%	-
5	Guner, et al. 2010. Journal of Laparoendo scopic and Advanced Surgical Techniques 20:481-4	Retrospective	Laparoscopic	57	0.0 %	-	1 mo to 18 yr	-	15. 8%	-
6	Ho, et al. 2010. Urology 76:134-7	Retrospective	Laparoscopy	20	100. 0%	1 yr	1yr to 13yr	-	30. 0%	-
7	Lee, et al. 2010. Journal of Pediatric Surgery 45:793-5	Retrospective	Inguinal Laparoscopy	81	-	-	"Children"	-	10. 3%	-
8	Lipskar, et al. 2010. Journal of Pediatric Surgery 45:1370-4	Retrospective	Laparoscopy	156	0.0 %	-	1 mo to 17 yr	-	34. 0%	-
9	Niyogi, et al. 2010. Pediatric Surgery Internationa 126:387-92	Retrospective	Expectant/Obs ervation	164	-	1 mo to 1 yr	0 mo to 15 yr	3.0 %	-	-
		Retrospective	Laparoscopy	58	-	1 mo to 1 yr	0 mo to 15 yr	-	27. 6%	0.0%
		Retrospective	Inguinal Laparoscopy	77	-	1 mo to 1 yr	0 mo to 15 yr	-	13. 0%	3.0%
10	Parelkar, et al. 2010. Journal of Pediatric Surgery 45:789-92	Retrospective	Laparoscopy	411	-	0 mo to 9 yr	1 mo to 11 yr	-	21. 2%	-
11	Shen, et al. 2010. European Journal of Pediatrics 169:1207- 12	Retrospective	Laparoscopy	69	-	1 yr 4 mo to	3yr to 13yr	-	27. 5%	-
		Prospective	Laparoscopy	80	-	3 yr	"Children"	-	35. 0%	0.0%
12	Tsai, et al. 2010. Surg Endosc 24:21-4	Prospective	Expectant/Obs ervation	41	-	4 mo to 3 yr	"Children"	9.8 %	-	-
13	Chang, et al. 2009. American Journal of Surgery 198:e13-e6	Prospective	Laparoscopy	12	66.7 %	6 mo to 1 yr	2 mo to 8 yr	-	33. 3%	-

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparos copy
14	Dutta, et al. 2009. Surgical Endoscopy and Other Interventional Techniques 23:103-7	Prospective	Laparoscopy	162	-	2 yr	-yr to 18yr	-	38.9%	-
15	Endo, et al. 2009. Surgical Endoscopy and Other Interventional Techniques 23:1706-12	Retrospective	Laparoscopy	636	58.4 %	1 yr	1 mo to 24 yr	-	47.0%	1.5%
		Retrospective	Expectant/Observation	53	71.0 %	1 yr	1 mo to 24 yr	1.9 %	-	-
		Retrospective	Inguinal Laparoscopy	189	-	1 yr	1 mo to 24 yr	-	21.7%	2.0%
16	Esposito, et al. 2009. World Journal of Surgery 33:1846-50	Retrospective	Laparoscopy	315	-	1 yr	1 mo to 8 yr	-	39.0%	-
17	Feber, et al. 2009. Journal of Urology 181:174	Retrospective	Inguinal Laparoscopy	40	0.0 %	-	1 mo to 13 yr	-	17.5%	-
18	Jallouli, et al. 2009. Hernia 13:613-5	Retrospective	Expectant/Observation	503	74.8 %	-	"Children"	4.4 %	-	-
19	Kalantari, et al. 2009. Hernia 13:41-3	Prospective	Expectant/Observation	301	89.7 %	-	1 mo to 12 yr	9.3 %	-	-
		Randomized	Expectant/Observation	42	77.0 %	-	1yr to 15yr	4.8 %	-	-
20	Koivusalo, et al. 2009. Pediatrics 123:332-7	Randomized	Laparoscopy	47	76.6 %	-	1yr to 15yr	-	25.5%	8.6%
21	Marte, et al. 2009. J Laparoendosc Adv Surg Tech A 19:259-62	Retrospective	Laparoscopy	204	78.1 %	6 mo to 3 yr	1yr to 11yr	-	1.5 %	-
22	Tam, et al. 2009. J Pediatr Surg 44:1502-5	Retrospective	Laparoscopy	395	-	-	0 mo to 15 yr	-	25.8%	1.4%
23	Toufique Ehsan, et al. 2009. Pediatr Surg Int 25:759-62	Retrospective	Laparoscopy	363	80.4 %	3 mo to 5 yr	0 mo to 18 yr	-	39.9%	-
