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Comparison of robot-assisted and laparoscopic-assisted modified Soave short muscle cuff anastomosis surgeries for classical Hirschsprung disease

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Abstract

Background In this study, we aimed to compare the efficacy of robot-assisted and laparoscopic-assisted modified Soave with that of short muscular cuff anastomosis surgery for classical Hirschsprung disease (HSCR).

Methods Sixty children with HSCR who underwent surgical treatment in our department between January 2021 and December 2023 were retrospectively enrolled. The collected data included operative time, anal dissection time, blood loss, length of hospital stay, postoperative complications, and postoperative defecation control status.

Results No significant differences were observed in the operative time between the robot and laparoscopic groups ($P > 0.05$); however, the anal dissection time and intraoperative blood loss in the robot group were significantly lower than those in the laparoscopic group ($P < 0.05$). Additionally, there was no significant difference in the incidence of enterocolitis and length of hospital stay between the two groups. Significantly more patients presented with anastomotic complications in the laparoscopic group than in the robot group ($P < 0.05$). The defecation and soiling frequencies in the robot group were significantly lower than those in the laparoscopic group at the follow-up examination ($P < 0.05$). The postoperative defecation function score in the robot group was better than that in the laparoscopic group ($P < 0.05$).

Conclusion Robot-assisted modified Soave with short muscular cuff anastomosis has a shorter anal dissection time, lower incidence of anastomotic complications, and better defecation function in patients with classical Hirschsprung disease.

Level of evidence III.

Keywords Robot-assisted, Laparoscope, Hirschsprung disease, Postoperative complications, Efficacy

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Introduction

Soave's first report on the endorectal pull-through approach for the treatment of Hirschsprung disease (HSCR) dates to 1963 [1]. Georgeson and colleagues described an operation using laparoscopic anatomy of the rectum and anal mucosal dissection in 1995 [2]. Our team designed a laparoscopic-assisted modified Soave short muscular cuff anastomosis procedure for early-stage HSCR, which achieved good results [3]. However, because of the limitations in terms of operating precision, flexibility, and 2D surgical scenarios of ordinary endoscopic equipment, particularly during the mobilization of the pelvic floor rectum in younger infants and children with HSCR, the amount of surgical space needed, and the presence of fragile tissues increase the demands on surgical techniques and equipment. Robotic surgery, an emerging minimally invasive surgical technique, is widely performed for a variety of pediatric surgical patients because of its high-definition 3D imaging system and good stability [4]. In 2011, Hebra et al. first reported a Da Vinci robot-assisted pull-through procedure for HSCR and achieved satisfactory results [5]. Since then, there have been many reports of the use of robotic surgery for HSCR [6, 7].

Insufficient mobilization of the rectum in children with HSCR may increase the risk of pelvic plexus injury, resulting in increased rates of postoperative complications [8]. However, robotic surgical platforms can perform delicate operations in small spaces with the help of magnified 3D visual images, which reduces the incidence of unnecessary side injuries and facilitates more precise dissection of the pelvic floor. The postoperative outcomes in infants have been deemed satisfactory [6]. However, to date, few studies have compared the robot-assisted modified Soave short muscular cuff anastomosis procedure (RAS) and laparoscopic-assisted modified Soave short muscular cuff anastomosis procedure (LAS) for classical HSCR. Therefore, the aim of this study was to investigate the efficacy of the two procedures in the treatment of HSCR.

Materials and methods

Study design

Data from 89 patients with HSCR who were treated at the Department of Pediatric Surgery, Affiliated Hospital of Zunyi Medical University from January 2021 to December 2023 were collected. All patients were divided into two groups: the RAS and LAS groups. The Ethics Committee of the Affiliated Hospital of Zunyi Medical University approved the study (approval number: 20210829), and written informed consent was obtained from the legal guardians of each patient. The inclusion criteria were patients diagnosed with rectosigmoid HSCR based on clinical manifestations, barium enema, anorectal manometry, and rectal mucosal biopsy. The exclusion criteria were as follows: (1) long-segment HSCR or total colonic aganglionosis; (2) patients with trisomy 21; (3) HSCR combined with preoperative enterostomy; and (4) severe cardiopulmonary disease. Ultimately, 60 children were included in this study.

