Surg Endosc (2016) 30:1466–1472
DOI 10.1007/s00464-015-4354-z

Comparison of percutaneous extraperitoneal closure (LPEC) and open repair for pediatric inguinal hernia: experience of a single institution with over 1000 cases

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Received: 11 March 2015 / Accepted: 16 June 2015 / Published online: 3 July 2015

Abstract
Background Recently, laparoscopic percutaneous extraperitoneal closure (LPEC) for pediatric inguinal hernia has become more popular. The aim of this study was to compare LPEC with open repair (OR) performed in one institution.
Methods In total, 1050 patients underwent OR from July 2003 to June 2008, and 1017 patients underwent LPEC from July 2008 to June 2013. The mean follow-up period was 100 months in OR and 40 months in LPEC ($p < 0.01$). Given the difference in the follow-up periods, the log-rank test was used for the analysis of the long-term results. The mean age at operation in OR and LPEC was 3.72 and 3.75 years, respectively ($p = 0.81$). The mean body weight was 14.73 and 14.72 kg, respectively ($p = 0.98$). The male/female ratio was 617/433 and 561/456, respectively ($p = 0.10$). In the LPEC procedure, the asymptomatic contralateral internal ring was routinely observed, and when a patent processus vaginalis (PPV) was confirmed, prophylactic surgery was performed.
Results The mean operative time for unilateral surgery in OR and LPEC was 28.5 and 21.2 min, respectively ($p < 0.01$). The mean operative time for bilateral surgery was 52.3 and 25.4 min, respectively ($p < 0.01$). Recurrence was confirmed in 0.52 % in OR and in 0.27 % in LPEC ($p = 0.53$). In the LPEC group, 41.7 % of patients with clinically unilateral inguinal hernia were confirmed to have a contralateral PPV and underwent prophylactic LPEC. Contralateral metachronous inguinal hernia (CMIH) was seen in 6.48 % in OR and in 0.33 % in LPEC ($p < 0.01$). Two patients showed postoperative testicular atrophy, and two had iatrogenic postoperative cryptorchism after OR, while no postoperative testicular complications were seen after LPEC.
Conclusion Both OR and LPEC obtained satisfactory results from the perspective of recurrence rate and complications. Prophylactic contralateral LPEC is useful for preventing CMIH without prolonging operative time compared with OR. The midterm safety and efficacy of LPEC are proven.

Keywords Laparoscopic percutaneous extraperitoneal closure · Pediatric inguinal hernia · Laparoscopic inguinal hernia repair · Contralateral metachronous inguinal hernia · Open herniorrhaphy

Inguinal hernia is one of the most common diseases in the area of pediatric surgery. Recently, laparoscopic repair for pediatric inguinal hernia has been increasing. The concept of laparoscopic hernia repair can be divided into two groups. The first group is intraperitoneal internal ring suturing [1–3], and the second is extraperitoneal closure [4–15]. Recently, there is a trend for increased reports of extraperitoneal closure because of its ease of use and good results. There are some comparative reports between laparoscopic hernia repair and open repair, including a systematic review [16–22]. However, few reports have compared extraperitoneal closure with conventional open hernia repair, especially large case series in one institution [22]. In the present study, laparoscopic percutaneous extraperitoneal closure (LPEC) was compared with open repair (OR) for over 1000 cases in each group performed in one institution.

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Materials and methods

The study protocol was approved by the Shizuoka Children's Hospital ethics board and complied with the Helsinki Declaration. This was a retrospective study in one institution. Our institution started LPEC for essentially all patients with inguinal hernia in July 2008. This study compared LPEC with OR in 1050 patients who underwent OR from July 2003 to June 2008 and 1017 patients who underwent LPEC from July 2008 to June 2013. From July 2008, 29 patients underwent OR for reasons such as a history of peritonitis and associated cryptorchidism. These 29 patients were excluded from the study. In this study, all cases of both OR and LPEC were clinically diagnosed as having an indirect inguinal hernia. Diagnosis of hernia was made when herniation was confirmed by examination via a surgeon or ultrasound. Diagnosis of recurrence was made in a similar way. All surgeries in both LPEC and OR were performed by pediatric surgical fellows under the supervision of two consulting surgeons. In our institution, the previous experience of the fellows has changed during the past few years. Thus, in the present study, the prior experience of the operating surgeons in the LPEC group did not match that of the surgeons in the OR group. In the OR group, all of the operating surgeons had previous experience with the procedure before starting our fellowship. In the LPEC group, most of the operating surgeons did not have previous experience with the LPEC procedure before starting our fellowship.

