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***Retrospective Study***

**Clinical outcomes and ergonomics analysis of three laparoscopic techniques for Hirschsprung’s disease**

Aubdoollah TH *et al*. hirschsprung’s disease: Age, transition-zone and cosmetics

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**Data sharing:** The technical appendix, statistical code, and dataset are available from the corresponding author at tshaotao83@126.com. All the participants gave informed consent for data sharing when they have enrolled in this study. No additional data are available.

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**Abstract**

**AIM:** To report the clinical outcomes and ergonomics analysis of three laparoscopic approaches in the management of Hirschsprung’s disease (HD).

**Methods:** There were 90 pediatric patients [63 boys, 27 girls; mean age: 3.6 ±2.7 (1–90.2) months] who underwent laparoscopic endorectal pull-through Soave procedure for short and long segment HD in our hospital. Three laparoscopic approaches were used; conventional laparoscopic pull-through (CLP) in 30 patients between 2009 and 2013, single-incision laparoscopic pull-through (SILP) in 28 patients between 2010 and 2013 and hybrid single-incision laparoscopic pull-through (H-SILP) in 32 patients between 2011 and 2013. We applied the hybrid version of single-incision approach in 2011 to preserve the cosmetic advantage of SILP and the ergonomic advantage of CLP. We retrospectively analyzed the clinical data, cosmetic results and ergonomics of these three approaches to have a better understanding of the selection of one approach over another.

**Results:** The CLP, SILP and H-SILP groups were similar in regard to age, sex, transition zone, blood loss, hospital stay and intraoperative complications. Early and late postoperative results were not different, with equal daily defecation frequency and postoperative complications. No conversion to open technique was needed and none of the patients had recurrent constipation. With proper training, the ergonomics challenges were overcome and insignificant operative times were registered for the general operative time, the patients < 1-year-old and the short segment HD patients. However, significant operative times (minutes) were registered for patients >1-year-old (CLP and H-SILP *vs* SILP: 120 ± 15 and 119 ± 12 *vs* 140 ± 7, *P*< 0.05 *vs* SILP) and for long segment HD patients (CLP and H-SILP *vs* SILP: 152 ± 3.5 and 154 ± 3.6 *vs* 176 ± 2.3, *P*< 0.05 *vs* SILP). The best cosmetic result was registered in the SILP (scarless) followed by the H-SILP (near scarless appearance) and the CLP (visible scars).

**Conclusion:** Based on the results, we believed that the laparoscopic approach should be selected according to the age, transition zone and desired cosmetics result.

**Key words:** hirschsprung’s disease; Laparoscopic pull-through; Ergonomic; Cosmetic; Age

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**Core tip:** This manuscript is about the comparison of the (1) hybrid single-incision laparoscopic endorectal pull-through; (2) conventional laparoscopic endorectal pull-through; and (3) single-incision laparoscopic endorectal pull-through in selected Hirschsprung’s disease patients. The cosmetic advantage was not the only concerns, but also the age and transition zone relating aspects of these three approaches. We reported the clinical outcomes and ergonomics analysis by comparing the results, in order to better understand the choice of one approach over the other regarding to the age, transitional zone and desired cosmetic result.

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**Introduction**

Hirschsprung’s disease (HD) is a well known disease among pediatric surgeons; it is defined as a congenital abnormality of the enteric nervous system with the absence of ganglion cells in the distal parts of the colon resulting in a functional obstruction[1].

The laparoscopic technique has improved the surgical treatment of HD and has inspired surgeons to undertake more complex laparoscopic procedures to (1) promote early resumption of gastrointestinal function; (2) decrease complications; and (3) achieve better cosmetic results. Georgeson *et al*[2] described the conventional laparoscopic pull-through (CLP) procedure in 1995 and the single-incision laparoscopic pull-through (SILP) procedure was reported by Muensterer *et al*[3] in 2010. Since 1999, we have adopted the CLP procedure to treat various types of HD patients. In 2010, we started to perform SILP for the cosmetic reason, however this procedure was challenging. In 2011, after accumulating a large amount of experience in CLP[4-6] and SILP[7], we applied the hybrid single-incision laparoscopic pull-through (H-SILP)[8], a combination of both procedures to preserve the cosmetic advantage of SILP and the ergonomic advantage of CLP.

