

# One-Stage Transanal Endorectal Pull-through for Hirschsprung Disease: experience with 229 neonates

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## Research Article

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# Abstract

## Objective

To evaluate the safety and efficacy of the transanal endorectal pull-through (TEPT) and the long-term outcomes in newborns with HD.

## Methods

A total of 229 newborns with HD underwent one-stage TEPT between 2007 and 2020, and the diagnoses were confirmed by rectal biopsy. The perioperative clinical course for all patients was reviewed, and the postoperative short- and long-term outcomes were assessed.

## Results

A total of 229 neonates (187 male and 42 female) had a median age at TEPT of 17 days (range, 6–28 days). Sixty-eight patients (29.7%) underwent TEPT combined with an abdominal approach or laparoscopy. Early postoperative complications were documented in 26 patients (11.4%). The follow-up period in the remaining 165 children ranged from 1.2 to 14.0 years (median, 5.0 years), and late postoperative complications were noted in 6 patients (3.6%). A total of 106 of the patients older than four years old took part in an interview about bowel function, and 85 patients (80.2%) had a bowel function scores (BFS)  $\geq 18$ .

## Conclusion

TEPT is effective and safe in the treatment of neonatal HD and presents with a low rate of complications and an acceptable outcome.

## 1. Introduction

Hirschsprung disease (HD) is a congenital disorder characterized by the absence of ganglion cells in the submucosal and myenteric plexus of the bowel, which results in functional obstruction. HD affects approximately one in 5000 live-born infants (Langer, 2013). The usual presentation of neonates with HD is delayed passage of meconium, abdominal distention, constipation, and vomiting (de Lorijn et al., 2007).

In the past several decades, increasing numbers of pediatric surgeons have abandoned the historical multiple-stage procedure in favor of a single-stage technique, with its safety and efficacy (Ghorbanpour et al., 2019; Langer et al., 2003). Since then, multiple series have reported that transanal endorectal pull-through (TEPT) is especially suitable for newborns and young infants (Teitelbaum et al., 2000; Vű et al., 2010). However, there is still insufficient data for establishing the optimal timing of the pull-through

surgery. Some surgeons recommend that surgery be performed in infants > 3 months old because there were lower rates of accurate and conclusive diagnostic results and poorer postoperative outcomes in younger infants(Kyrklund et al., 2020; Zhu et al., 2019). However, some surgeons believe that delaying surgical treatment might lead to persistent colorectal obstruction, malnutrition, and enterocolitis(Demehri et al., 2013).

The purpose of this study was to evaluate the short and long-term results of primary TEPT during the newborn period. We collected the data of neonates who were treated for HD by TEPT in our hospital within the past 14 years.

## 2. Materials And Methods

### 2.1 Patients

We retrospectively reviewed the medical records of all newborns who had a one-stage TEPT for HD between 2007 and 2020 at Beijing Children's Hospital (BCH). The criteria for inclusion in the study were as follows: (1) preoperative diagnosis of HD based on the results of suction rectal biopsy (SRB), (2)  $\leq 28$  days old at the time of one-stage TEPT. The exclusion criteria were as follows: (1) staged enterostomy performed, or (2) > 28 days old at the time of one-stage TEPT. The criteria of pathological diagnosis were as follows: (1) a biopsy specimen was at least 3 mm diameter, and a minimum of one-third of the sample should include the submucosa; (2) representative tissue sample should show the absence of ganglion cells and/or hypertrophic nerve fibers; and (3) another ancillary methods should support the diagnoses of HD at least, including immunohistochemistry staining of calretinin, CD56, and S100.

The demographic information, details of surgery, the length of aganglionosis, early postoperative complications (within 6 months of the surgery) and follow-up data including late postoperative complications, bowel function and development condition were documented. Follow-up information was obtained in the form of telephone inquiries or outpatient reviews. In addition, the bowel function scores (BFS) was used to assess the bowel functional outcomes in children older than 4 years of age, which consists of questions on urgency, rectal sensation, stool frequency, soiling, fecal continence, and social impacts of bowel habits(Jarvi et al., 2010). The maximum score is 20. In individuals considered healthy, the mean ( $\pm$  SD) score was  $19.1 \pm 1.3$  and the 10th percentile was 18(Rintala et al., 1997). The development condition of children was evaluated by Z score calculated for all 3 growth indicators (height for age, weight for height, and body mass index for age) using the World Health Organization's Anthro Software (Version 3.2.2, WHO, Geneva, Switzerland). This retrospective study was approved by the Medical Ethics Committee of the BCH (2020-Z-082), and the patient informed consent requirements were waived.