Operative procedure

The RAS procedure was performed using the Da Vinci Xi™ surgical system (Intuitive Surgical, Inc. USA). Briefly, under general anesthesia, the patient was placed in the supine position, and gastric and urinary tubes were inserted. Three robotic ports were placed, an 8-mm port was made in the umbilicus for the camera, and two working trocars with 8-mm robotic devices were placed on either side. The CO_2 insufflation pressure was set at 8–12 mmHg. Port placement changes were made according to the age and size of the patient. The patient was placed in the high head-foot position. A robotic Maryland dissector, a robotic monopolar scissor, and a robotic needle holder were used for the procedure, which consists of six major steps. The pelvic floor wall peritoneum was sutured, and the bladder or uterus was suspended (Fig. 1A). A ganglionic segment range was assessed by seromusculature biopsy using a robotic monopolar scissor. Two 0.5-cm muscular layers were removed from both the stenotic and dilated segments of the colon (Fig. 1B), before closing the biopsy sites with interrupted 5 – 0 absorbable sutures.

A Maryland dissector and a robotic hook were used for dissection. Dissection was circumferentially performed down to the pelvis, which was the most crucial and unique part of the procedure. Dissection began circumferentially at 0.5 cm above the peritoneal reflection. With the help of the 10× magnification and 3D camera, the plasma membrane layer and longitudinal rectus muscle were easily separated to avoid damaging the Denovillers fascia, presacral fascia, and perirectal neurovascular plexus until the rectum was dissected downward to the dentate line (Fig. 1C). Turning to the lower edge of the marginal vessels of the proximal colon to dissect the lateral peritoneum of the sigmoid colon, sigmoid mesocolon, and descending mesocolon, blood flow in the pulled-through intestinal tubes was assessed via IV indocyanine green (Fig. 1D). If necessary, the splenocolic ligament was loosened to ensure that the pull-through colon could be dragged to the anus. After unlocking the robot, the patient underwent perineal surgery. The anal canal was dilated using a long Starr radial retractor, and a circular incision was made 0.5 cm from the edge of the dentate line. The rectal mucosa duct was dissected approximately 0.5 cm from the surface of the robotic dissection plane in the pelvis (Fig. 1E). One-third of the anterior wall of the muscular cuff was retained because there were afferent nerves controlling urination and defecation in the anterior wall of the muscular cuff. The next step was resection of the aganglionic bowel, and the ganglionic bowel was pulled through, resulting in colo-anal anastomosis with interrupted 5/0 or 4/0 absorbable sutures (Fig. 1F).

The LAS procedure was performed as previously reported. Briefly, three typical trocars were used with a 5-mm transumbilical camera trocar and two 3- or 5-mm operative trocars at the right and left lateral abdomen. Initially, several bowel myometrial biopsies were performed to confirm the presence of ganglion cells in the