Here by, we described the main three laparoscopic approaches that we have been using to treat HD with the same endorectal pull-through modified Boley-Soave procedure. We reported the clinical outcomes and ergonomics analysis by comparing the results, in order to better understand the choice of one approach over the other regarding to the age, transitional zone and desired cosmetic result.

**MATERIALS AND METHODS**

Retrospectively, we compared the clinical data of 90 cases (63 boys, 27 girls; mean age: 3.6 ± 2.7 (1–90.2 mo) who underwent laparoscopic pull-through modified Soave procedure for short and long segment HD between 2009 and 2013. Three laparoscopic approaches were used; CLP in 30 patients between 2009 and 2013, SILP in 28 patients between 2010 and 2013 and H-SILP in 32 patients between 2011 and 2013.

The diagnosiswas established in all the patients by rectal biopsy and anorectal manometry before the surgery[9,10]. Contrast barium enema[11] was done to estimate the extent of the disease. The intraoperative frozen section biopsies and postoperative pathology report confirmed the absence of ganglion cells and the transitional zone. Hematoxylin and eosin (HE), calretinin and microtubule-associated protein-2 (MAP-2)antibodies were used as histochemical staining for the detection of the presence or absence of the ganglion cells[12].

All these 90 patients underwent the same coloanal anastomosis. The transitional zone was located in rectosigmoid (80 cases) and distal descending colon (10 cases). Patients who (1) required total or subtotal colectomy; (2) were treated by other procedures than the modified Boley-Soave procedure; and (3) lost of follow-up or previously operated in other hospitals, were not included in this study. We also excluded three patients from the SILP group with long segment HD (aged 22, 34 and 49 mo), because an additional working port was added to the right lower abdomen in order to retract the huge elongated colon for better exposure and to facilitate the dissection. Otherwise, it would have been very difficult to expose the vascular arcades of descending colon and mobilize the splenic flexure. The operative time for the patients < 1-year-old (*n* = 63; infant) and > 1-year-old (*n* = 27; toddler, preschooler and school-age), and for the transitional zone of the three groups were compared to analyze the ergonomic impact or difficulties of the different laparoscopic approaches related to the age and transitional zone. None of the patients had previous colostomy. Preoperatively, daily colon irrigations (mechanical bowel preparation) were performed for two to seven days. Usually, intravenous antibiotics were started one to two days prior to operation and stopped three days after operation. Patients were reviewed on a monthly basis for 6 mo post-operatively and then on an interval of 3-6 months with mean follow-up 36 ± 10 (17-53) mo.

***Statistical analysis***

SPSS 13.0 package was used for data analysis. The transition zone, age at surgery, operative time, estimated blood loss, intraoperative complications, conversion to open surgery, time of flatus passage, postoperative hospital stay and defecation frequency were compared by the ANOVA test. The sex and postoperative complications were compared using the *χ*2 test. Student t-test was used to compare the mean scar score between the CLP and the H-SILP groups. All the results were described in mean ± SD or percentage. A *P* value < 0.05 was considered as significant. The statistical methods of this study were reviewed by Prof. Ping Yin, PhD (Department of Epidemiology and Biostatistics School of Public Health Tongji Medical College, Huazhong University of Science and Technology. 13, Hangkong Road Wuhan, 430030，PR. China. Email: ping\_y2000@163.com).

### *Surgical procedure*

### All the cases were performed under endotracheal general anesthesia. Cleaning and draping was done for intraoperative change of position from laparoscopic to transanal part. Usually, the surgeon would position himself at the head or on the right of the table, facing the monitor and the table was adjusted with the patient lying in a 30° head-down position.

In all the three groups of patients, the surgery was performed in two phases: (1)the laparoscopic phase; and (2) the transanal phase.