### 2.2 surgery

All the patients were operated TEPT. The mucosal incision was made 5 mm proximal to the dental line, and a submucosal dissection was carried proximally. The rectal muscular cuff was 3 cm long. And then it

separated upward along the rectum wall to the level of the peritoneal reflection. The transition zone was confirmed by frozen section analysis of the intraoperative biopsy sample. In some cases, we identified the pathological transition zone by laparoscopy or laparotomy to undergo a seromuscular biopsy because of the atypical colon appearance such as long-segment HD (the proximal aganglionic bowel segment extends to the transverse or descending colon) and total colonic aganglionosis (TCA). The bowel was then transected and an anastomosis was performed.

## **2.3 Statistical analysis**

We analyzed all the data using SPSS 26.0. Continuous variables were presented as the mean with standard deviation or median and interquartile range if the normality hypothesis test rejected the null hypothesis of normal distribution. Categorical variables were reported as counts and percentages. The two independent samples *t*-tests and Mann Whitney U test were used to compare BFS, and the Kruskal-Wallis H test was used to compare the operating time.  $P < 0.05$  was considered statistically significant.

## **3. Results**

### **3.1 Patient characteristics**

A total of 229 neonates (187 male and 42 female), with a median age of 17 days when receiving TEPT, were included in the study analysis. The patient characteristics were listed in Table 1. There were only four premature infants (1.7%). The median birth weight was 3490 g, and the median weight at the time of surgery was 3375 g. There was a case of Waardenberg syndrome. In addition, other associated anomalies were found in 31 patients (13.5%), including 18 cardiac anomalies, 11 urogenital anomalies and 2 polydactylisms. Nine patients (3.9%) had a specific family history of HD.

Table 1  
Patient characteristics.

Variables		Results
Gender (n, %)	Male	187 (81.7)
	Female	42 (18.3)
Gestation (n, %)	Mature	225 (98.3)
	Premature	4 (1.7)
Birth weight (median, range, g)		3490 (2100–4500)
Surgery weight (median, range, g)		3375 (1900–4500)
Age at surgery (median, range, day)		17 (6–28)
Presenting symptom (n, %)	Abdominal distention	222 (96.9)
	Vomiting	172 (75.1)
	Diarrhea	20 (8.7)
	Delayed meconium discharge	198 (86.5)
	Tight anal sphincter with an empty rectum or explosive discharge	198 (198/215, 92.1)
Family history (n, %)	Radiological transitional zone	9 (3.9)
Barium enema (n, %)	No radiological transitional zone	167 (72.9)
		62 (27.1)

The presenting symptoms included abdominal distention (96.9%), vomiting (75.1%), and diarrhea (8.7%). Thirty-one patients (13.5%) passed meconium within 24 hours. Thirty-two patients (14.0%) passed meconium between 24 and 48 h, and fifteen patients (6.6%) passed meconium after 48 h. Furthermore, 151 patients (65.9%) were unable to discharge the meconium after birth and required an irrigation or a rectal stimulation to relieve their discomfort. The rectal examinations of 198 of the 215 patients (92.1%) who underwent the study demonstrated a tight anal sphincter or explosive discharge of stool and gas.

A contrast enema examination was diagnostic in 167 of the patients (72.9%). However, 62 patients (27.1%) did not demonstrate a radiological transition zone, who were finally confined to the lower rectum (22, 35.5%), sigmoid colon (26, 41.9%), and long-segment (14, 22.6%).

### 3.2 Surgical course

The patients were determined to be the lower rectum (24.0%), sigmoid colon (52.0%), long-segment (22.3%), and TCA (1.7%), and the average distances of the transition zone from the dentate line in the lower rectum, sigmoid colon, and long-segment were  $3.6 \pm 0.7$ ,  $8.3 \pm 3.5$ , and  $21.5 \pm 8.2$  cm, respectively. The aganglionosis segment that was removed in the TCA included the entire colon with additional small intestine (Table 2).

Table 2  
Level of aganglionosis and distance of the transition zone from the dentate line.

Level of aganglionosis	N (%)	Distance of the transition zone from the dentate line (mean $\pm$ SD, range, cm)
Lower rectum	55 (24.0)	$3.6 \pm 0.7$ (1.5-5.0)
Sigmoid colon	119 (52.0)	$8.5 \pm 3.5$ (4.5–20.5)
Long-segment	51 (22.3)	$21.5 \pm 8.2$ (9.0-47.5)
TCA	4 (1.7)	Entire colon

The treatment process of the sigmoid colon is similar to that of the lower rectum, so we sometimes combine them into one category called the short-segment HD. In the short-segment group, 161 patients underwent TEPT, and 13 patients underwent TEPT combined with an abdominal approach or laparoscopy. Among these, 11 patients needed to have the pathologic transition zone identified before initiating the anal dissection. In the long-segment and TCA groups, 38 patients underwent TEPT combined abdominal approach, and 17 patients underwent TEPT combined with laparoscopy.