The patient characteristics are shown in Table 1. The mean age at operation was 3.72 years in the OR group and 3.75 years in the LPEC group ($p = 0.81$). The mean body weight at operation was 14.7 kg in the OR group and 14.7 kg in the LPEC group ($p = 0.98$). The male/female ratio was 617:433 in the OR group and 561:456 in the LPEC group ($p = 0.10$). In the OR group, 546 cases were clinically right-sided inguinal hernias, 391 were left-sided inguinal hernias, and 113 were bilateral inguinal hernias. In the 937 clinically unilateral patients, 58 had undergone contralateral inguinal herniorrhaphy. In the LPEC group, 534 cases were clinically right-sided inguinal hernias, 391 were left-sided inguinal hernias, and 92 were bilateral inguinal hernias. In the 925 clinically unilateral inguinal hernia cases, 17 had undergone contralateral inguinal herniorrhaphy. In the LPEC procedure, an asymptomatic contralateral internal ring was routinely observed, and when a patent processus vaginalis (PPV) was confirmed, prophylactic surgery was performed regardless of the size of the patency.

In the first clinic visit, we explained to parents that LPEC may have an unknown risk because LPEC was a relatively new procedure. We also explained to parents in advance, the concept of contralateral prophylactic surgery, including the risk of complications such as spermatic cord injury. No parents in the LPEC group rejected the operation because of this risk.

The mean follow-up period was 100 months in the OR group and 40 months in the LPEC group ($p < 0.01$). Given this difference in follow-up period, log-rank testing was used to analyze long-term results such as recurrence rate and contralateral metachronous inguinal hernia (CMIH). Anesthesia time, operation time, CMIH, and the complications of each operative procedure were compared. In some cases in each procedure, other surgery, such as umbilical hernia repair and orchiopexy, was performed at the same time. In the comparisons of anesthesia time and operation time, such cases were excluded.

Table 1 Patient characteristics

	OR	LPEC	*p*
All patients	1050	1017	
Age (years) (mean)	3.72	3.75	0.81
Body weight (kg) (mean)	14.7	14.7	0.98
Male/female	617/433	561/456	0.1
Age under 1 year	16.4 % (172/1050)	18.5 % (188/1017)	0.21
Side (right/left/bilateral)	546/391/113	534/391/92	0.42
Follow-up period (months) (mean)	100	40	<0.01
Male patients	617	561	
Age (years) (mean)	3.11	3.16	0.73
Body weight (kg) (mean)	13.7	13.8	0.85
Side (unilateral/bilateral)	546/71	511/50	0.14
Female patients	433	456	
Age (years) (mean)	4.59	4.67	0.53
Body weight (kg) (mean)	16.2	16	0.75
Side (unilateral/bilateral)	391/42	414/42	0.8

Operative procedure

Open repair

The OR procedure was based on that described by Potts et al. [23]. The concept of surgery was simple high ligation and possible removal of the hernia sac.

LPEC

The LPEC procedure was based on what was described by Takehara et al. [4]. Surgery was performed under general anesthesia with spinal or epidural block. The patient was placed in the supine position. A 3-mm cannula for the laparoscope was placed at the umbilicus, and a 2-mm cannula for the grasping forceps was placed on the right side of the umbilicus. First, bilateral internal inguinal rings were checked carefully, and when a PPV was confirmed on the asymptomatic side, prophylactic surgery was performed. Then, a 19-gauge LPEC needle (Lapaherclosure; Hakko Medical Co., Nagano, Japan), which has a wire loop to hold the material at the tip with nonabsorbable suture, was inserted at the midpoint of the inguinal line. The orifice of the hernia sac was closed extraperitoneally with circuit suturing around the internal inguinal ring using the LPEC needle. The detailed technique was based on the description reported by Takehara et al. [4].