**laparoscopic phase:** the CLP, SILP and H-SILP differ from each other in regard to the positioning of the trocars and instruments (Figure 1) but the objective remains the same. Usually, one assistant surgeon was needed for handling the 30° straight laparoscopic camera. No additional trocar was used.

In CLP, the first 5-mm trocar was introduced in the umbilicus via an umbilical skin incision as laparoscope port. Under vision, after pneumoperitoneum was stabilized, two additional 5-mm trocars were introduced in the abdomen at the respective position: 1 on the left side and 1 on the right side (Figure 1A).

In SILP, the first 5-mm trocar was introduced in the umbilicus centrally via a single vertical umbilical skin incision as a laparoscope port, and pneumoperitoneum was stabilized. Laterally to the laparoscopic port, two additional trocars as operator ports were introduced into the abdominal cavity after the skin was stretched horizontally (one 5-mm trocar introduced on the right for an ultrasonic scalpel and one 3-mm trocar introduced on the left for a grasping forceps) (Figure 1B).

In H-SILP, two 5.0 mm trocars were introduced in the abdominal cavity via a vertical incision at the umbilicus. After pneumoperitoneum was stabilized, the left port was used as the laparoscope port and the right port was used as the working port for the ultrasonic scalpel or grasping forceps. A trocarless 3.0 mm grasping forceps was punctured in the abdomen via a stab incision, 10 cm to the left side of the umbilicus (Figure 1C).

After the insertion of the laparoscopic instruments, an overall view was obtained and the transition zone was located. One or two seromuscular biopsies were obtained for frozen section histology to identify the ganglionic bowel and to decide the dissecting level of the mesentery. Using the ultrasonic scalpel a window was made in the sigmoid mesentery and the rectosigmoid colon was mobilized 5 cm above the transitional zone by dissecting the mesentery and relative vessels; however, the marginal arcade was preserved. The colonic pedicle was freed long enough, so that it could be pulled-through without tension or over stretching. The dissection was stopped at the rectal peritoneal reflection. After laparoscopic dissection, the ports were left in situ and we changed our position for the transanal phase. For long segment HD patients, mobilization of the colon was done to a higher level.

**transanal phase:** all the three groups underwent the same modified Boley-Soave’s endorectal pull-through procedure[4-13]. This modified procedure consists of: (1) lesser dissection in the pelvic cavity by the harmonic scalpel; (2) a long muscular rectal cuff was developed for more than 5 cm until the peritoneal reflection by dissecting the submucosa layer of the rectum using electrocautery which was then shortened to 2-3 cm; (3) the rectal muscular cuff was then partially resected in a “V-shaped” at the posterior wall; and (4) resection of the necessary amount of the mobilized colon and coloanal anastomosis with the short cuff (Figure 2A, B, C and D).

Once the anastomosis was completed, a rectal tube was inserted and laparoscopy was performed again to check for orientation of the pull-through bowel. Chitogel (15 ml of medical chitosan and physiological balanced solution) was injected at the dissection site via one of the port to prevent peritoneal adhesion[14]. No abdominal drain was inserted. The port site at the umbilicus was stitched by 2-0 vicryl. The skin of the umbilicus and the other incisions were closed with skin glue. The post operative appearance of the umbilicus and abdominal wound in the three groups were compared (Figure 3A, B and C).

Post-operatively, patients were kept on intravenous total parenteral nutrition[15] and nasogastric decompression for 12-24 h. Intravenous antibiotics were given for 72 h and urinary catheter was removed after 72 h. Patients were fed orally when bowel sounds returned. The parents were taught about wound caring and toileting of the patients. The patients were discharged when they were clinically stable. Each patient was reviewed 2 wk after the operation, where a digital rectal examination was performed and anal dilatation[16,17] was taught to the parents, so that they could perform it at home with Hegar dilators twice daily for 3-6 mo, until the dilatation process became easy and painless with the recommended dilator size.

