Laparoscopic surgical technique to enhance the management of anorectal malformations: 330 cases' experience in a single center

Long Li[1] · Xianghai Ren[1,2] · Anxiao Ming[1] · Hang Xu[1] · Rui Sun[1,2] · Yan Zhou[1,2] · Xuelai Liu[1] · Hailin Sun[3] · Qi Li[1] ·
Xu Li[1] · Zhen Zhang[1] · Wei Cheng[4,5] · Mei Diao[1] · Paul K. H. Tam[6]

Abstract

Purpose Laparoscopic-assisted anorectoplasty (LAARP) is considered to benefit the patients with vesico-prostatic fistula. The aim of this study is to present the details of our LAARP technique for improving the short- and long-term outcomes in the patients with high and intermediate types of anorectal malformations (ARMs).

Methods 330 patients with high-type (174 cases) and intermediate-type (156 cases) anorectal malformation (aged 8 days to 15 years) underwent LAARP from 2001 to 2019. LAARP was performed for full mobilization and resection of the dilated rectum, intra-rectal closure of the fistula, visualization, and enlargement of the center of the longitudinal muscle tube (LMT) from pelvic and perineal aspects.

Results LAARP was performed in all patients and no patient was converted to open procedure. The urethral diverticulum was found in three patients (1.02%, 3/294) according to postoperative protocol voiding cystourethrogram but was not associated with any symptoms such as urinary tract infection and dysuria. Rectal prolapse requiring surgical intervention developed in 25 (7.6%) of 330 patients. Anal stricture occurred in three patients and re-do anoplasty was performed 5 months after LAARP. Anal retraction occurred in two patients and re-pull-through was conducted at 5 and 6 days, respectively, after LAARP. 228 patients who were older than 3 years were followed up. The median follow-up period was 5.8 years (range 3–15 years). 217 patients (95.2%) had voluntary bowel movements; 202 patients (88.6%) were free from soiling or with grade 1 soiling; 30 patients (13.6%) and 25 patients (11.3%) suffered from grade 1 and grade 2 constipation, respectively, while no patient had grade 3 constipation.

Conclusion Our experience demonstrates that the LAARP has advantages on rectal mobilization and resection, intra-rectal fistula closure and accurate tunnel formation in the LMT with minimal trauma. The improvement of the short-term and longterm outcomes after LAARP has been shown not only for high-type ARM but also for intermediate-type ARM.

Keywords Laparoscopic-assisted anorectoplasty · High-type anorectal malformation · Intermediate-type anorectal malformation · Sphincter muscle complex · Long-term outcomes

Long Li and Xianghai Ren contributed equally to this article.

* Long Li
lilong23@126.com

* Mei Diao
psps3001@hotmail.com

[1] Department of Pediatric Surgery, Capital Institute of Pediatrics, No. 2 Yabao Road, Chaoyang District, Beijing 100020, People's Republic of China

[2] Graduate School of Peking Union Medical College, Chinese Academy of Medical Sciences, Beijing 100730, People's Republic of China

[3] Department of Medical Imaging, Capital Institute

of Pediatrics, Beijing 100020, People's Republic of China
4 Department of Pediatrics, Faculty of Medicine, Nursing and Health Sciences, Monash University, Clayton, Australia
5 New Century Healthcare, Hong Kong, People's Republic of China
6 Dr. Li Dak Sum Research Centre, The University of Hong Kong, Hong Kong, People's Republic of China

Introduction

For the last 3 decades, the posterior-sagittal anorectoplasty (PSARP) [1] has become the mainstay of surgical technique for high and intermediate anorectal malformations (ARMs). The results of PSARP represent an improvement over the prior operations [2]. However, the incidence of constipation was up to nearly 40% following the PSARP, and most patients require bowel management to avoid the physiologic and social problems associated with fecal incontinence [3–5]. This complication might theoretically result from the damage of the muscle complex by splitting and wrapping the sphincter muscle complex around the pulled-through neorectum, although an experimental study indicated complete division of the sphincter mechanism followed by a meticulous reconstruction did not produce negative effects [6, 7].

The laporoscopic-assisted anorectoplasty (LAARP) was first reported by Willital in 1998 [8] and subsequently improved and popularized by Keith Georgeson in 2000, with the aim of accomplishing a correction of high ARM without mid-sagittal division of any of the muscles of continence [9]. Since then, many other centers [10–12] had gained experience with this minimally invasive technique for this complex malformation. Although the laparoscopic approach offered some advantages in the experienced surgeons, the absence of clearly defined technical standards had hindered the wide application and improvement of the surgical outcomes [13]. Additionally, because of reports of the distinct complications associated with LAARP, such as prolapse, posterior urethral diverticulum and urethral injuries, it is considered that only the patients with vesico-prostatic fistula could benefit from LAARP surgery [14, 15]. The aim of this study is to present the details of our LAARP technique for decreasing the complications and the surgical outcomes in patients with high-type and intermediate-type ARMs.