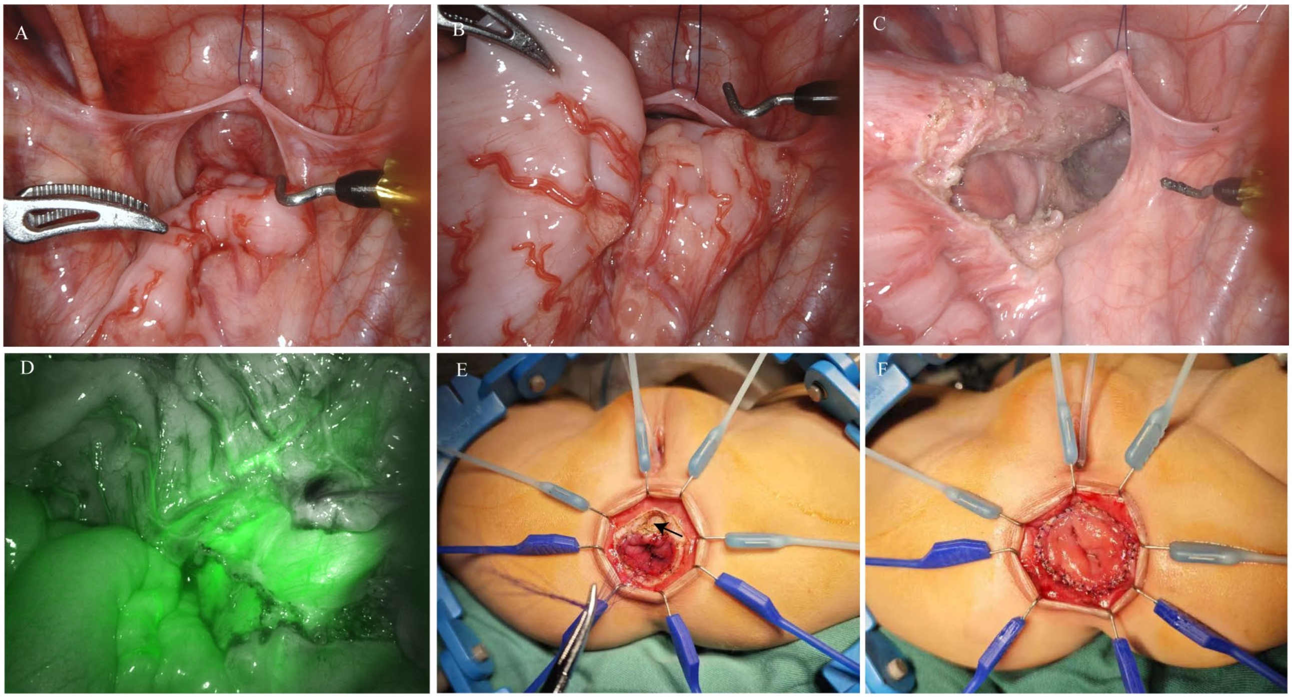

Fig. 1 Da Vinci robot-assisted modified Soave with short muscular cuff anastomosis surgery. (**A**) Exploring the tissue structure around the pelvic and rectal regions. (**B**) Exploring the extent of expansion and determining the location of resection. (**C**) Separating the rectum from the pelvic floor. (**D**) Indocyanine green angiography was used to assess blood flow through the pulled-through colon. (**E**) Dissecting the mucosa of the anus to allow the colon to be pulled through (as indicated by the arrow at the free position of the pelvic floor by the robot). (**F**) Anastomosis

myometrial plexus. The mesentery of the colon was separated by laparoscopy to preserve the vessel of the pull-through bowel. Under the rectal peritoneal reflex, close to the rectal wall separated with the electric hook, the anterior wall of the rectum was separated to the bladder neck or the posterior wall of the vagina. The posterior wall of the rectum was separated down to 1–2 cm above the dentate line. After laparoscopy, an anal tractor was used to expose the dentate line (Fig. 2A). The anal canal was dilated using a long Starr radial retractor, and a circular incision was made 0.5 cm from the edge of the dentate line. The rectal mucosal duct was dissected approximately 3–4 cm from the surface of the laparoscopic dissection plane in the pelvis (Fig. 2B and C). The posterior wall of the muscular cuff was completely removed along the left and right sides, accounting for two-thirds of the entire circular muscular cuff to 0.5 cm of the dentate line edge. One-third of the anterior wall of the muscular cuff was retained (Fig. 2D). Subsequently, the aganglionic bowel was resected and the ganglionic bowel was pulled through. Finally, colo-anal anastomosis was performed with interrupted 5/0 or 4/0 absorbable sutures.

Postoperative treatment

The gastric tube was removed 24 h after surgery, a small amount of water was removed, and a rectal tube was left in place for 5 days postoperatively. A small amount of milk was consumed on the second day after surgery, before gradually transitioning to a normal diet. Intravenous antibiotics (Ceftazidime for injection; 5 0 mg/kg body weight, bid) were administered for 5 days, and the patients were discharged 7 to 8 days after surgery. A routine digital rectal exam was conducted postoperatively after 2 weeks, and an anal dilatation plan was developed. Outpatient follow-up examination was conducted 2 weeks, 1 month, and 3 months postoperatively.

Outcome measures

The operation time, anal dissection time, intraoperative blood loss, length of hospital stays, incidence of HAEC, anastomotic complications (anastomotic stricture, anastomotic leakage, rectovaginal fistula), and HSCR recurrence of each patient were recorded. Patient/family surveys were conducted for patients older than 2 years and scored using an improved uniform postoperative fecal continence (POFC) score to evaluate defecation function at 3 months of pull-through in Table 1.