24	Zamakhshary, et al. 2009. Pediatric Surgery International 25:69-71	Retrospective	Expectant/Observation	5,095	-	-	1 mo to 18 yr	5.2 %	-	-
25	Chang, et al. 2008. World Journal of Surgery 32:2459-63	Prospective	Laparoscopy	29	-	4 mo to 1 yr	1 mo to 16 yr	-	58.6%	-
26	Stein, et al. 2008. Hernia 12:631-4	Prospective	Expectant/Observation	368	75.5 %	-	0 mo to 15 yr	6.0 %	-	-
		Randomized	Inguinal Laparoscopy	42	76.2 %	6 mo to 5 yr	"Children"	-	19.0%	11.8%
27	Tsai, et al. 2008. JTUA 19:94-7	Randomized	Expectant/Observation	166	80.1 %	6 mo to 5 yr	"Children"	9.0 %	-	-
28	Watanabe, et al. 2008. Journal of Pediatric Surgery 43:1543-7	Retrospective	Laparoscopy	211	59.2 %	-	1 mo to 15 yr	-	51.2%	-
29	Chan, et al. 2007. Journal of Pediatric Surgery 42:1993-7	Retrospective	Laparoscopy	292	-	-	3 mo to -yr	-	39.4%	-

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparoscopy
30	Ozgediz, et al. 2007. Surgical Endoscopy and Other Interventional Techniques 21:1327-31	Retrospective	Laparoscopy	171	76.5 %	-	1 mo to 16 yr	-	36.8 %	-
31	Ein, et al. 2006. Journal of Pediatric Surgery 41:980-6	Retrospective	Expectant/Observation	5,362	84.0 %	1 mo to 1 yr	0 mo to 18 yr	5.9 %	88.1 %	-
32	Handa, et al. 2006. Asian J Surg 29:28-30	Retrospective	Laparoscopy	171	93.0 %	1 yr	2 mo to 12 yr	-	24.0 %	-
33	Maruliah, et al. 2006. Journal of Pediatric Surgery 41:2004-7	Prospective	Expectant/Observation	256	87.5 %	3 mo to 4 yr	1 mo to 1 yr	7.4 %	-	-
34	Pakowski, et al. 2006. Advances in Clinical and Experimental Medicine 15:851-6	Retrospective	Laparoscopy	94	86.2 %	1 yr	1 mo to 15 yr	-	23.4 %	-
		Retrospective	Expectant/Observation	214	-	2 mo to 6 yr	0 mo to 14 yr	4.2 %	-	-
35	Sozubir, et al. 2006. Hernia 10:74-8	Retrospective	Inguinal Laparoscopy	211	78.0 %	2 mo to 6 yr	0 mo to 14 yr	-	19.4 %	0.0 %
36	Takehara, et al. 2006. Journal of Pediatric Surgery 41:1999-2003	Retrospective	Laparoscopy	602	54.7 %	5 mo to 10 yr	1 mo to 19 yr	-	25.2 %	-
37	Valusek, et al. 2006. J Laparoendosc Adv Surg Tech A 16:650-3	Retrospective	Inguinal Laparoscopy	1,676	-	-	-yr to 10yr	-	40.1 %	0.5 %
		Randomized	Expectant/Observation	40	83.0 %	-	3 mo to 18yr	12.5 %	-	-
38	Chan, et al. 2005. Surg Endosc 19:927-32	Randomized	Laparoscopy	40	85.0 %	-	3 mo to 18yr	-	30.0 %	0.0 %
39	Chinnaswamy, et al. 2005. JSLS: Journal of the Society of Laparoendoscopic Surgeons/Society of Laparoendoscopic Surgeons 9:393-8	Unclear/Unknown	Laparoscopy	35	-	2 mo to 7 yr	3yr to 13yr	-	20.0 %	-
40	Manoharan, et al. 2005. J Pediatr Surg 40:1163-6	Prospective	Expectant/Observation	264	81.1 %	3 yr	-yr to 18yr	5.3 %	-	-
41	Oue, et al. 2005. Pediatric Surgery International 21:964-8	Retrospective	Laparoscopy	115	0.0 %	1 yr	4 mo to 13 yr	-	34.8 %	-
		Retrospective	Expectant/Observation	415	0.0 %	-	4 mo to 13 yr	6.5 %	-	-