Analysis

GraphPad Prism 6 (GraphPad Software Inc., San Diego, CA) was used for statistical analysis. Continuous data were analyzed using the Mann–Whitney test. Categorical data were mainly analyzed using the Chi-square test and Fisher's exact test. Only long-term results (incidence of recurrence and contralateral metachronous inguinal hernia) were analyzed using the log-rank test. p values were considered significant when <0.05.

Results

In LPEC, all surgery was completed laparoscopically. In the OR group, 937 of 1050 patients diagnosed with unilateral inguinal hernia underwent unilateral surgery, and 113 of 1050 patients underwent bilateral surgery. In the LPEC group, 41.7 % (379/908 patients diagnosed as unilateral, excluding cases in which contralateral surgery had already been performed) were confirmed to have a contralateral PPV and underwent prophylactic LPEC. Thus, in LPEC, 546 of 1017 patients underwent unilateral surgery and 471 underwent bilateral surgery. Surgical outcomes are listed in Table 2. Mean anesthesia times for unilateral surgery in the OR and LPEC groups were 64.5 and 60.7 min, respectively ($p < 0.01$). Mean anesthesia times for bilateral surgery were 90.6 and 64.9 min, respectively ($p < 0.01$). Mean operative times for unilateral surgery in the OR and LPEC groups were 28.5 and 21.2 min, respectively ($p < 0.01$). Mean operative times for bilateral surgery were 52.3 and 25.4 min, respectively ($p < 0.01$). The frequency of postoperative recurrence was 0.52 % in the OR group (6/1163 preoperative symptomatic sides) and 0.27 % in the LPEC group (3/1109 preoperative symptomatic sides) ($p = 0.53$, log-rank test) (Fig. 1). The frequency of postoperative contralateral metachronous inguinal hernia (CMIH) was 6.48 % in the OR group (57/879 preoperative asymptomatic sides without a history of herniorrhaphy) and 0.33 % in the LPEC group (3/908 preoperative asymptomatic sides without history of herniorrhaphy; $p < 0.01$, log-rank test) (Fig. 2).

Table 2 Outcomes by procedure

	OR	LPEC	p
Operation (uni/bi)	937/113	546/471	
Anesthesia time (min)			
Unilateral	64.5	60.7	<0.01*
Bilateral	90.6	64.9	<0.01*
Operation time (min)			
Unilateral	28.5	21.2	<0.01*
Bilateral	52.3	25.4	<0.01*
Recurrence	0.52 % (6/1163)	0.27 % (3/1109)	0.51**
CMIH	6.48 % (57/879)	0.33 % (3/908)	<0.01**

CMIH contralateral metachronous inguinal hernia

* Mann–Whitney U test, ** log-rank test

LPEC and OR were also compared by sex (Table 3). Mean anesthesia time for unilateral surgery was 70.2 min for male patients with OR (OM), 61.1 min for male patients with LPEC (LM), 57.1 min for female patients with OR (OF), and 60.0 min for female patients with LPEC (LF) (OM vs. LM, $p < 0.01$; OF vs. LF, $p = 0.02$). Mean anesthesia time for bilateral surgery was 100.8 min in OM, 66.2 min in LM, 74.4 min in OF, and 63.5 min in LF (OM vs. LM, $p < 0.01$; OF vs. LF, $p < 0.01$). Mean operative time for unilateral surgery was 33.4 min in OM, 23.1 min in LM, 22.1 min in OF, and 18.6 min in LF (OM vs. LM, $p < 0.01$; OF vs. LF, $p < 0.01$). Mean operative time for bilateral surgery was 61.6 min in OM, 27.5 min in LM, 37.6 min in OF, and 23.2 min in LF (OM vs. LM, $p < 0.01$; OF vs. LF, $p < 0.01$). The frequency of postoperative recurrence was 0.87 % in OM, 0.49 % in LM, 0 % in OF, and 0 % in LF (OM vs. LM, $p = 0.62$; OF vs. LF, $p = 1$: log-rank test). The frequency of CMIH was 3.64 % in OM, 0.59 % in LM, 10.64 % in OF, and 0 % in LF (OM vs. LM, $p < 0.01$ OF vs. LF, $p < 0.01$: log-rank test).