Statistical analysis

Data were analyzed using SPSS software version 29.0. Continuous data are expressed as the mean ± standard deviation. A t-test was used to compare the operative time, anal dissection, and length of hospital stay between the RAS and LAS procedures. Qualitative data are

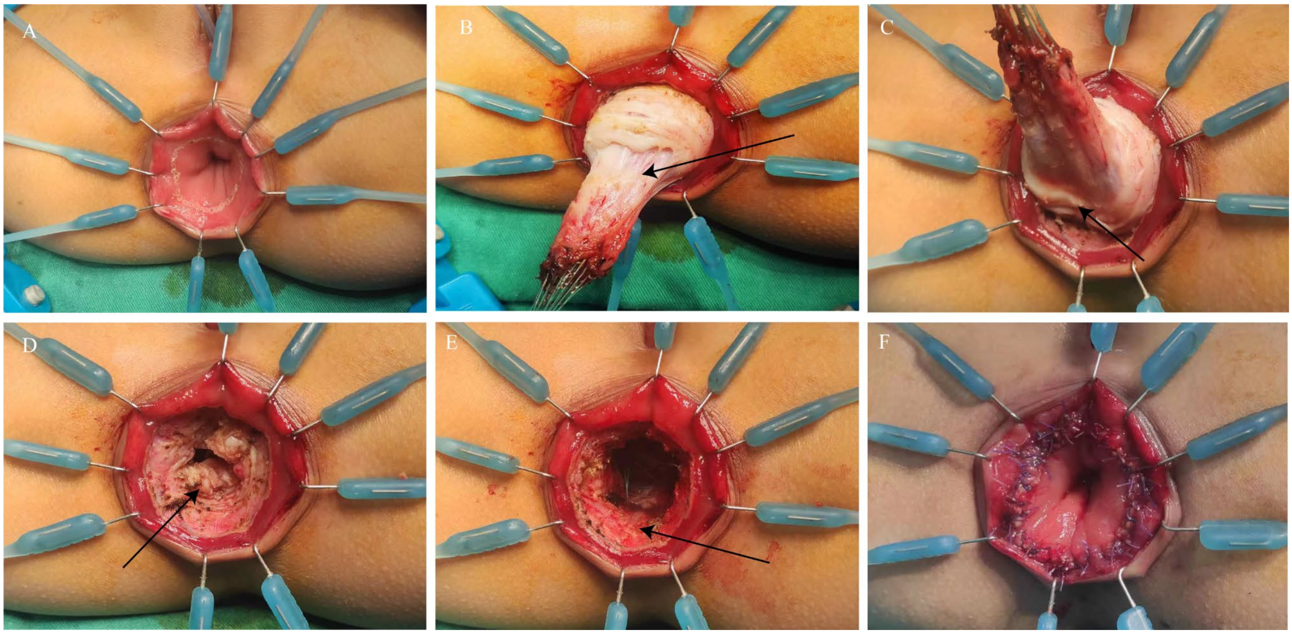

Fig. 2 Laparoscopic-assisted modified Soave procedure with short muscular cuff anastomosis surgery. (**A**) Position of the dissected rectal mucosal duct. (**B**) Dissection of the anterior wall of the rectal mucosal duct (the dissection between the submucosal and muscular layers, as indicated by the arrow). (**C**) Laparoscopic dissection of the posterior wall of the rectal mucosal duct (laparoscopically dissected close to the pelvic floor, as indicated by the arrow). (**D**) The remaining rectal muscle cuff. (**E**) The partial muscle cuff of the posterior rectum was removed to expose the external sphincter (indicated by the arrow). (**F**) Anastomosis

Table 1 Scale for postoperative fecal continence score

Evaluation on the POFC scores	0	1	2
Frequency of defecation (/day)	≥ 6	3 ~ 5	1 ~ 2
Soiling	**Usually**	**Sometimes**	**Never**
Rupture of perianal abscess	**Usually**	**Sometimes**	**Never**
Appearance of anal	mucosal prolapse (surgical treatment)	mucosal prolapse (No surgical treatment)	Normal
Medication	Laxative use	Laxative/ enema	unnecessary

presented as percentages and were compared using the chi-square test. A *p*-value of 0.05 was considered statistically significant.

Results

A total of 89 patients with HSCR were assessed for eligibility, and 60 patients were finally enrolled in the study (Fig. 3). The patients' general clinical data are presented in Table 2. No significant differences were observed in sex, age, or weight ($P > 0.05$). The operative times did not differ significantly between the RAS and LAS groups (203.1 ± 68.0 min vs.180.9 ± 30.9 min; $P > 0.05$). However, in the RAS group, the anal dissection time (20.2 ± 3.3 min vs. 33.1 ± 5.6 min; $P < 0.05$) and intraoperative blood loss (11.0 ± 6.0 ml vs. 16.9 ± 13.2 ml; $P < 0.05$) were significantly decreased compared to those in the LAS group. The two groups showed no significant difference in the length of hospital stays.