Materials and methods

Between April 2001 to June 2019, 330 patients (294 male and 36 female) with ARMs were treated by LAARP in our center. Their age at surgery ranged from 2 days to 15 years (mean age 3.2 ± 0.42 months). There were 59 patients with associated rectovesical fistula, 99 patients with rectoprostatic fistula, 136 patients with rectobulbar fistula, 30 patients with cloaca, and 6 patients with rectovestibular fistula (the intermediate-type ARM). The LAARP operation was performed with 3 ports in 87 patients and with single incision in 243 patients. One stage LAARP was conducted in 38 neonates. Except for neonate patients, the

children had a high-pressure distal colostogram, a phased array MRI technique and computed tomography scanning routinely performed for evaluating the topography of the fistula and sphincter muscle complex before and after surgery. Follow-up ranging from 3 months to 15 years was performed by our team. The fecal continence was evaluated by Krickenbeck 2005 scoring criteria [16].
The study protocol was approved by our hospital medical ethics committees. All statistical analyses were conducted using SPSS version 17.0 software (SPSS, Chicago, IL). The Chi-squared test was used to compare characteristics between the groups. All *P* values were derived from twotailed analyses, with significance accepted at $p < 0.05$.

Operative techniques

Rectal mobilization and fistula closure

The patient was positioned supine and placed with the buttocks at the end of the table, allowing laparoscopic access by the surgical team on three sides. The legs were elevated to the lithotomy position for the perineal access on the tunnel formation. One trocar (5 mm) was inserted in the umbilicus and two 3-mm trocars were inserted 3–4 cm away from the left and the right of the first port for the conventional threeport technique or 1.5–2 cm away in the same umbilical incision for the single-incision technique.
Laparoscopic dissection of the rectum began laterally at about 1–2 cm proximal to the peritoneal reflection, which made dissection of the lateral and posterior rectal wall easier. The distal mesorectum was divided using monopolar hook cautery and a window was created behind the distal rectal wall. The dissection was made circumferentially along the rectal longitudinal muscle to the terminal rectum. For the rectovesical or rectoprostatic fistula, as the rectum tapered into the fistula distally, a deliberate dissection toward the termination of the rectum was made in the submucosa layer to avoid injury to the important autonomic nerve plexus near the walls of the fistula and terminal rectum. For the rectobulbar and rectovestibular fistula, the dissection was facilitated by traction applied to the rectal wall and a transabdominal retraction suture on the bladder neck (rectobulbar fistula) or the uterus (rectovestibular fistula) to suspend the bladder (rectobulbar fistula) or the uterus and vagina (rectovestibular fistula) anteriorly to the abdominal wall for a better pelvic visualization. The circumferential dissection toward the fistula was made as close as possible to the longitudinal fibers of the rectal wall to avoid damaging the surrounding pelvic nerve plexus and the vas deferens (rectobulbar fistula) or the posterior wall of the vagina (rectovestibular fistula). Moreover, the vessels encountered here were relatively small and could be easily cauterized and severed with monopolar electrocoagulation.
The rectourethral fistula was closed by the intra-rectal approach in the patients. As the fistula was approached, the dissection was made in the submucosa layer of the rectal pouch because the urethra and the distal rectum or fistula might share the common muscular wall, especially in the

rectobulbar fistula. Both in high and intermediate ARMs, the anterior mucosal layer of the terminal rectum was opened and the orifice of the fistula was identified from inside of the rectum. The rectal mucosa became columnar and radial pointing towards the orifice, which signaled the junction between urethral mucosa and rectal mucosa. The mucosal layer of the rectum was transected at the junction and peeled off the hypertrophic muscular cuff using a 3-mm hook cautery. Then the distal fistula mucosa layer would retract back into the fistula stump. The fistula was closed by suturing the muscular cuff with a running suture of 5-0 PDS to avoid injuring the urethra or the vagina. Turning the 30° angled laparoscopic camera upward and using a magnified view were the most critical steps to (i) visualize the fistula in detail, (ii) to completely excise the rectal mucosa, (iii) to close the muscular cuff and (iv) to identify the center of the pelvic longitudinal muscle tube (LMT).

For the patient with low rectobulbar fistula, the rectal pouch descended near the perineum. After the distal rectal pouch was dissected as low as possible laparoscopically, its anterior wall was opened and a suction tube was introduced into the rectal pouch to push the wall down to the perineum. From the perineal approach, after a vertical incision was made in the center of the external anal sphincter (EAS), the distal rectal wall was identified and opened by guidance of the suction tube; the fistula was visualized, transected at the junction with the rectum and closed.