**Results**

***General characteristics, operative data and complications***

The CLP, SILP and H-SILP groups were similar in regard to age, sex, transition zone, blood loss, general operative time, hospital stay, and intraoperative complications (Table 1). Early and late postoperative results were not different, including equal daily defecation frequency and postoperative complications. There was no conversion to open technique. Post-operative enterocolitis occurred in 2 patients, one from the SILP (3.6%) and the other one from H-SILP (3.3%) groups respectively, and both of them were treated by intravenous fluid, antibiotic, parenteral nutrition and enemas during re-hospitalization. Anastomotic leak occurred in 1 (33.3%) case from the CLP group and was treated conservatively by; rectal decompressing tube, intravenous antibiotic and total parenteral nutrition to allow the leak to heal by itself. Perianal excoriation occurred in 26 (28.8%) patients (7 SILP, 10 CLP and 9 H-SILP) and was treated by keeping the perianal clean, dry and application of stomahesive. All the patients achieved normal defecation without incontinence or recurrent constipation with a mean timespan of 3.0 mo to obtain normal defecation frequency (1-2 times/d).

***Operative time among the three groups relatively to the age and transitional zone***

The difference in operative time was insignificant for the patients < 1-year-old (*P* > 0.05), but was significant for patients > 1 year (CLP and H-SILP *vs* SILP: 120 ± 15 and 119 ± 12 *vs* 140 ± 7, *P* < 0.05 *vs* SILP). Similarly, the operative time for short segment HD patients was insignificant (P> 0.05), but was significant for long segment HD patients (CLP and H-SILP *vs* SILP: 152 ± 3.5 and 154 ± 3.6 *vs* 176 ± 2.3, *P* < 0.05 *vs* SILP) (Table 2).

***Cosmetic assessment***

The wound was healthy at hospital discharge and healed by 3 wk postoperatively. The cosmetic assessment was done at 12 mo post-operatively (Table 3). The assessment of the abdomen revealed 2 visible scars in the CLP patients (Figure 4A), 1 barely remarkable/near scarless scar in the H-SILP (Figure 4C) patients and a scarless abdomen in the SILP patients (Figure 4B). The scar at the umbilicus was unremarkable, as it was embedded inside and the umbilicus appeared normal in all the patients. We used the Manchester Scar Scale (MSS)[18,19] (Table 4) to assess the scar score only for the CLP patients (10 ± 0.72, good) and for the H-SILP patients (5 ± 0.72, excellent), with a significant *P* < 0.05 value. None of the patients suffered from wound infection or complications like keloid and hypertrophied scar.

**Discussion**

The advancements in minimally invasive techniques have allowed HD to be treated quickly and safely, with their well-known benefits such as minimal surgical trauma, short operative time and less postoperative pain[20], which lead to fast rehabilitation and avoidance of prolonged hospitalization. Many centers around the world have adopted the laparoscopic procedures as the standard procedure to treat HD but the open approach is inevitable in case of laparoscopic failure[6].

More recently, in view of better cosmetic results and new laparoscopic procedures, De la Torre-Mondragon *et al*[21] described the transanal-endorectal pull-through (TERP)and Vahdad *et al*[22] described the totally transanal LESS pull-through colectomy (TLPC). Both procedures are also relatively safe and feasible for short and long segment HD. However, besides the ergonomics disadvantages[23,24], the possibility of over stretching of the anal sphincter and mesentery of rectosigmoid colon had been reported: which can increase the risk of fecal incontinence[3]. Similar to the single-incision laparoscopy[25-28], these minimal invasive procedures have excellent cosmetic results and are gaining popularity.

As for any new technique, there was a learning curve for each of the procedures. In this study, there was no learning curve for the CLP, as a large amount of experience was accumulated by using the CLP[4-6] to treat HD patients. However, the training skill for the SILP procedure was acquired by training on simulator[29,30] for at least 50 correct attempts and then it was successfully applied in real practice. Initially, we had a prolonged operative time among the first five cases, but gradually decreased with the mean operating time 118 ± 22 (90-178) min. After overcoming the difficulties encountered in the SILP, the learning curve was rather short for the H-SILP, training on simulator for at least 10 correct attempts were enough because maneuverability was the same as the CLP. We believed that the general operative time among these procedures was insignificant (*P* > 0.05) because of the proper training, to overcome the challenges of the minimal invasive surgery.