Comparison of postoperative complications are listed in Table 3. One patient in the RAS group exhibited incisional hernia, but no patients in the LAS group. One patient (4.0%) in the RAS group and four patients (10.3%) in the LAS group presented with perianal dermatitis. One patient (2.9%) in the LAS group exhibited urinary retention, but no patients in the RAS group. One patient (4.0%) in the RAS group and five patients (14.2%) in the LAS group were presented with enterocolitis in the early postoperative period. The incidence of incisional hernia, perianal dermatitis, urinary retention, and enterocolitis did not differ significantly between the two groups ($P > 0.05$). Six patients (17.1%) in the LAS group exhibited anastomotic complications that were significantly higher than those in the RAS group ($P < 0.05$). Additionally, three patients in the LAS group suffered from anastomotic stricture, two patients were diagnosed with anastomotic leakage, and one patient suffered from rectovaginal fistula 2 months after pull-through surgery. However, no patients were diagnosed with anastomotic complications in the RAS group.

The POFC score is shown in Table 4. Fouty-six patients aged > 2 years were evaluated using the POFC systems during follow-up. The defecation frequency in the RAS

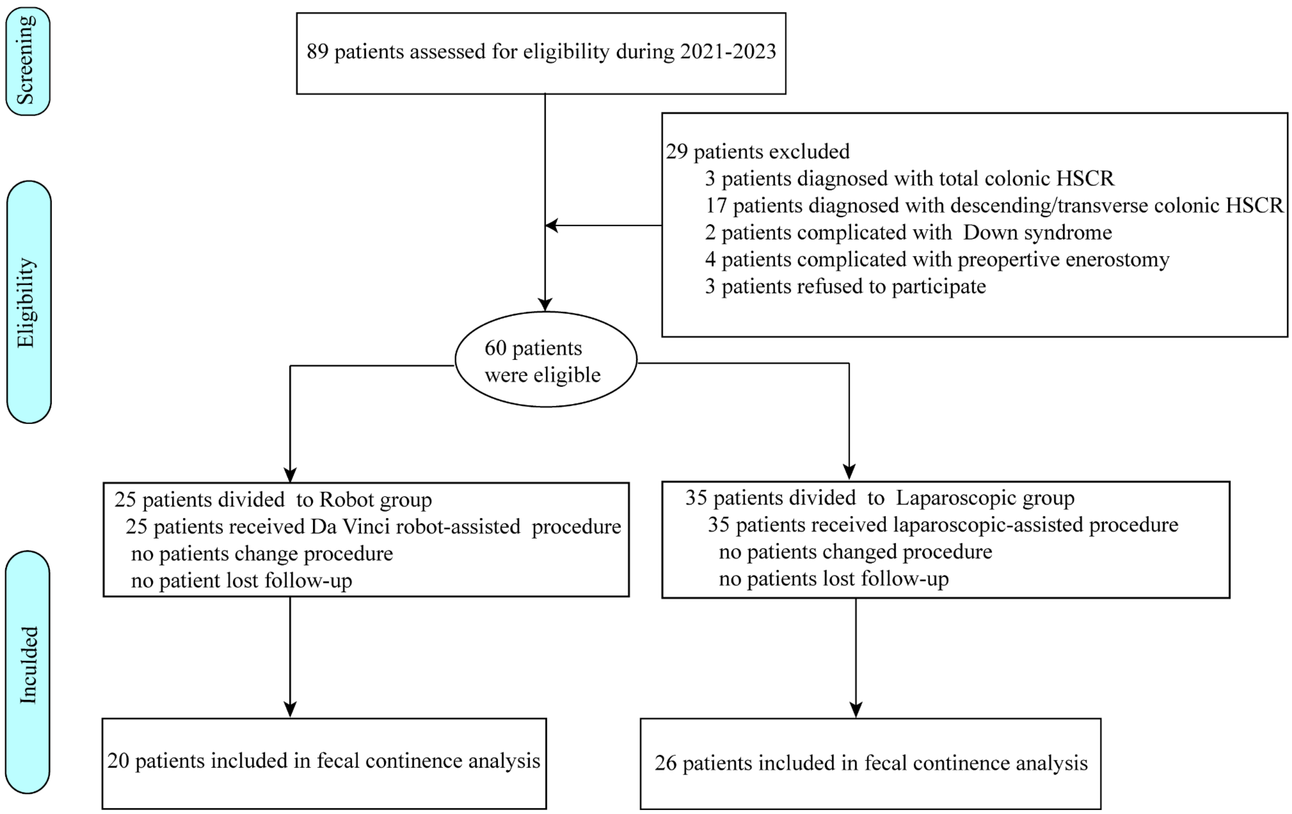

Fig. 3 Flowchart of patient randomization to LIC and LCEC groups

Table 2 The clinical characteristics between the two groups

Perioperative indicators	LAS group ($n=35$)	RAS group($n=25$)	P-value
Sex(M: F)	25:10	17:8	0.77
Age(month)	32.1 ± 15.7	37.8 ± 21.5	0.63
Weight(kg)	12.1 ± 7.7	11.9 ± 8.9	0.90
Operative time (min)	203.1 ± 68.0	180.9 ± 30.9	0.13
Anal dissection time (min)	33.1 ± 5.6	20.2 ± 3.3	< 0.001
Blood loss(ml)	16.9 ± 13.2	11.0 ± 6.0	0.043
hospital stays (day)	11.8 ± 4.1	11.3 ± 2.7	0.60

Table 3 Comparison of postoperative complications between the two groups