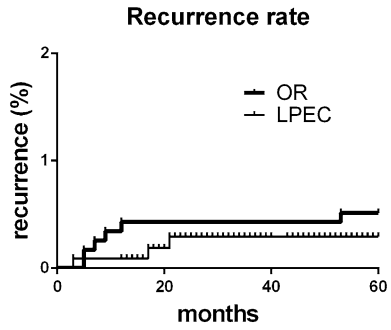

Fig. 1 Kaplan–Meier estimate for recurrence

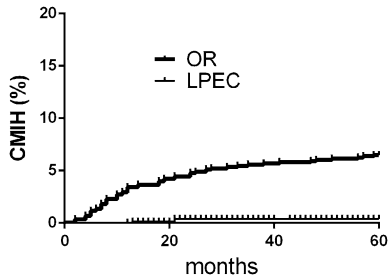

Fig. 2 Kaplan–Meier estimate for CMIH

Postoperative complications are listed in Table 4. Postoperative testicular atrophy was seen in 0.29 % of patients in the OR group (2/689 sides of surgery performed in males) and 0 % in the LPEC group (0/806 sides of surgery performed in males) ($p = 0.21$). Iatrogenic cryptorchidism was seen in 0.29 % of patients in the OR group (2/689 sides of surgery performed in males) and 0 % in the LPEC group (0/806 sides of surgery performed in males) ($p = 0.21$). Surgical site infection was seen in 0.48 % (5/1050) in the OR group and in 0.79 % (8/1017) in the LPEC group ($p = 0.54$).

In LPEC, surgical site infection occurred in the umbilical incision in all patients. Among the six patients who underwent repeat LPEC due to recurrence or CMIH, none showed intra-abdominal adhesions during the second surgery. In consideration of the difference in follow-up periods, we also compared recurrence rate and testicular atrophy at 40 months after operation. At 40 months after operation, testicular atrophy was seen in 0.29 % of the patients in the OR group (2/689 sides of surgery performed in males) and 0 % in the LPEC group (0/367 sides of surgery performed in males) ($p = 0.55$). The frequency of postoperative recurrence at 40 months after operation was

Table 3 Outcomes by procedure and sex

	OR	LPEC	*p*
Male patients	617	561	
Operation (unilateral/bilateral)	546/71	316/245	
Anesthesia time (min)			
Unilateral	70.2	61.1	<0.01*
Bilateral	100.8	66.2	<0.01*
Operative time (min)			
Unilateral	33.4	23.1	<0.01*
Bilateral	61.6	27.5	<0.01*
Recurrence	0.87 % (6/688)	0.49 % (3/611)	0.62**
CMIH	3.6 % (19/522)	0.59 % (3/506)	<0.01**
Female patients	433	456	
Operation (unilateral/bilateral)	391/42	230/226	
Anesthesia time (min)			
Unilateral	57.1	60	0.02*
Bilateral	74.4	63.5	<0.01*
Operative time (min)			
Unilateral	22.1	18.6	<0.01*
Bilateral	37.6	23.2	<0.01*
Recurrence	0	0	1**
CMIH	10.6 % (38/357)	0	<0.01**

* Mann–Whitney *U* test, ** log-rank test

Table 4 Complications by procedure

	OR	LPEC	p*
All patients			
Hydrocele	0 (0/1163)	0.07 % (1/1488)	1
Recurrence	0.52 % (6/1163)	0.27 % (3/1109)	0.51
Surgical site infection	0.48 % (5/1050)	0.79 % (8/1017)	0.54
Iatrogenic cryptorchidism	0.29 % (2/689)	0 (0/806)	0.21
Testicular atrophy	0.29 % (2/689)	0 (0/806)	0.21
40 months after operation			
Recurrence	0.43 % (5/1163)	0.54 % (3/557)	0.72
Testicular atrophy	0.29 % (2/689)	0 (0/367)	0.55

* Fisher's exact test

0.43 % in the OR group (5/1163 preoperative symptomatic sides) and 0.54 % in the LPEC group (3/557 preoperative symptomatic sides) ($p = 0.72$: Fisher's exact test).