42	Tamaddon, et al. 2005. Journal of Laparoendoscopic and Advanced Surgical	Retrospective	Inguinal Laparoscopy	81	76.5 %	-	1 mo to 10 yr	-	39.5 %	-
43	Becmeur, et al. 2004. Surgical Endoscopy 18:1738-41	Retrospective	Laparoscopy	73	-	-	2yr to 12yr	-	6.8 %	-
44	Bhatia, et al. 2004. Journal of Pediatric Surgery 39:778-81	Retrospective	Laparoscopy	272	-	-	0 mo to 8 yr	-	30.9 %	-

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45	Cameiro, et al. 2004. East African medical journal 81:574-6	Retrospective	Expectant/Obs ervation	732	91.7 %	1 yr	1 mo to 10 yr	3.4 %	-	-
46	Chan, et al. 2004. Surg Endosc 18:957-60	Retrospective	Laparoscopy	58	79.0 %	3 mo to 1 yr	3 mo to 15 yr	-	25.9 %	0.0 %
47	Gonzalez Santacruz, et al. 2004. Acta Paediatrica, Internationa l Journal of Paediatrics 93:94-8	Retrospective	Expectant/Obs ervation	30	87.8 %	-	0 mo to 0 yr	6.7 %	-	-
48	Hata, et al. 2004. Journal of Pediatric Surgery 39:1396-9	Retrospective	Ultrasound	348	48.3 %	-	"Children"	-	22.4 %	-
49	Lotan, et al. 2004. Israel Medical Association Journal 6:339-41	Retrospective	Inguinal Laparoscopy	124	80.6 %	1 yr	1 mo to 17 yr	-	22.8 %	-
50	Akansel, et al. 2003. Pediatric Radiology 33:693-6	Retrospective	Laparoscopy	17	-	-	2 mo to 12 yr	-	47.1 %	-
51	Chertin, et al. 2003. 5 Journal of l Pediatric Surgery 38:756-7	Unclear/Un known	Expectant/Obs ervation	300	0.0 %	2 yr	1 mo to 14 yr	8.0 %	-	-
52	Gorsler, et al. 2003. Surgical Endoscopy 17:571-3	Retrospective	Laparoscopy	250	-	1 mo to 5 yr	0 mo to 15 yr	-	38.0 %	-
53	Shabbir, et al. 2003. Irish Journal of Medical Science 172:18-9	Retrospective	Expectant/Obs ervation	101	-	-	0 mo to 1 yr	8.9 %	-	-
54	Toki, et al. 2003. Journal of Pediatric Surgery 38:224-6	Retrospective	Expectant/Obs ervation	545	59.3 %	2 yr	0 mo to 14 yr	6.8 %	-	-
55	Eller Miranda, et al. 2002. Pediatric Surgery Internationa l 18:463-9	Retrospective	Inguinal Laparoscopy	100	60.0 %	-	5 mo to 11 yr	-	21.0 %	-
56	Nassiri 2002. Pediatric Surgery Internationa l 18:470-1	Prospective	Expectant/Obs ervation	521	89.4 %	4 yr	1 mo to 12 yr	3.6 %	-	-
57	Shalaby, et al. 2002. Pediatric Surgery Internationa l 18:153-6	Retrospective	Laparoscopy	111	-	6 mo to 1 yr	6 mo to 8 yr	-	10.8 %	-
58	Yeung, et al. 2002. Hong Kong medical journal = Xianggang yi xue za zhi/Hong Kong Academy of Medicine 8:245-8	Retrospective	Expectant/Obs ervation	248	-	-	3 mo to 18 yr	1.6 %	-	-
59	Ballantyne, et al. 2001. 5 British 9 Journal of Surgery 88:720-3	Retrospective	Expectant/Obs ervation	181	91.2 %	5 yr	0 mo to 1 yr	7.7 %	-	-
60	El-Awady, et al. 2001. Egyptian Journal of Surgery 20:555-60	Retrospective	Inguinal Laparoscopy	81	86.2 %	1 yr	1yr to 6yr	-	47.7 %	-
61	Fette, et al. 2001. Hernia 5:92-6	Retrospective	Expectant/Obs ervation	16	-	4 mo to 3 yr	1 mo to 0 yr	18.8 %	-	-

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparoscopy
62	Geisler, et al. 2001. American Journal of Surgery 182:693-6	Retrospective	Inguinal Laparoscopy	259	81.1 %	-	0 mo to 13 yr	-	30.1 %	-