postoperative complications	LAS group ($n=35$)	RAS group $n=25$)	P-value
Incisional hernia(n,%)	0	1(4.0%)	0.23
Perianal dermatitis(n,%)	4(10.3%)	1(4.0%)	0.36
Urinary retention (n,%)	1(2.9%)	0	0.39
Enterocolitis (n,%)	5(14.3%)	1(4.0%)	0.19
Anastomotic complications (n,%)	6(17.1%)	0	0.029
Anastomotic stricture (n,%)	3(8.6%)	0	0.13
Anastomotic leakage (n,%)	2(5.7%)	0	0.22
Rectovaginal fistula (n,%)	1(2.9%)	0	0.39

Table 4 Comparison of postoperative fecal continence between the two groups(3 months postoperatively)

Defecation functions	LAS group ($n=26$)	RAS group ($n=20$)	P-value
Defecation frequency (times/d)	3.4 ± 1.2	2.4 ± 0.8	0.0011
Soiling (times/d)	1.4 ± 0.9	0.7 ± 0.7	0.002
Fecal incontinence	0	0	0
Fecal function scores	6.8 ± 0.9	7.7 ± 0.9	< 0.001

Table 5 Comparison of postoperative fecal continence between the two group(1year)

Defecation functions	LAS group ($n=14$)	RAS group ($n=9$)	P-value
Defecation frequency (times/d)	1.9 ± 0.5	1.3 ± 0.3	0.735
Soiling (times/week)	3.8 ± 2.2	1.2 ± 0.5	0.034
Fecal incontinence	0	0	0
Fecal function scores	8.3 ± 1.5	9.4 ± 0.3	0.047

group (2.4 ± 0.8 times/d) was significantly lower than that in the LAS group (3.4 ± 1.2 times/d), and the soiling frequency in the RAS group (0.7 ± 0.7 times/d) was significantly lower than that in the LAS group (1.4 ± 0.9 time/d). None of the patients suffered from fecal incontinence during follow-up. The POFC scores of the RAS group at 3 months postoperatively demonstrated better fecal continence than the LAS group (7.7 ± 0.9 vs. 6.8 ± 0.9; $P < 0.05$). The POFC system was used to evaluate the defecation function of 23 children who underwent surgery for more than 1 year during the follow-up in Table 5. The soiling frequency in the RAS group (1.2 ± 0.5 times/week) was significantly lower than that in the LAS group (3.8 ± 2.2 times/week). The two groups showed no significant difference in defecation frequency and POFC scores at postoperative one-year follow-up.