Discussion

Laparoscopic inguinal hernia repair can be divided into two groups. The first group is intraperitoneal internal ring repair. In the early days of laparoscopy, this type of repair accounted for the majority of repairs [1–3]. The second group is extraperitoneal closure. Recently, there is a trend for increased reports of extraperitoneal closure because of its ease of use and good results [24]. In particular, LPEC, reported by Takehara et al. [4], is performed widely in Japan [10, 11, 13–15]. There have been some comparisons between traditional open herniorrhaphy and laparoscopic repair, including a randomized study and a systematic review. However, reports that covered extraperitoneal closure are limited, especially large case studies in a single institution [5]. In our institution, we changed the operative procedure for inguinal hernia in July 2008 for all patients in principle. Thus, we could compare LPEC performed after July 2008 with OR performed before June 2008 for patients with generally similar backgrounds, though with different follow-up periods.

In the present study, operative time was significantly shorter with LPEC than with OR for both unilateral and bilateral inguinal hernias. In previous reports, the operative time for unilateral surgery had a tendency to be equal or longer with laparoscopic repair than with open repair [18–21]. A comparison between intraperitoneal suturing closure and extraperitoneal closure showed that operative time was shorter in extraperitoneal closure [24]. The present result suggested that LPEC could be the superior procedure with respect to operative time. Previous reports showed that operative time for bilateral hernia was shorter in laparoscopic repair than in open repair [18, 19, 21]. This seems mainly due to the fact that bilateral surgery can be performed using the same port setting with laparoscopic repair, while open surgery needs almost double the time of unilateral surgery. The present results fit these previous results.

Anesthesia time usually correlates with operative time. In the present study, anesthesia time was longer with LPEC for female unilateral surgery. In our institution, both OR and LPEC were performed under general anesthesia. However, the difference between operative time and anesthesia time seemed to be greater with LPEC than with OR. This may have been because pneumoperitoneum was needed in LPEC. When pneumoperitoneum was performed, deeper sedation was needed, and thus, LPEC required longer postoperative recovery.

Postoperative recurrence is the most important complication. Since the present series had a significant difference in the follow-up period between the two procedures, the log-rank test was used for analysis. In this respect, the present results may vary from those of previous reports. However, we believe that this analysis was more reliable for long-term results. LPEC was acceptable from the perspective of recurrence. Interestingly, recurrence was seen only in males in both groups. In OR, the most important difference in the operative procedure between males and females is dissection of testicular vessels and the spermatic duct. In this process, the hernia sac is likely to be injured. On the other hand, injury of the hernia sac rarely occurs in female patients. This injury might contribute to recurrence. A similar process of dissection also exists in LPEC. In LPEC, the peritoneum was likely to be injured and skipped in the process to pass the testicular vessels and spermatic duct. When peritoneum was skipped, complete circuit suturing of the hernia sac became impossible. This injury or skip might also contribute to recurrence in LPEC. Complete circuit ligation of the hernia sac is important to prevent recurrence. Recurrence was more frequent in a previous report of intraperitoneal suturing closure than in the present study [1, 3, 21, 24]. This fact also supports the importance of complete ligation of the hernia sac.