With minimally invasive surgery (MIS), a man-machine environment was brought into the operating room, which created mental and physical challenges for the operating team. The science of ergonomics analyzes these challenges and formulates guidelines for creating a work environment that is safe and comfortable for its operators while effectiveness and efficiency of the process are maintained. From the ergonomics analysis[31] of the three procedures; the operating room, man power and technical requirement were similar, with experienced operating team and same coaxial alignments. The only difference in the three approaches was the positioning (Figure 1) of the working ports which affected the ergonomics of the standard instruments[32]. In this study, curved instruments and TriPort system were not considered as they were inappropriate to be used for younger children, especially newborns and infants[33,34].

Since the SILP was technically the most challenging, the following findings were observed besides the routine challenges of minimally invasive surgery.

Optimum working angles are necessary for suturing and desired tissue manipulation. These working angles are directly influenced by the distance between the working ports. Ideally, good angles for working and suturing are acquired by placing the working ports 10 cm apart outside the body cavity, which provided a working distance of 4 cm inside the body cavity. In the SILP, the distance between the two working ports was approximately 4 to 5 cm outside the body cavity and the laparoscopic port was situated in the middle. In this context, the working angles were rather restricted and the manipulation was quite difficult.

Relatively to the abdomen, each working port projects an internal and an external cone-shaped field which limit our manipulations to a specific working field perimeter. In the SILP, the interception of these cone-shaped fields narrows the working area and eventually leads to internal and external clashing of the instruments and difficult manipulation.

The operative field of vision is affected by the triangulation of the ports with the camera centrally placed. In the SILP, due to one site location of all the working ports, the field of the camera was narrowed, resulting in a restricted field of vision and often clashing of the camera with instruments manipulations (internally and externally).

These odds were absent in the CLP and H-SILP, but SILP had the best cosmetic result. The H-SILP is a “novel” modified version of the SILP. For ergonomic reasons we shifted the left working port from the umbilical site to the left side the abdomen without trocar. Technically, the maneuverability of the instruments are much easier, similar to the CLP procedure the working ports were 10 cm apart outside the body cavity; improving the triangulation, working angles and working field. This provided better intra-abdominal exposure with greater in-line endoscope viewing, greater degrees of freedom and minimal clashing of the instruments.

We used a trocarless instrument on the left side of the abdomen in the H-SILP because there was no indication for interchange of instrument at that site and to improve the cosmetic result. Although, a 5.0 mm or 3.0 mm trocar is less traumatic to the surrounding skin tissue, it leaves a small remarkable and shiny scar on the abdomen (Figure 4A) compared to a matte and non-distorted scar of a 3 mm trocarless instrument (Figure 4C). In this study, the SILP (scarless) claimed the best cosmetic result (Table 3), followed by the H-SILP (near scarless appearance, scar score 5 ± 0.72) and the CLP (2 visible scars, scar score 10 ± 0.72), and there was no significant change in the scar score during the whole follow-up. The scar at the umbilicus was embedded inside and the appearance was similar to a normal umbilicus, which favors the SILP[35]. The cosmetic result does play an important role in the life of a child, especially in term of psychological and psychosocial functioning of the child[36,37].

Ergonomically, the CLP and the H-SILP have the same maneuverability and were less challenging than the SILP. But relatively to the general operative times (*P* > 0.05), we can say that the ergonomics challenges were overcome. Furthermore, to support this statement, the operative times for patients < 1-year-old and short segment HD patients were insignificant. So, we can conclude that the SILP is as effective as the CLP and H-SILP. On the other hand, the operative times were significant for the patients > 1-year-old (CLP and H-SILP *vs* SILP: 120 ± 15 and 119 ± 12 *vs* 140 ± 7, aP < 0.05 *vs* SILP) and for the patients with long segment HD (CLP and H-SILP *vs* SILP: 152 ± 3.5 and 154 ± 3.6 *vs* 176 ± 2.3, *P* < 0.05 *vs* SILP). So, we can conclude that the CLP and H-SILP are more convenient for patients > 1-year-old (toddler, preschooler and school age patient) and for long segment HD patients. The most possible reasons for the age and transitional zone ergonomic-related significances are: (1) children > 1-year-old have a thicker and larger abdominal wall than children < 1-year-old; (2) the mesenteries and organs are more developed (larger, thinker and longer); (3) manipulations and dissections were done in a deeper depth; and (4) for the long aganglionic segment, a longer length of the mesentery was dissected to mobilize the colon to a higher level.