Discussion

Robotic surgery has been predominantly used for oncological, thoracic, urological, or abdominal procedures in pediatric surgery worldwide. In 2013, Rickey et al. reported an adult patient who underwent an uneventful Soave robotic-assisted endorectal pull-through [10]. In 2017, Pini Prato et al. first reported totally robotic Soave pull-through for HSCR children [7]. In 2023, Tang et al. reported a multicenter prospective study on robotic-assisted proctosigmoidectomy for HSCR [8]. Based on the series results, the robotic Soave procedure is a safe and effective alternative for treating HSCR, with no major intraoperative surgical issue or technical malfunction for low rectal dissection in children. Soave surgery is currently the most widely employed surgical technique for HSCR [11]. However, the traditional Soave procedure retained a longer muscle cuff, which led to muscle cuff infection, recurrence of constipation, and enterocolitis [12]. Many modified Soave procedures have been designed to shorten the muscle cuff and reduce the incidence of postoperative complications; these surgeries reduce the incidence of postoperative complications [13]. However, we observed that a shorter muscular cuff procedure could increase the incidence of soiling [9]. Therefore, our modified Soave procedure retained the anterior wall of the muscular cuff and completely removed the posterior wall of the muscular cuff. At the same time, with the precision and high stability of the robotic procedure, we expect to achieve the best postoperative fecal continence effect.

With the popularization of laparoscopic minimally invasive technology for treating HSCR, the laparoscopic-assisted Soave procedure has been adopted by most pediatric surgeons in China [9]. However, the narrow pelvic space of children, inflexible laparoscopic instruments, and unstable vision make submucosal rectal dissection in the pelvic floor more difficult, resulting in a higher rate of damage to the surrounding tissue and mucosal rupture. Therefore, the laparoscopic procedure needs to increase the extrarectal dissection time to reduce the risk of damaging pelvic floor tissues, especially the urethra, vagina, and pelvic plexus, which also increases the traction time of the anal sphincter, causes more sphincter injury, and results in poorer defecation function [14]. However, the Da Vinci robotic system provides a magnified 3D vision and a flexible and stable robotic arm and is suitable for delicate surgical operations in a narrow space [6]. These merits facilitate ideal identification close to the longitudinal muscle for endorectal dissection in the RAS procedure. Moreover, this potential gap is farther away from the urinal and sexual nerves ahead of Denonvillier's fascia. In this study, the anal dissection time in the RAS group was significantly shorter, even though the total operative time was longer than that in the LAS group. The results indicated that the robotic-assisted Soave procedure has superior advantages in extrarectal dissection, which is performed close to the rectal wall to 4–5 cm below the peritoneal reflection. Therefore, the robotic procedure could shorten the time of sphincter traction and avoid injury to the sphincter. Notably, no patient with related tissue injury around the rectum was observed in the RAS group; however, one patient had a complicated rectovaginal fistula in the LAS group. We speculate that this may be due to the narrow pelvic floor space and unclear vision of the infant, resulting in intraoperative damage to the vagina and failure to detect and treat it in a timely manner.

In our center, we have used the stepwise gradient cutting muscular cuff procedure since 2003 and shortened the muscular cuff to avoid the long aganglionic muscular cuff problem. We found that the shortened muscular cuff procedures could decrease the incidence of enterocolitis and obstruction symptoms [3]. However, there were still some patients who suffered from recurrent enterocolitis during the 20-year follow-up, which severely affected the long-term quality of life. In 2013, Levitt et al. reported that enterocolitis was effectively reduced by removing the entire rectus muscular cuff by adopting the Swenson procedure, although the frequency of soiling still increased for a short time after surgery [15]. Based on the above reasons, we adopted short muscular cuff anastomosis and removed the posterior wall of the muscular cuff to treat HSCR, which could effectively balance the relationship between outlet obstruction and fecal contamination. In this study, the incidence of soiling and defecation frequency in the RAS group was significantly decreased compared to that in other literature reports during early postoperative follow-up. At the same time, it was lower than that in the LAS group. The robotic procedure could shorten the time of sphincter traction and avoid injury to the sphincter.

Although many researchers have indicated that the modified Soave procedure for shortening the muscular cuff is similar to the Swenson procedure [16], there are also many differences. First, the Swenson procedure involves dissecting the rectum below the peritoneal reflex line to the lower margin of the levator ani. If rectal dissection is not sufficient, high anal anastomosis may occur, increasing the risk of anastomotic leak and HSCR recurrence. Our modified Soave procedure involves dissecting the rectal mucosa through the anus and reaching the anatomical plane of the rectum by laparoscopic or robotic surgery, avoiding damage to the surrounding tissue of the rectum as much as possible. Second, in the modified Swenson procedure, full-thickness rectal dissection was performed from the Herrmann line, while the mucosa dissection began 0.5 cm above the dentate line in the modified Soave procedure. Finally, the modified Swenson surgery requires removal of all aganglionic segments of muscles around the rectum, whereas our approach preserves the muscle cuff of the anterior wall of the rectum, which also serves as a site for both voiding and sexual nerve afferents.