63	Guvenc 2001. Pediatric Endosurgery and Innovative Techniques 5:259-65	Retrospective	Inguinal Laparoscopy	52	-	-	1 mo to 9 yr	-	28.3 %	3.0%
64	Schier, et al. 2001. Journal of Pediatric Surgery 36:1561-3	Retrospective	Laparoscopy	143	67.1 %	-	1 mo to 13 yr	-	44.8 %	-
65	Ikeda, et al. 2000. Journal of Pediatric Surgery 35:1746-8	Retrospective	Expectant/Observation	2646	58.0 %	-	1 mo to 16 yr	6.2 %	-	-
66	Kervancioglu, et al. 2000. Acta radiologica 41:653-7	Prospective	Ultrasound	128	80.5 %	6 mo to 1 yr	1 mo to 15 yr	-	7.8 %	-
67	Birk, et al. 1999. Der Chirurg; Zeitschrift für alle Gebiete der operativen Medizin 70:290-3	Retrospective	Inguinal Laparoscopy	112	-	-	1 yr to 7 yr	-	17.0 %	-
68	Delarue, et al. 1999. Archives de Pédiatrie 6:22-6	Retrospective	Inguinal Laparoscopy	125	-	-	1 mo to 15 yr	-	29.6 %	-
69	Lym, et al. 1999. Journal of Urology 162:1169-71	Retrospective	Expectant/Observation	85	-	6 mo to 13 yr	5 mo to 9 yr	7.1 %	-	-
70	Saya, et al. 1999. La Pediatria medica e chirurgica: Medical and surgical pediatrics 21:125-7	Retrospective	Laparoscopy	56	-	-	3 yr to 10 yr	-	44.6 %	-
71	Schwobel, et al. 1999. Pediatric Surgery International 15:115-8	Retrospective	Expectant/Observation	761	68.1 %	-	-yr to 1 yr	5.0 %	-	-
72	Tackett, et al. 1999. J Pediatr Surg 34:684-7	Prospective	Expectant/Observation	548	85.2 %	6 mo to 3 yr	0 mo to 18 yr	8.8 %	-	-
73	Van Glabbeke, et al. 1999. J Pediatr Surg 34:1213-5	Prospective	Inguinal Laparoscopy	93	84.9 %	-	0 mo to 1 yr	-	46.6 %	-
74	Birk, et al. 1998. J Laparoendosc Adv Surg Tech A 8:373-9	Prospective	Inguinal Laparoscopy	75	68.0 %	-	1 yr to 7 yr	-	16.0 %	1.6%
75	Chen, et al. 1998. J Pediatr Surg 33:1784-7	Prospective	Ultrasound	203	-	-	0 mo to 13 yr	-	32.0 %	-
76	Gardner, et al. 1998. J Pediatr Surg 33:1486-9	Prospective	Inguinal Laparoscopy	24	91.7 %	2 yr	1 yr to 14 yr	-	16.7 %	0.0%
77	Kemotsu, et al. 1998. J Pediatr Surg 33:1099-102; discussion 102-3	Retrospective	Expectant/Observation	1001	64.6 %	1 yr	1 mo to 14 yr	11.6 %	-	-
78	Liu, et al. 1998. Zhonghua yi xue za zhi = Chinese medical journal; Free China ed 61:188-92	Retrospective	Inguinal Laparoscopy	91	-	1 yr	"Children"	-	35.2 %	-

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparoscopy
79	Pavlovich, et al. 1998. Tech Urol 4:141-4	Retrospective	Inguinal Laparoscopy	37	91.9 %	-	4 mo to 12 yr	-	21. 6%	-
80	Rogers, et al. 1998. Am Surg 64:119-21	Randomized	Inguinal Laparoscopy	9	66.7 %	-	3 mo to 4 yr	-	33. 3%	-
81	El- Gohary, 199 7. Pediatr Endosurg Innov Tech 1:185-8	Unclear/Un known	Laparoscopy	24	0.0 %	-	5 mo to 10 yr	-	12. 5%	-
82	Gursoy, et al. 1997. JSLs 1:225-6	Prospective	Inguinal Laparoscopy	20	80.0 %	-	1yr to 4yr	-	30. 0%	0.0%
83	Phelps, et al. 1997. J Pediatr Surg 32:445-7	Unclear/Un known	Expectant/Obs ervation	52	96.0 %	3 mo to 3 yr	0 mo to 0 yr	19. 2%	-	-