After the terminal rectum was divided, the rectum was pulled up and out of the pelvis to facilitate inspection and further mobilization of the mesorectum. Minimal proximal dissection of the rectum was required for the patient with rectobulbar fistula or non-dilated rectum. For the patients with high ARM or with a hypertrophic dilated rectum requiring partial rectal resection to prevent severe postoperative constipation, the proximal rectum was fully mobilized by dividing the sigmoidal vessels (the main inferior mesenteric artery branch) at their origin and keeping the marginal vessels feeding the proximal rectum intact to make the rectal vascularization well and the anastomosis tension free.

One-stage laparoscopic-assisted anorectoplasty was carried out for male neonates with high and intermediate ARMs. After a 2.0–2.5-cm incision was made in the middle of the umbilicus, the dilated sigmoid colon was exteriorized. A small incision was made on the anti-mesenteric wall of the proximal sigmoid colon and a short tube was introduced into the rectum and descending colon for the decompression of the meconium by intraoperative irrigation. A fine syringe needle puncture could be used for the decompression of the small intestine. Then the incision of the colon was closed in two-layer running suture with 5-0 PDS. Pneumoperitoneum (8–10 mmHg of pneumoperitoneum) was established after the closure of the umbilical wound and the LAARP was performed [17].

Tunnel formation from perineal aspect

An electrical stimulator elicited the contraction of the superficial EAS and the distal LMT muscle. The anal dimple represented the center of the perineal LMT and was mapped using a transcutaneous electrostimulator. A vertical incision was made in the middle of the dimple. In the subcutaneous layer of the dimple, the center of the LMT was located by the contraction of the circular superficial EAS upon electrostimulation. Using a clamp (18 cm, curved Kelly clamp), the terminal intra-LMT plane was bluntly and gently dilated to open according to the size of the circular EAS. The deeper intra-LMT plane was avascular and demarcated by the longitudinal muscle fibers which showed a radial gradient from the perineal to the pelvic direction under the gradual clamp dilatation. Guided by the electrostimulation, the tip of the clamp traced the center of the perineal LMT and dilated gently to make the columnar perineal LMT open in a stepwise fashion for a distance about 1.5–2.0 cm.

Tunnel formation from the pelvic aspect

In the high-type ARM, because the fistula was located above the pelvic diaphragm, the pelvic fascia (the fascia of Waldeyer) between the rectal pouch and the levator ani muscle, was first divided in the midline by the hook cautery after the closure of the fistula (Fig. 1a). The posterior wall of the urethra was exposed by clearing the surrounding tissue, and the pelvic LMT was visualized just posterior to the urethra. In the intermediate ARM, because the fistula and the rectal pouch penetrated down into the pelvic floor, the pelvic LMT was wider than that in the high ARM. After the fistula was divided and the rectum was pulled up and out of the pelvis, the center of the LMT could be visualized just posterior to the fistula stump, which could be further cleared of the adhesion with the longitudinal muscle. After the hemostat passed through the perineal LMT from the perineal aspect, it was advanced into the pelvic LMT just posterior to the posterior urethra in high ARM or to the fistula stump in intermediate ARM in the midline under the laparoscopic guidance (Fig. 1b). Once the clamp was led within the pelvic LMT from the perineal LMT, the LMT was gently dilated to form a cylindrical tract with the size of the superficial EAS ring. The rectum was grasped by the clamp and gently pulled through the LMT tract down to the perineum. By this pulling-through technique, the LMT was widened by the rectum to fit with the size of the rectum exactly.

The rectum was pulled out as much as possible, and the redundant rectum was trimmed to prevent prolapse. The anastomosis between the rectum and anus was next completed with circumferential interrupted 5-0 PDS sutures.

An intra-rectal tube via the anus into the rectum was left for 1 week after one-stage LARRP to decompress the rectum before the neoanus started functioning for the defecation.

To the patients with vestibular fistula, we employed LAARP for fully rectal mobilizing, separating the rectum from vagina and then transecting the rectum–fistula junction. Intra-fistula mucosectomy was conducted from the perineal aspect, ensuring the fourchette and perineal body intact. For the persistent cloaca, LAARP was used for anorectoplasty, vaginoplasty and urethroplasty was performed though perineal approach [18].

Results

LARRP was performed in all patients and no patient was converted to open procedure. Average operative time was 1.54 h (Fig. 2) and the median length of the hospitalization was 11.8 ± 1.8 days. No patient suffered from wound infection, urethral injury, recurrent fistula or urinary incontinence (in male). The urethral diverticulum was found in three patients according to postoperative protocol voiding cystourethrogram and was not associated with any symptoms of urinary tract infection, dysuria, dribbling, passage of mucous

Fig. 1 **a** The intraplane of the perineal longitudinal muscle tube (LMT) is bluntly and gently dilated to open according to the size of the circular external anal sphincter (EAS) by using a curved Kelly clamp, **b** after the clamp passes through the perineal LMT from the perineal aspect, it advances into the pelvic LMT at just posterior to the fistular stump (F) in rectobulbar fistula in the midline