The median operating time (including the time needed to wait for the frozen biopsy results) of the short-segment, long-segment, and TCA was 75, 161, and 190 minutes, respectively, and it was significantly shorter in short-segment, long-segment, and TCA groups ( $p < 0.001$ ). No patients required a blood transfusion. There were no intraoperative complications.

Postoperatively, the median time of initial oral nutrition was 2 days (range, 1–15 days), and the median postoperative hospital stay of the patients in the short-segment group was 7 days (range, 6–36 days), while that of the long-segment group was 10 days (range, 6–44 days).

### 3.3 Early complications

Early postoperative complications (within 6 months of the surgery) were documented in 26 patients (11.4%), which are cited in Table 3. Wound infection developed in 3 patients (1.3%), and all of them were cured by conservative treatment without surgical treatment. Two patients (0.9%) had anastomotic leakages, of which 1 infant with sigmoid colon segment improved after conservative treatment and was discharged 30 days after surgery. Another patient with long-segment disease eventually underwent an

enterostomy on the seventeenth postoperative day. An anal fistula occurred in 1 patient (0.4%), and repair surgery was performed.

Table 3  
Early complications.

Complications	N (%)	Level of aganglionosis
Wound infection	3 (1.3)	2 Long-segment, 1 Lower rectum
Anastomotic dehiscence	2 (0.9)	1 Long-segment, 1 Sigmoid colon
Anal fistula	1 (0.4)	Lower rectum
Enterocolitis	16 (7.0)	1 TCA, 4 Long-segment, 9 Sigmoid colon, 2 Lower rectum
Early intestinal obstruction	2 (0.9)	Sigmoid colon
Sepsis	3 (1.3)	2 Long-segment, 1 Sigmoid colon
Total	27 (11.8)*	
*The total number of patients was 26 because 1 patient experienced early intestinal obstruction and enterocolitis after the operation.		

Postoperative enterocolitis occurred in 16 children (7.0%), of which 1 patient underwent a transient ileostomy to relieve the condition and underwent a stoma closure surgery after 2 months. Unfortunately, 1 patient, who had TCA and had his entire colon removed during the surgery, developed severe diarrhea resulting in dehydration and died without treatment after two weeks of discharge.

Early intestinal obstructions were noted in 2 patients (0.9%). The first patient had a delayed discharge due to intestinal obstruction but did not require additional surgery. The second infant, who had undergone laparoscopically assisted TEPT, developed intestinal obstruction after discharge from the hospital. Finally, an uneventful bowel enterolysis was performed after admission.

Unfortunately, one patient with long-segment disease died of septic shock after surgery. Two patients had severe infection after surgery, and their parents gave them up due to the high cost and possible poor outcome. The level of their aganglionosis was in the long-segment and sigmoid colon. Therefore, the early complications rate of the lower rectum was 7.7% (4/52), it was 9.8% (12/122) in the sigmoid colon, it was 17.6% (9/51) in the long-segment, and it was 25% (1/4) in the TCA.

\*The total number of patients was 26 because 1 patient experienced early intestinal obstruction and enterocolitis after the operation.

### 3.4 Late complications and outcomes

The follow-up period in the remaining 165 children (72.1%) ranged from 1.2 to 14.0 years (median, 5.0 years). Fifty-eight patients (25.3%) were lost during follow-up, and another two late deaths were noted,

both of which were unrelated to the pull-through. One patient died of congenital cardiac disease, and the second died of cephalomeningitis.

Late postoperative complications were noted in 6 patients (Table 4). In one child, mild rectal prolapse developed, but he did not require additional surgery. Five patients required additional surgery. Anastomotic strictures were observed in 2 patients (1.2%). Finally, they required a redo pull-through, but the postoperative pathology revealed ganglion cells in the resected bowel. Rectovestibular fistulas and a rectourethral fistula occurred in 2 patients and 1 patient, respectively. All of them were readmitted and underwent transanal fistulectomies, and they were followed up for more than 5 years and there was no recurrence.

Table 4  
Late complications.

Complications	N (%)	Level of aganglionosis
Anastomotic stricture	2 (1.2)	1 Sigmoid colon, 1 Long-segment
Rectovestibular fistula	2 (1.2)	1 TCA, 1 Sigmoid colon
Rectourethral fistula	1 (0.6)	Long-segment
Rectal prolapse	1 (0.6)	Lower rectum
Total	6 (3.6)	

A total of 106 of the patients above four years of age took part in an interview about bowel function. Eighty-five patients (80.2%) had a BFS  $\geq 18$ , and 61 patients (57.5%) had a BFS 20/20. In the individual items assessing bowel function, fecal soiling was observed in 22 patients (20.8%), of which 6 patients required protective aids due to soiling, 3 of whom had long-segment and others had sigmoid colon. Eleven patients (10.4%) had problems feeling the urge to defecate. Four patients (3.8%) had fecal accidents weekly, and 9 patients (8.5%) had fecal accidents less than one week. Constipation was noted in only 2 patients (1.9%), one of whom managed it with diet, and another managed it with laxatives. The frequency of defecation consisted of 92 children (86.8%) having defecation every other day to twice a day, 12 children (11.3%) defecated more often and 2 children (1.9%) defecated less often. The children's stool patterns were as follows: formed in 102 (96.2%), loose in 2 (1.9%), and dry in 2 (1.9%). Only 3 patients sometimes reported social problems.