In conclusion, all the procedures are feasible and safe with the same functional outcome. The laparoscopic approach should be selected according to the age, transition zone and desired cosmetics result. The SILP is more suitable for short segment HD in neonates and infants. The H-SILP is more convenient for patients > 1-year-old and long segment HD in patients. The CLP can be used in difficult cases where the SILP or the H-SILP might fail.

**COMMENTS**

***Background***

hirschsprung’s disease (HD) is one of the diseases that are responsible for constipation in children. Here by, we described the main three laparoscopic approaches that we have been using to treat HD with the same endorectal pull-through modified Soave procedure. The authors compared their outcomes and difficulties, in order to better understand the choice of one approach over the other regarding to the age, transitional zone and desired cosmetic result.

***Research frontiers***

The laparoscopic technique has improved the surgical treatment of HD and has inspired surgeons to undertake more complex laparoscopic procedures to promote early resumption of gastrointestinal function, decrease complications and to achieve better cosmetic results.

***Innovations and breakthroughs***

Since 1999, the authors used to conventional laparoscopic procedure (CLP) to treat HD. In 2010, the authors applied the single-incision laparoscopic procedure (SILP). However, it was more challenging than CLP. In 2011, the authors applied the hybrid single-incision (H-SILP) to preserve the cosmetic advantage of the SILP and the ergonomic advantage of the CLP.

***Applications***

Accordingly, to the results, the authors found that we have overcome the ergonomics challenges for the SILP for a specific group of patients only. So, relating to the age, transitional zone and desired cosmetic results, the authors prefer to use (1) the SILP for short segment HD in neonates and infants; (2) the H-SILP for patients > 1-year-old and long segment HD in patients; and (3) the CLP can be used in difficult cases where the SILP or the H-SILP might fail.

***Terminology***

The transitional zone is the boundary between the ganglionic and aganglionic segment of the colon. Surgically, it is very important to localized the specific affected segment of the colon for proper amount of bowel resection and reduce the risk redo surgery for remnant aganglionic segment. Laparoscopic/endoscopic surgery is also known as minimal invasive surgery, where the surgeon uses machine to operate on patients. Ergonomics is an applied scientific analysis of the interaction of man and machine in a specific environment.

***Peer-review***

This is a well and nice paper to read, a well done analysis of three different approaches for the same disease, and a well done analysis especially in facing different patients and localization of the disease.