Fig. 2 The relationship of the increment of the patient number and the operating time for the laparoscopic-assisted anorectoplasty (LAARP)

via urethra, or stone formation. Evident rectal prolapse was found in 25 (7.6%) of 330 patients and required surgical intervention. Anal stricture occurred in three patients and anoplasty was performed 5 months after LAARP. Anal retraction occurred in two patients and re-pull-through was conducted 5 and 6 days, respectively, after LARRP. The comparative study between the high ARM (56 vesical fistula and 95 prostatic fistula) and intermediate ARM (119 bulbar fistula) demonstrated that there were no significant differences in operating time (1.78 vs 1.95 h), anal stenosis (1.9% vs 1.6%), and urethral diverticulum (0.66% vs 1.70%). Postoperative MRI examination confirmed placement of the neoanus centrally within the LMT (Fig. 3).

The outline of the superficial EAS muscle and the deepening of the perineal LMT were often visualized under the electric stimulation. In some patients, the muscles were well developed. In others, they were poorly developed. The outline of the anal dimple under the electric stimulation was carefully described in 233 out of the 330 patient records. This contraction was powerful and centralized with a deeper dimple in 58.2% (46/79) of the male and 75.0% (12/16) of female patients with high ARM, and in 94.1% (111/118) of the male and 100% (20/20) of the female patients with intermediate ARM, which indicated the EAS and LMT were well developed (Tables 1, 2). The contraction was weaker and decentralized with a flat dimple in the other 41.8% (33/79) of the male and 25.0% (4/16) of the female with high ARM and 5.9% (7/118) of the male and 0/20 of female with intermediate ARM, which indicated the EAS and LMT mal-developed (Tables 1, 2). 61.1% (58/95) of patients with high ARM and 94.9% (131/138) of patients with intermediate ARM had the well-developed anal dimple, with the former being significantly lower than the latter ($p < 0.001$) (Table 3).

There was no significant difference between the male and female patients in the development of anal dimple even

Fig. 3 **a** Before laparoscopicassisted anorectoplasty (LAARP), MRI visualizes the longitudinal muscle tube (arrows) in the patient with a prostatic fistula, **b** before LAARP, MRI visualizes the longitudinal muscle tube (arrows) in the patient with a bulbar fistula. **c** After LAARP, MRI visualizes the rectum located in the longitudinal muscle tube for the patient with a rectoprostatic fistula (sagittal image), **d** after LAARP, MRI visualizes the rectum located in the longitudinal muscle tube for the patient with the rectoprostatic fistula (coronal image)

Table 1 The development of external anal sphincter (EAS) and perineal longitudinal muscle fiber (LMT) between male and female in high-type anorectal malformation (ARM)

Characteristic (case, number)	Male	Female	*p* value
Well-developed muscle	46	12	0.210
Maldevelopment muscle	33	4	

Table 2 The development of external anal sphincter (EAS) and perineal longitudinal muscle fiber (LMT) between male and female in intermediate-type anorectal malformation (ARM)

Characteristic (case, number)	Male	Female	*p* value
Well-developed muscle	111	20	0.571
Maldevelopment muscle	7	0	

though the incidence of well-developed dimple appeared higher in female patients ($p > 0.05$).

Two hundred twenty-eight male patients were successfully followed up for more than 3 years. The median followup period was 5.8 years (range 3–18 years). The overall rate of voluntary bowel movement was 95.2% (217/228). Among them, the voluntary bowel movement presented in 77.3% (17/22) patients with rectovesical fistula, 95.6% (88/92) with rectoprostatic fistula and 98.2% (106/112) with rectobulbar fistula. Two hundred and two (88.6%) patients were free from soiling or with grade 1 soiling. Twenty-three (10.1%) patients had grade 2 soiling and 12 (5.3%) patients had grade 3 soiling. Thirty (13.6%) and 25 (11.3%) patients suffered from grade 1 and grade 2 constipation, respectively, while no patient had grade 3 constipation (Table 4).

Discussion

The aims of surgical treatment for ARM are to mobilize the rectum from the pelvic floor to the perineum, to close the rectourethral fistula and to make the tunnel through the center of the sphincter muscle complex. In order to fulfill these aims, the anorectoplasty has evolved from a perineal, abdominal–perineal [19, 20], abdominal–sacral–perineal [21], and posterior-sagittal (PSARP) [1, 3, 5] approached, to the current laparoscopic-assisted abdominal–perineal approach.