Perioperative complications of inguinal hernia repair include surgical site infection (SSI), iatrogenic cryptorchidism, and testicular atrophy. In the present results, there was no significant difference between OR and LPEC in these complications. Inguinal hernia repair is classified as a "clean operation"; as such, the incidence of SSI should be as low as possible. In the present study, although the difference was not significant, the frequency of SSI was higher in LPEC. We believe the reason is that LPEC requires an umbilical incision. In the umbilicus, it is very difficult to remove blot. Therefore, the umbilical incision is likely to be a contaminated incision. In fact, all SSIs were seen in umbilical incisions in LPEC. Nevertheless, the results regarding SSIs in the present study seem acceptable, and in this respect, both OR and LPEC can be said to be equally safe operations. Testicular complications, such as iatrogenic cryptorchidism and testicular atrophy, are very important complications for pediatric inguinal hernia. In most previous reports, laparoscopic inguinal hernia repair was considered less invasive to the spermatic cord than OR because the laparoscopic approach did not destroy the structure of the inguinal canal. In the present study, there was no significant difference in testicular complications. However, we think it is very important that there were no testicular complications in LPEC. This fact supports the lower invasiveness of LPEC.

One of the advantages of laparoscopic inguinal hernia repair is prevention of CMIH. In the present study, 41.7 % of patients with clinically unilateral inguinal hernia had a contralateral PPV and underwent prophylactic surgery. Previous reports stated that laparoscopic contralateral internal inguinal ring observation was attempted from the early 1990s [25]. A contralateral PPV was seen in 6–66 % of cases [16, 25–32]; the range is very wide. This seems to be because the way of observing the contralateral internal ring varied in each study. A contralateral PPV is sometimes concealed by a peritoneal slit or veil. To confirm a contralateral PPV strictly, the internal ring should be checked carefully using forceps not to miss such a slit or veil. In the present study, these checks were performed carefully, and thus, the rate of contralateral PPV seemed to be reliable. Some comparative studies between OR and laparoscopic repair reported that prophylactic surgery reduced the occurrence of CMIH [15, 17–19, 21, 27]. As in previous reports, the present results showed that CMIH was significantly less frequent in LPEC than in OR. Given the difference in the follow-up periods, the log-rank test was used for analysis as it has for recurrence. Thus, we believe that this analysis for CMIH was also reliable as a long-term result. Of course, the fact that not all patients who have contralateral PPV develop CMIH is very important. In the present study, 6.48 % patients who underwent OR developed CMIH. This may indicate that in 41.7 % of patients who have contralateral PPV, only about 15 % will develop CMIH. But at the present time, it is impossible to predict specifically who will develop CMIH. The possibility of developing CMIH would not always depend on the size of the PPV. Actually, three patients who were diagnosed as not having contralateral PPV developed CMIH.

The present results also showed that operative time was shorter for bilateral LPEC than for unilateral OR (25.4 vs. 28.5 min: $p < 0.01$). Because of these results, the superiority in operative time and complication rates related to testicular atrophy and iatrogenic ascending testes; we can say that prophylactic surgery significantly reduced the occurrence of CMIH without increasing the incidence of complications.

The present results showed that LPEC had better outcomes than OR in the short- to midterm, but of course, some controversies remain regarding the long-term effects of LPEC, including fertility. In OR, there were some extremely long-term assessments [33, 34]. The present results suggest that LPEC was less invasive for testicular vessels and the spermatic duct, but the long-term impact is unknown. Laparoscopic inguinal hernia repair has been used for only 10–20 years worldwide. In the future, LPEC should also be assessed with respect to lifelong effects. If new problems arise, the indications for LPEC, especially prophylactic contralateral surgery, may need to be changed.

In conclusion, in our institution, both OR and LPEC produced satisfactory results from the perspective of recurrence rate and complications. In the present series, operative time was shorter for bilateral LPEC than for unilateral OR. This shows that prophylactic contralateral LPEC is useful for preventing CMIH without prolonging operative time, compared with OR. The midterm safety and efficacy of LPEC are proven, but lifelong assessment remains an outstanding issue.

Compliance with Ethical Standards

Disclosures Hiromu Miyake, Koji Fukumoto, Masaya Yamoto, Hiroshi Nouso, Masakatsu Kaneshiro, Hideaki Nakajima, Mariko Koyama, and Naoto Urushihara have no conflicts of interest or financial ties to disclose.

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