		Retrospective	Ultrasound	179	75.8 %	-	0 mo to 14 yr	-	31. 3%	-
84	Chou, et al. 1996. Radiology 201:385-8	Retrospective	Inguinal Laparoscopy	141	75.8 %	-	0 mo to 14 yr	-	15. 6%	-
85	Kaufman, et al. 1996. Urology 47:566-8	Retrospective	Inguinal Laparoscopy	24	87.5 %	1 yr	1 mo to 4 yr	-	54. 2%	0.0%
86	Nazir, et al. 1996. Acta Chir Belg 96:28-30	Retrospective	Expectant/Obs ervation	161	88.8 %	20 yr	1 mo to 12 yr	10. 6%	-	-
		Prospective	Inguinal Laparoscopy	11	-	-	"Children"	-	54. 5%	-
87	Pellegrin, et al. 1996. Am J Surg 172:602-5	Prospective	Laparoscopy	39	-	-	"Children"	-	17. 9%	-
88	Wulkan, et al. 1996. J Pediatr Surg 31:1174-6	Prospective	Inguinal Laparoscopy	80	80.0 %	-	2 mo to 12 yr	-	38. 6%	2.3%
89	Zitsman 1996. J Laparoendo sc Surg 6 Suppl 1:S15-20	Unclear/Un known	Laparoscopy	41	-	-	1 mo to 6 yr	-	24. 4%	-
90	Chin, et al. 1995. J Pediatr Surg 30:1663-5	Retrospective	Inguinal Laparoscopy	338	80.8 %	-	1 mo to 14 yr	-	31. 5%	-
91	Hrabovszky, et al. 1995. Eur J Pediatr Surg 5:152- 5	Unclear/Un known	Expectant/Obs ervation	2554	-	-	-yr to 10yr	5.4 %	-	-
92	Liu, et al. 1995. British Journal of Surgery 82:106-8	Retrospective	Laparoscopy	96	72.9 %	5 mo to - yr	1 mo to 14 yr	-	29. 2%	-
93	Ullman, et al. 1995. J Pediatr Surg 30:1684-6	Retrospective	Expectant/Obs ervation	245	0.0 %	2 yr	-yr to 18yr	10. 2%	-	-
94	Hatch, et al. 1994. J Urol 151: 237	Retrospective	Laparoscopy	8	100. 0%	1 mo to 1 yr	1yr to 18yr	- 5%	62.	-
95	Lawrenz et al. 1994. Clin Radiol 49:546-8	Prospective	Ultrasound	23	100. 0%	-	0 mo to 1 yr	-	78. 3%	-

No.	Study	Study Type	Strategy type	No. of Subjects	% Male	Follow- up	Age Range	% MCH	% CPP	% MCH after Neg Laparos copy
96	Misra, et al. 1994. J Pediatr Surg 29:1496-8	Retrospective	Expectant/Obs ervation	210	96.4 %	1 mo to 5 yr	1 mo to 6 mo	9.5 %	-	-
97	Wolf, et al. 1994. J Pediatr Surg 29:1118- 20; discussion 20-1	Retrospective	Laparoscopy	38	100.0%	-	2 mo to 11 yr	-	52. 6%	-
98	Chatterjee. 1993. Pediatr Surg Int. 8:462-3	Unclear/Un known	Expectant/Obs ervation	588	-	-	-	4.4 %	-	-
99	Chu, et al. 1993. Pediatric Surgery Internationa l 8:385-8	Retrospective	Inguinal Laparoscopy	74	75.7 %	-	3 mo to 10 yr	-	29. 7%	-
100	Hasan 1993. Pediatric Surgery Internationa l 8:462-3	Prospective	Expectant/Obs ervation	148	91.0 %	-	3 mo to 12 yr	2.0 %	-	-
101	Muraji, et al. 1993. Pediatric Surgery Internationa l 8:455-7	Retrospective	Expectant/Obs ervation	206	62.6 %	7 yr	0 mo to 13 yr	5.8 %	-	-
102	Surana, et al. 1993. Pediatric Surgery Internationa l 8:412-4	Retrospective	Expectant/Obs ervation	551	88.9 %	-	-yr to 2yr	9.8 %	-	-
103	Wardhani, et al. 1993. Pediatr Surg Int 8:464-5	Unclear/Un known	Expectant/Obs ervation	408	-	-	-	3.7 %	-	-
104	Rajput, et al. 1992. J Pediatr Surg 27:1322-4	Retrospective	Expectant/Obs ervation	45	-	-	-yr to 2yr	13. 3%	-	-
105	Sebastiani, et al. 1987. Journal de chirurgie 124:391-3	Unclear/Un known	Expectant/Obs ervation	438	-	-	-yr to 18yr	8.0 %	-	-