LAARP rectal mobilization

The incidence of constipation was up to nearly 40% following the PSARP with the distal rectal preservation or tapering for dilated rectum [3–5]. Xiao et al. reported that distinct defects in the neuro-musculature changes were found in the dilated rectal pouch which were responsible for the rectal dysfunction in association with the postoperative constipation and megarectum [22]. The present study shows that after resection of the dilated rectum, only 13.6% and 11.3% patients suffered from grade 1 and grade 2 constipations, respectively, while no patient suffered grade 3 constipation in our series. This result indicates that the resection of the dilated rectal pouch can improve the functional outcomes of the remaining gut. Even though there is excellent intramural blood supply of the rectum, the preservation of the marginal vascular arcade of the rectosigmoid colon may predispose the recto-skin anastomosis to good vascularization. This study shows that laparoscopic approach can help to fully mobilize the rectum and sigmoid colon by dividing the main inferior mesenteric artery branches at their origin to secure the recto-skin anastomosis tension free. Additionally, the resection of the large rectum is also helpful to fit it adequately within the limits of the narrowed LMT avoiding the over-stretch causing the muscle damage [23].

Table 3 The development of external anal sphincter (EAS) and perineal longitudinal muscle fiber (LMT) between high-type anorectal malformations (ARMs) and intermediate-type ARMs

Characteristic (case, number)	High-type ARM	Intermediatetype ARM	*p* value
Well-developed muscle	58	131	< 0.001
Maldevelopment muscle	37	7	

Table 4 Demographic features and bowel function of patients with rectourethral fistula (228 patients)

Characteristic (case, number)	Rectal vesical fistula, $n = 22$	Rectal prostatic fistula, $n = 92$	Rectal bulbar fistula, $n = 114$
SR (lateral position)	0.62 ± 0.07 (0.32–0.90)	0.72 ± 0.11 (0.45–0.92)	0.78 ± 0.09 (0.47–0.94)
Lumbosacral anomalies			
Sacral agenesis[a]	13 (59.1%)	5 (5.4%)	4 (3.5%)
Spinal dysraphism	5 (22.7%)	24 (26.1%)	10 (8.8%)
Tethered cord	2 (9.1%)	3 (3.3%)	3 (2.6%)
Voluntary bowel movements	17 (77.3%)	88 (95.6%)	112 (98.2%)
Soiling grade 1 or free from soiling	12 (54.5%)	84 (91.3%)	106 (93.0%)
Soiling grade 2	7 (31.8%)	4 (4.3%)	6 (5.3%)
Soiling grade 3	3 (13.6%)	4 (4.3%)	2 (1.8%)
Constipation grade 1	2 (9.1%)	10 (11.0%)	18 (15.8%)
Constipation grade 2 (require laxatives)	3 (13.6%)	9 (9.8%)	13 (11.4%)
Constipation grade 3 (resistant to diet and Laxatives			

Data are presented as the mean ± SD or number (percentage)

SR sacral ratio

[a] Sacral agenesis: miss at least one sacral vertebrae or sacral hemivertebra

A high incidence of rectal prolapse after LAARP had been reported in up to 52% patients, especially in those patients with rectovesical fistula [24, 25]. This complication may be associated with excessive rectal mobilization and less adhesion between the rectal wall and the tunnel. The prolapse can be reduced by tacking the posterior rectal wall to the posterior edges of the muscle complex in PSARP [26] or by anchoring stitches of the rectum to the presacral fascia [27]. Our present study shows the rectal prolapse occurs in only 7.6%, demonstrating that complete traction of the redundant rectum out of the anal skin and its extracorporeal trimming may help to minimize the risk in the prolapse.

LAARP closure of the fistula

According to the literature, the techniques for laparoscopic closures of the rectourethral fistula include silk ligation, endoloop ligation, clip ligation, suturing ligation and endoscopic stapling [14, 15]. The posterior urethral diverticulum and urinary incontinence have been reported as the distinct complications after laparoscopic anorectal reconstruction [28–30]. Trusler and Wilkinson [30] reported that 5 out of 15 (33%) patients who had undergone abdominoperineal pull-through had urinary incontinence. However, our study showed that the incidence of the urethral diverticulum was 1.02% and no male patient suffered the urinary incontinence by intra-rectal closure of the fistula. Our previous study shows that the nerve plexus to the bladder and the penis closely surrounds the fistula wall in high ARM [31, 32]. The damage to this autonomic nerve plexus may likely occur during the fistula dissection and the ligations. We postulate that postoperative urinary incontinence in male patients may result from the iatrogenic injury with the external fistula closure techniques and this can be prevented by the intrarectal closure of the fistula. Because the mucosal junction between the rectum and the urinary tract may be difficult to identify extra-luminally, the retained remnant of the terminal rectum may be responsible for the urethral diverticulum after the external ligation techniques. The major advantage of our intra-rectal fistula closure is that it enables the surgeon to accurately identify the junction of the urethral–rectal mucosa, to secure complete resection of the rectal mucosa preventing urethral diverticulum, and to avoid potential injury to the nerve plexus near the fistula wall. This advantage also renders the preoperative high-pressure colostogram unnecessary for identifying the presence of a rectourethral fistula for one-stage neonatal anorectoplasty. No difference in urinary complications between the high and intermediate ARMs (0.66% vs 1.70%) was shown in our study indicating that LAARP can be recommended for the bulbar fistula as well as for the vesical fistula.