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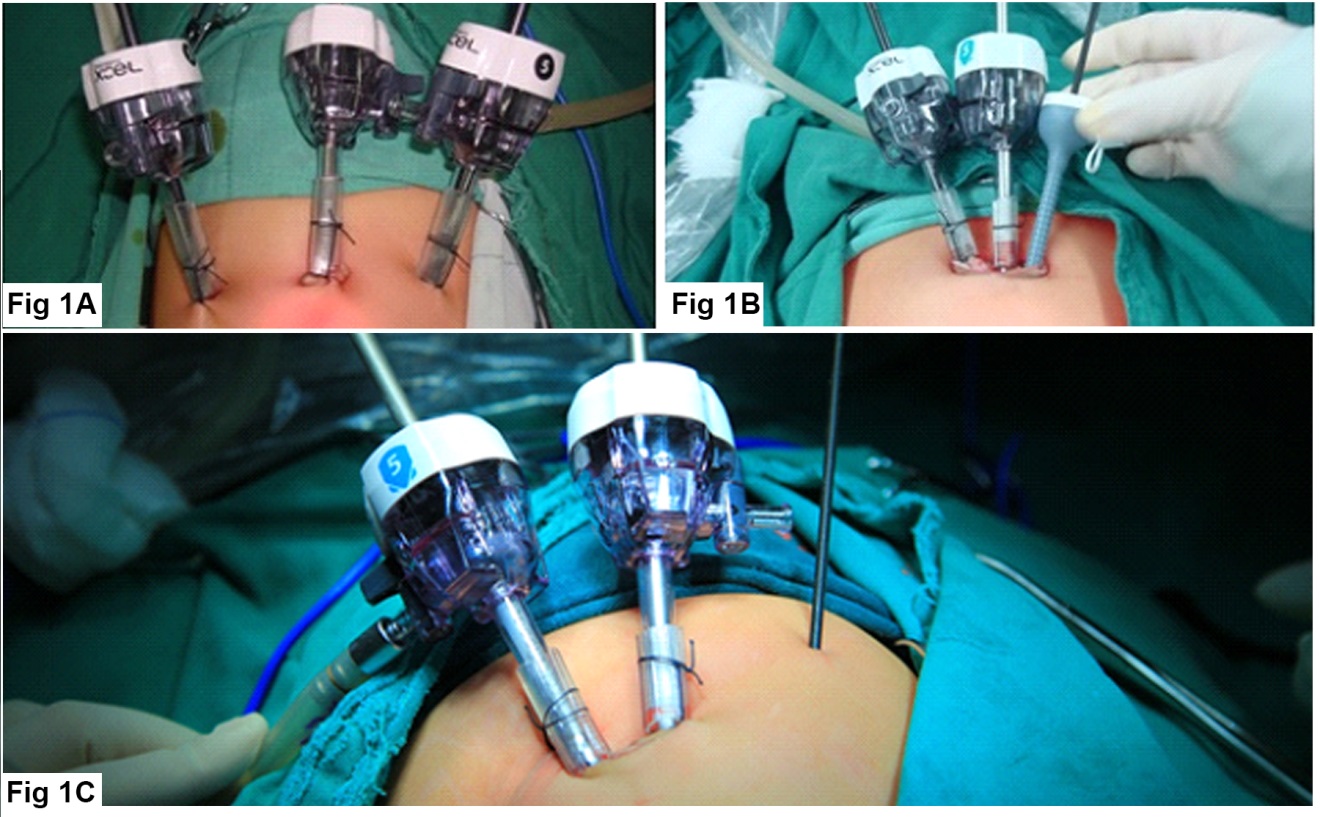
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**Figure 1 Positioning of trocars and instruments.** A: Conventional laparoscopic pull-through; B: Single-incision laparoscopic pull-through (SILP); C: Hybrid SILP.

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**Figure 2 resection of the necessary amount of the mobilized colon and coloanal anastomosis with the short cuff.** A: rectal submucosa dissection with a long cuff; B: Cuff shortening; C: Partial resection of the muscular cuff in “V-shaped” of the posterior wall; D: Coloanal anastomosis after the endorectal pull-through and resection of the necessary amount of colon.

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**Figure 3 appearance of umbilicus and abdominal wound post-operative**. A: Conventional laparoscopic pull-through; B: Single-incision laparoscopic pull-through (SILP); C: Hybrid SILP.

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**Figure 4 appearance of abdominal scars on follow-up.** A: Conventional laparoscopic pull-through; B: Single-incision laparoscopic pull-through (SILP); C: Hybrid SILP.