106	Tepas Ili, et al. 1986. American Surgeon 52:70-1	Retrospective	Expectant/Obs ervation	179	-	3 yr	1yr to 2yr	1.1 %	-	-
107	Wright 1982. Aust Paediatr J 18:55-7	Unclear/Un known	Expectant/Obs ervation	130	-	-	-yr to 12yr	22. 3%	-	-
108	McGregor, et al. 1980. J Pediatr Surg 15:313-7	Retrospective	Expectant/Obs ervation	125	83.1 %	10 yr	-yr to 10yr	19. 2%	-	-
109	Bock, et al. 1970. Acta Chir Scand 136:707-9	Unclear/Un known	Expectant/Obs ervation	174	-	-	-yr to 15yr	14. 9%	-	-
110	Hardy, et al. 1970. N C Med J 31:222-4	Unclear/Un known	Expectant/Obs ervation	279	-	-	-yr to 7yr	10. 8%	-	-
111	Gunnlaugss on, et al. 1967. Mayo Clin Proc 42:129-36	Unclear/Un known	Expectant/Obs ervation	11	-	-	-yr to 15yr	18. 2%	-	-
112	Deboer, et al. 1963. Arch Surg 86:1072-4	Unclear/Un known	Expectant/Obs ervation	100	-	-	-yr to 2yr	9.0 %	-	-
113	Hamrick, et al. 1962. Am J Surg 104:52-3	Retrospective	Expectant/Obs ervation	229	88.6 %	2 yr	-yr to 12yr	6.6 %	-	-

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114	Moscarella, et al. 1962. Am J Surg 103:453–6	Retrospective	Expectant/Obs ervation	396	88.1 %	-	1 mo to 13 yr	6.8 %	-	-
115	Sparkman 1962. Surgery 51:393–406	Unclear/Un known	Expectant/Obs ervation	259	-	-	-yr to 13yr	12. 0%	-	-
116	Martin Jr 1961. The American surgeon 27:182–5	Unclear/Un known	Expectant/Obs ervation	16	-	-	-yr to 13yr	37. 5%	-	-
117	Santulli, et al. 1961. JAMA 176:110–3	Unclear/Un known	Expectant/Obs ervation	331	-	-	-yr to 18yr	13. 0%	-	-
118	Davis 1960. Am Surg 26:470–5	Unclear/Un known	Expectant/Obs ervation	266	-	-	-yr to 18yr	12. 8%	-	-
119	Kiesewetter, et al. 1959. J Am Med Assoc 171:287–90	Unclear/Un known	Expectant/Obs ervation	237	-	-	-yr to 2yr	31. 2%	-	-
120	Williams 1959. Va Med Mon (1918) 86:314–8	Unclear/Un known	Expectant/Obs ervation	191	-	-	-yr to 16yr	2. 1 %	-	-
121	Clausen, et al. 1958. Surgery 44:735–40	Unclear/Un known	Expectant/Obs ervation	568	-	-	-yr to 18yr	9.2 %	-	-
122	Goldstein, et al. 1958. Ann Surg 148:819–22	Retrospective	Expectant/Obs ervation	136	0.0 %	-	0 mo to 16 yr	8.1 %	-	-
123	Clatworthy, et al. 1957. Postgrad Med 22:122–31	Unclear/Un known	Expectant/Obs ervation	478	-	-	-yr to 18yr	6.1 %	-	-
124	Fischer, et al. 1957. Helv Chir Acta 24:346–50	Unclear/Un known	Expectant/Obs ervation	625	-	-	-	9.6 %	-	-
125	Shidler 1957. Stanford Med Bull 15:83–9	Unclear/Un known	Expectant/Obs ervation	52	-	-	-yr to 11yr	3.8 %	-	-
126	Kleager, et al. 1956. AMA J Dis Child 92:266–71	Unclear/Un known	Expectant/Obs ervation	211	-	-	-yr to 12yr	7.6 %	-	-
127	Packard, et al. 1953. Surg Gynecol Obstet 97:603–7	Unclear/Un known	Expectant/Obs ervation	614	-	-	-yr to 18yr	3.7 %	-	-
128	Larsen 1949. Surgery 25:307–28	Unclear/Un known	Expectant/Obs ervation	93	-	-	-yr to 10yr	4.3 %	-	-
129	Hogg 1941. Surg Clin North A 21:425–32	Unclear/Un known	Expectant/Obs ervation	105	-	-	-yr to 12yr	18. 1%	-	-