None of the patients in our serial suffer from the recurrent rectourethral fistula after LAARP: this result is in agreement with other literature reports [24, 25]. We believe that the lower incidence of the recurrent urethral fistula may be associated with the tighten connection between the rectal wall and the intact tonic LMT making the urine leakage to the perineum unlikely.

LAARP tunnel formation

Our previous study [32] shows that in the region of the anal canal, three muscular tubes can be classified: the internal anal sphincter muscular tube (IAST), the transverse muscular tube (TMT) and the longitudinal muscular tube (LMT) which is interposed between the IASM and TMT. The LMT extends vertically from the levator ani muscle to the perianal dermis, consisting of outer striated muscle fibers from the levator ani and inner smooth muscle fibers from the rectum. In ARM, the IAST and the inner longitudinal muscular fibers of the rectum are absent and the LMT only comes from the longitudinal striated muscle from the levator ani muscle. The pelvic LMT became narrowed and anteriorly dislocated to the posterior urethra in high ARM or to the terminal rectal pouch in intermediate ARM, whereas the perineal LMT fuses to form a column both in high and intermediate ARMs. The combination of the LMT and the TMT corresponds to the sphincter muscle complex described by Pena. However, our observation suggests that the center of the sphincter muscle complex in ARM is precisely focused on the narrowed LMT which should be widened to open to sleeve the rectum for establishing the normal anatomy between the neorectum and the muscle complex. In PSARP, the sphincter muscle complex (LMT and TMT) is incised, then sutured and wrapped around the pulled-through rectum, and hence the technique splits the LMT and may not properly reconstruct this narrowed muscle tube because the size of the rectum is beyond the limitation of the LMT in ARM. The phased array MRI technique and computed tomography scanning are the gold standards for preoperative evaluation of the topography of the LMT and TMT in all patients with ARM [33–35]. These imaging examinations allow the surgeon to figure out the shape of the LMT before the operation.

The conventional technique for the tunnel formation in LAARP is mainly conducted by a Veress needle with a radially expanding sheath passing through the pelvic plane in the muscle complex using laparoscopic surveillance from above and then introducing the trocar through the perineum [15, 36]. Opponents of the LAARP refer to the possible semi-blind introduction of the trocar through the pelvic sphincter muscle complex with its potential of missing its center and injury to the urinary tract and vas

deferens [14]. Our technique shows that in intermediate ARM, after mobilization of the terminal rectum from the pelvic floor, the opened pelvic LMT is already formed; in high ARM, the narrowed pelvic LMT can be exposed and widened by clearing the tissue behind the posterior urethra. In this way, an accurate passage of the clamp through the pelvic LMT is readily achieved under the laparoscopic surveillance. From the point of view on pelvic LMT tunnel formation, it is easier in intermediate ARM than in high ARM.

The observation in this study shows that both in high and intermediate ARM, the columnar perineal LMT runs downwards to terminate at the deep aspect of the skin creating the anal dimple, which represents the center of the LMT and could be mapped using a transcutaneous electrostimulator. The deeper the dimple is, the better the LMT is developed. The developments of LMT and TMT are significantly better in intermediate ARM (94.9%) than in high ARM (61.1%). The incidence of well-developed anal dimple appears higher in female than in male ARM; however, the statistic difference is not significant. Using a clamp, the perineal intra-LMT plane is easily visualized, bluntly dilated to open to the size of the circular EAS from the perineal approach and readily advanced into the pelvic LMT under the laparoscopic surveillance.

Besides the advantages of the small scar, lower wound infection and fistula recurrent risks of LAARP, even though no report claimed that LAARP produced better long-term fecal continence results compared to the PSARP [11, 37], a higher incidence of an anorectal reflex and superior compliance of the rectum was found [38–41]. Our retrospective cohort study [42] demonstrated that the voluntary bowel movement of the patients with mean age 6.2 years after LAARP was comparable to that of the patients with a mean age 15.5 years after PSARP (70% vs 67%) in high ARM. It is well known that the anal control function can improve with the increase of patient age after ARM corrections [43, 44]. The present study shows that 77.3% patients with rectovesical fistula, 95.6% with rectoprostatic fistula and 98.2% with rectobulbar fistula achieving voluntary bowel movement. These results may be explained that LAARP technique allows the neorectum to be pulled through LMT and, therefore, controlled by two mechanisms of LMT and TMT. It is reasonable to believe that the bowel control is better with two muscular tubes as in normal than with one tube. In the current study, however, it should be noted that a better bowel function may result from a higher sacral ratio (0.62 ± 0.07) and lower incidence of tethered cord (9.1%) in patients with rectovesical fistular. And the high proportion of patients with rectal prostatic fistula and rectal bulbar fistula (90.4%) may account for the overall high rate of voluntary bowel movement (Table 4). Additionally, the relatively small number of patients with rectovesical fistular may have prevented the identification of some outcomes, these hypotheses are worthy of further study.