Enterocolitis is one of the most important reasons for recurrent hospitalization for HSCR, and its etiology is related to numerous factors. Many studies have reported that the HAEC incidence rate was 4.6–54%, and anastomotic obstruction was an independent risk factor [17]. The incidence of enterocolitis was 14.2% in the LAS group and 4.0% in the RAS group, both of which were lower than those of the same type of procedures [8]. This may be due to the removal of the partial muscle cuff on the posterior wall of the rectum in our procedure, while only retaining the 1–2 cm muscle sheath on the anterior wall of the rectum, effectively avoiding outlet obstruction and reducing postoperative constipation recurrence and anastomotic stenosis. Research has reported that 75% of recurrent enterocolitis can be relieved through internal sphincter lysis [18], with studies reporting that injection of botulinum toxin into the internal sphincter can effectively improve the frequency of enterocolitis [19]. The robotic procedure dissects the rectum from the longitudinal muscle that adhere closely to the rectum under the pelvic floor peritoneal reflex, and the preserved muscle sheath is shorter than that of the laparoscopic procedure; therefore, the probability of postoperative anastomotic obstruction and the incidence of enterocolitis are reduced in the RAS group.

Excessive shortening of the internal sphincter may raise concerns among pediatric surgeons because of its potential association with an increased occurrence of postoperative fecal incontinence and soiling [20]. In this study, none of the patients suffered from fecal incontinence. The frequency of soiling ranged from 1 to 2 times per day, and the frequency of soiling in most of the children gradually decreased with increasing operation time. Research suggests that postoperative bowel control is related to normal anal receptors, autonomous control of the sphincter, and regular colonic peristalsis. The partial or complete absence of these factors is an important cause of postoperative fecal incontinence or contamination. For patients with partial colon dilation and fecal contamination, colonic lavage and a high fiber diet can effectively improve symptoms. Furthermore, we used the POFC score to analyze fecal incontinence, reflecting its role in nerve and sphincter protection. The POFC scores in the RAS group were higher than those in the LAS group during the early follow-up. Many studies reported that the POFC score gradually improved with time and may eventually return to a normal range [8]. Therefore, the robotic-assisted modified Soave procedure used for HSCR, resection of the posterior rectal muscle cuff, and anastomosis with the short muscle cuff can effectively reduce the incidence of enterocolitis and soiling and improve the quality of life of children with HSCR.

This study also has certain limitations, including the small number of cases and the fact that it is a single-center study. The cases in this study lack long-term follow-up results on bowel function to support the advantages and disadvantages of the two surgical methods. In the future, multicenter, large-sample, and long-term follow-up studies will be needed to further evaluate the advantages and disadvantages of the two surgical methods.

To summarize, the robot-assisted modified Soave short muscular cuff anastomosis procedure has a shorter anal dissection time, lower incidence of anastomotic complications, and better postoperative fecal function than the laparoscopic-assisted modified Soave short muscular cuff anastomosis procedure for classical HSCR.

Abbreviations

HSCR	Hirschsprung disease
RAS	Robot-assisted modified Soave short muscular cuff anastomosis
LAS	Laparoscopic-assisted modified Soave short muscular cuff anastomosis

Author contributions
ZZB, JZ, and LYM conceived and designed the experiments; TCY, GY, HL, XXR, ZDW, and LZP recorded the follow-up data; LYY and HSY analyzed the data; and LYY and ZZB wrote the manuscript.

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Data availability
The datasets of the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by The Ethics Committee of Affiliated Hospital of Zunyi Medical University (Approval number: ICUC-20210829) and was performed in accordance with the Declaration of Helsinki. All patients or their authorizers gave written informed consent before the operation.

Consent for publication
The manuscript is approved for publication by all the authors. Written informed consent was obtained from the patients and/or their legal guardians for publication, and any accompanying images, sex, age of these patients.

Competing interests
The authors declare no competing interests.

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