|  | **CLP (*n* = 30)** | **SILP (*n* = 28)** | **H-SILP (*n* = 32)** | ***P*-value** |
| --- | --- | --- | --- | --- |
| Median age (mo)  Sex (male)  General operative time (min) | 3.8 ± 2.6 (1-90.2)  21 (70.0)  115 ± 22 (75–156) | 3.4 ± 2.1(1–78.8)  18 (64.3)  118 ± 22 (90–178) | 3.6 ± 2.1(1–78.6)  24 (75.0)  115 ± 24 (75–158) | > 0.05  > 0.05  > 0.05 |
| Conversion to open surgery  Estimated blood loss (ml)  Hospital stays (d)  Intraoperative complications  Time of passage of flatus (h) | 0  5 ± 1.0  7 ± 1.5  0  22 ± 5.0 | 0  6 ± 1.5  7 ± 1.0  0  21.5 ± 4.5 | 0  4.5 ± 1.0  7 ± 1.0  0  21.5 ± 4.0 | > 0.05  > 0.05  > 0.05  > 0.05  > 0.05 |
| Early postoperative complications  Perianal excoriation  Anastomotic leak  Enterocolitis | 11 (36.7)  10 (33.3)  1 (3.3)  0 | 8 (33.3)  7 (25.0)  0  1 (3.6) | 8 (31.3)  9 (28.1)  0  1 (3.1) | > 0.05 |
| Defecation frequency  (times per day)  One week postoperatively  One month postoperatively  Three months postoperatively | 5 ± 3.5  4 ± 2  2 ± 1 | 6 ± 4  4 ± 3  2 ± 1 | 5 ± 4  4 ± 2  2 ± 1 | > 0.05  > 0.05  > 0.05 |
| Recurrent constipation | 0 | 0 | 0 | > 0.05 |

**Table 1 General characteristics, operative data and complications *n* (%)**

CLP: Conventional laparoscopic pull-through; SILP: Single-incision laparoscopic pull-through; H-SILP: Hybrid single-incision laparoscopic pull-through.

**Table 2 Operative time among the three groups relatively to the age and transitional zone**

|  | **CLP**  **(*n* = 30)** | **SILP**  **(*n* = 28)** | **H-SILP (*n* = 32)** | ***P*-value** |
| --- | --- | --- | --- | --- |
| Patients < 1-yr-old  Operative time (min)  Patients > 1-yr-old  Operative time | 21  113 ± 23  9  120 ± 15 | 20  109 ± 8  8  140 ± 7 | 22  113 ± 12  10  119 ± 12 | > 0.05  < 0.05 *vs* SILP |
| Rectosigmoid colon  Operative time (min)   Descending colon  Operative time (min) | 27  111 ± 20  3  152 ± 3.5 | 26  114 ± 17  2  176 ± 2.3 | 27  109 ±20  5  154 ± 3.6 | > 0.05  < 0.05 *vs* SILP |

CLP: Conventional laparoscopic pull-through; SILP: Single-incision laparoscopic pull-through; H-SILP: Hybrid single-incision laparoscopic pull-through.

**Table 3 Cosmetic assessment**

|  | **CLP**  **(*n* = 30)** | **SILP (*n* = 28)** | **H-SILP (*n* = 32)** | ***P* value** |
| --- | --- | --- | --- | --- |
| Number of visible scar on the abdomen | 2 | 0 | 1 |  |
| Scar appearance on the abdomen | Visible | Scarless | Near scarless |  |
| MSS score of visible scar on the abdomen | 10 ± 0.72 (good) | - | 5 ± 0.72 (excellent) | < 0.05 |
| Appearance at the umbilicus | Normal | Normal | Normal |  |

CLP: Conventional laparoscopic pull-through; SILP: Single-incision laparoscopic pull-through; H-SILP: Hybrid single-incision laparoscopic pull-through; MSS: Manchester scar scale.

**Table 4 Manchester scar scale: 5 (best) to 18 (worse)**

|  |  |  |
| --- | --- | --- |
| **Excellent** | **Visual analog scale** | **Poor** |
|  |
| Color | Perfect | 1 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Slight mismatch | 2 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Obvious mismatch | 3 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Gross mismatch | 4 |
| Matte vs shiny | Matte | 1 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Shiny | 2 |
| Contour | Flush with surrounding skin | 1 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Slightly proud/Indented | 2 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Hypertrophic | 3 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Keloid | 4 |
| Distortion | None | 1 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Mild | 2 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Moderate | 3 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Severe | 4 |
| Texture | Normal | 1 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Just palpable | 2 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Firm | 3 |
| http://img.medscape.com/ornament/spcms/spacer.gif | Hard | 4 |