Our experience demonstrates that the LAARP technique is beneficial (i) to fully mobilize and resect as much of the dilated rectum as is needed while preserving vascularization of the pull-through rectum, (ii) to accurately visualize the center of the LMT and make it open from pelvic and perineal aspects with minimal trauma, (iii) to diminish the risks of rectal mucous remnant and recurrent urethral fistula, and (iv) to improve the outcomes for both high and intermediate ARMs.

.

References

1. Peña A, Devries PA (1982) Posterior sagittal anorectoplasty: important technical considerations and new applications. J Pediatr Surg 17:796–811

2. Rintala RJ, Lindahl HG (1999) Posterior sagittal anorectoplasty is superior to sacroperineal–sacroabdominoperineal pullthrough: a long-term follow up study in boys with high anorectal anomalies. J Pediatr Surg 34:334–337

3. Bliss DP Jr, Tapper D, Anderson JM et al (1996) Does posterior sagittal anorectoplasty in patients with high imperforate anus provide superior fecal continence? J Pediatr Surg 31:26–30
4. Langemeijer RA, Molenaar JC (1991) Continence after posterior sagittal anorectoplasty. J Pediatr Surg 26:587–590
5. Tsuji H, Okada A, Nakai H et al (2002) Follow-up studies of anorectal malformations after posterior sagittal anorectoplasty. J Pediatr Surg 37:1529–1533
6. Peña A, Amroch D, Baeza C et al (1993) The effect of posterior sagittal approach on rectal function (experimental study). J Pediatr Surg 28:773–778
7. Peña A, Hong AR (2003) The posterior sagittal trans-sphincteric and transrectal approach. Tech Coloproctol 7:35–44
8. Willital GH (1998) Endosurgical intrapuborectal reconstruction of high anorectal anomalies. Pediatr Endosurg Innov Tech 2:5–11
9. Georgeson KE, Inge TH, Albanese CT (2000) Laparoscopically assisted anorectal pull-through for high imperforate anus—a new technique. J Pediatr Surg 35:927–931
10. England RJ, Warren SL, Bezuidenhout L et al (2012) Laparoscopic repair of anorectal malformations at the Red Cross War Memorial Children's Hospital: taking stock. J Pediatr Surg 47:565–570
11. Tainaka T, Uchida H, Tanaka Y et al (2018) Long-term outcomes and complications after laparoscopic-assisted anorectoplasty vs. posterior sagittal anorectoplasty for high- and intermediate-type anorectal malformation. Pediatr Surg Int 34:1111–1116
12. Yazaki Y, Koga H, Ochi T et al (2016) Surgical management of recto-prostatic and recto-bulbar anorectal malformations. Pediatr Surg Int 32:939–944
13. Al-Hozaim O, Al-Maary J, AlQahtani A et al (2010) Laparoscopic-assisted anorectal pullthrough for anorectal malformations: a systematic review and the need for standardization of outcome reporting. J Pediatr Surg 45:1500–1504
14. Bischoff A, Levitt MA, Peña A (2011) Laparoscopy and its use in the repair of anorectal malformations. J Pediatr Surg 46:1609–1617
15. Cairo SB, Rothstein DH, Harmon CM (2017) Minimally invasive surgery in the management of anorectal malformations. Clin Perinatol l44:819–834
16. Holschneider A, Hutson J, Pena A, Beket E et al (2005) Preliminary report on the international conference for the development of standards for the treatment of anorectal malformations. J Pediatr Surg 40:1521–1526
17. Diao M, Li L, Ye M et al (2016) Congenital anomaly rectified at birth: one-stage single-incision laparoscopic-assisted anorectoplasty for newborns with anorectal malformations and rectourethral fistula. Surg Endosc 30:5156–5164
18. Ren X, Xiao H, Li L, Diao M, Chen L, Zhou R, Li H, Li X, Cheng W (2018) Single-incision laparoscopic-assisted anorectoplasty versus three-port laparoscopy in treatment of persistent cloaca: a midterm follow-up. J Laparoendosc Adv Surg Tech A 28:1540–1547. https ://doi.org/10.1089/lap.2018.0225
19. de Vries PA (1984) The surgery of anorectal anomalies: its evolution, with evaluation of procedures. Curr Probl Surg 21:1–75
20. Durham Smith E (1987) The bath water needs changing but don, t throw out the baby: an overview of anorectal anomalies. J Pediatr Surg 22:335–348
21. Stephens FD (1953) Imperforate rectum; a new surgical technique. Med J Aust 7:202–203
22. Xiao H, Huang R, Cui DX, Xiao P et al (2018) Histopathologic and immunohistochemical findings in congenital anorectal malformations. Medicine 97:11675
23. Li L, Zhang JZ, Lu GW et al (1996) Damaging effects of anal stretching on the external anal sphincter. Dis Colon Rectum 39:1249–1254
24. Jung SM, Lee SK, Seo JM et al (2013) Experience with laparoscopic-

assisted anorectal pull-through in 25 males with anorectal malformation and rectourethral or rectovesical fistulae: postoperative complications and functional results. J Pediatr Surg 48:591–596
25. Kudou S, Iwanaka T, Kawashima H et al (2005) Midterm followup study of high-type imperforate anus after laparoscopically assisted anorectoplasty. J Pediatr Surg 40:1923–1926
26. Belizon A, Levitt MA, Shoshany G et al (2005) Rectal prolapse following posterior sagittal anorectoplasty for anorectal malformations. J Pediatr Surg 40:192–196
27. Leung Jessie L, Chung Patrick HY et al (2016) Application of anchoring stitch prevents rectal prolapse in laparoscopic assisted anorectal pullthrough. J Pediatr Surg 51:2113–2116
28. Alam S, Lawal TA, Peña A et al (2011) Acquired posterior urethral diverticulum following surgery for anorectal malformations. J Pediatr Surg 46:1231–1235
29. Rentea RM, Halleran DR, Vilanova-Sanchez A et al (2019) Diagnosis and management of a remnant of the original fistula (ROOF) in males following surgery for anorectal malformations. J Pediatr Surg pii S0022–3468(19):30116–30122
30. Trusler GA, Wilkinson RH (1962) Imperforate anus: a review of 147 cases. Can J Surg 5:269ery
31. Li L, Li Z, Huo HS et al (1990) Sensory nerve endings in puborectalis and anal region: normal findings in the newborn and changes in anorectal anomalies. J Pediatr Surg 25:658–664
32. Li L, Ren XH, Xiao H et al (2019) Anorectal musculatures: normal anatomy and abnormalities in anorectal malformation. Pediatr Surg Int **(in press)**
33. Podberesky DJ, Towbin AJ, Eltomey MA, Levitt MA (2013) Magnetic resonance imaging of anorectal malformations. Magn Reson Imaging Clin N Am 21:791–812
34. Thomeer MG, Devos A, Lequin M et al (2015) High resolution MRI for preoperative work-up of neonates with an anorectal malformation: a direct comparison with distal pressure colostography/fistulography. Eur Radiol 25:3472–3479
35. Tang ST, Cao GQ, Mao YZ et al (2009) Clinical value of pelvic 3-dimensional magnetic resonance image reconstruction in anorectal malformations. J Pediatr Surg 44:2369–2374
36. Georgeson K (2007) Laparoscopic-assisted anorectal pull-through. Semin Pediatr Surg 16:266–269
37. Shawyer AC, Livingston MH, Cook DJ et al (2015) Laparoscopic versus open repair of recto-bladder neck and recto-prostatic anorectal malformations: a systematic review and meta-analysis. Pediatr Surg Int 31:17–30
38. Lin CL, Wong KK, Lan LC et al (2003) Earlier appearance and higher incidence of the rectoanal relaxation reflex in patients with imperforate anus repaired with laparoscopically assisted anorectoplasty. Surg Endosc 17:1646–1649
39. Chung PHY, Wong CWY, Wong KKY, Tam PKH (2018) Assessing the long term manometric outcomes in patients with previous laparoscopic anorectoplasty (LARP) and posterior sagittal anorectoplasty (PSARP). J Pediatr Surg 53:1933–1936
40. Yang J, Zhang W, Feng J et al (2009) Comparison of clinical outcomes and anorectal manometry in patients with congenital anorectal malformations treated with posterior sagittal anorectoplasty and laparoscopically assisted anorectal pull through. J Pediatr Surg 244:2380–2383
41. Ren X, Xu H, Jiang Q et al (2019) Single-incision laparoscopicassisted anorectoplasty for treating children with intermediatetype anorectal malformations and rectobulbar fistula: a comparative study. Pediatr Surg Int. https ://doi.org/10.1007/s0038 3-019-04549 -3
42. Ming AX, Li L, Diao M et al (2014) Long term outcomes of laparoscopic-assisted anorectoplasty: a comparison study with posterior sagittal anorectoplasty. J Pediatr Surg 49:560–563
43. Nixon HH, Puri P (1977) The results of treatment of anorectal

anomalies: a thirteen to twenty year follow-up. J Pediatr Surg 12:27–37
44. Rintala RJ, Lindahl HG (2001) Fecal continence in patients having undergone PSARP procedure for a high anorectal malformation improves at adolescence as constipation disappears. J Pediatr Surg 36:1218–1221