In the short-segment, the mean BFS was decreased among the patients who were 4–7 years old ( $18.84 \pm 2.36$ ) in relation to the patients who were 8–14 years old ( $19.06 \pm 1.55$ ). The data showed that the older group had better scores in all aspects, but there was no significant difference between the two groups. (Table 5)

Table 5  
BFS of the short-segment.

<b>Variable</b>	<b>4–7 y (n = 44)</b>	<b>8–14 y (n = 35)</b>	<b>P</b>
Urgency period	2.84 ± 0.57	2.89 ± 0.40	0.91
Sensation of the urge to defecate	2.91 ± 0.29	2.94 ± 0.23	0.58
Frequency of defecation	1.89 ± 0.32	1.97 ± 0.17	0.16
Soiling	2.48 ± 0.90	2.54 ± 0.85	0.72
Fecal accidents	2.89 ± 0.39	2.91 ± 0.28	0.91
Constipation	3.00	3.00	1.00
Social problems	2.84 ± 0.43	2.80 ± 0.53	0.89
Total	18.84 ± 2.36	19.06 ± 1.55	0.94

In the long-segment, the mean BFS of the patients who were 4–7 years old and 8–14 years old was  $17.67 \pm 3.18$  and  $17.44 \pm 2.83$ , respectively. Of the individual factors assessing bowel function, the scores of the two groups were similar. (Table 6).

Table 6  
BFS of the long-segment.

<b>Variable</b>	<b>4–7 y (n = 15)</b>	<b>8–14 y (n = 9)</b>	<b>P</b>
Urgency period	2.73 ± 0.70	2.78 ± 0.44	0.82
Sensation of the urge to defecate	2.80 ± 0.41	2.78 ± 0.44	0.95
Frequency of defecation	1.67 ± 0.48	1.89 ± 0.33	0.38
Soiling	2.27 ± 1.03	1.89 ± 1.27	0.48
Fecal accidents	2.67 ± 0.72	2.78 ± 0.44	0.96
Constipation	2.80 ± 0.78	2.78 ± 0.67	0.83
Social problems	2.73 ± 0.46	2.56 ± 0.53	0.48
Total	17.67 ± 3.18	17.44 ± 2.83	0.68

Compared with the short-segment, the patients who had long-segment disease scored worse on questions assessing urgent bowel movements, fecal soiling, constipation, uncontrollable stools, and social problems as well as on the total scores. However, this was not statistically significant in either the

4–7 age group or the 8–14 age group. Of the 3 TCA patients followed up, 2 patients had a BFS of 18, and 1 patient had a BFS of 13 and had a poor bowel function.

Growth was evaluated during the follow-up by recording the height and weight centiles of all 165 children. The mean ( $\pm$  SD) weight for age Z score (WAZ), height for age Z score (HAZ), and body mass index for age Z score (BAZ) were  $0.53 \pm 1.02$ ,  $0.45 \pm 1.09$ , and  $0.4 \pm 1.22$ , respectively.  $< -2$  SD Z scores were noted in 3 (WAZ, 3/166, 1.8%), 1 (HAZ, 1/165, 0.6%), and 4 (BAZ, 4/165, 2.4%) patients, respectively.  $> 2$  SD Z-scores were noted in 9 (WAZ, 9/165, 5.5%), 12 (HAZ, 12/165, 7.3%) and 11 (BAZ, 11/165, 6.7%) patients, respectively. Actually, the total numbers of patients who had  $< -2$  SD Z scores and  $> 2$  SD Z scores were 6 (6/165, 3.6%) and 22 (22/165, 13.3%), respectively.

## 4. Discussions

It has previously been observed that more than 90% of HD patients show symptoms such as abdominal distention and vomiting during the neonatal period (Bradnock et al., 2017). In our study, all children had symptoms of incomplete obstruction and needed to be hospitalized.

In the past, some researchers believed that the enteric nervous system is immature and is still developing in neonates, so they suggested that conservative management, including anal dilation and colon enema, could be provided first, and then biopsies and surgical treatment could be performed when the infants were older (Nakao et al., 2001). However, in recent years, many studies have demonstrated that this conclusion might not be reliable. For example, even in premature infants, the incidence of HD is the same as that of full-term infants (Downey et al., 2015; Duess et al., 2014). The impression above may be related to the difficulty in identifying ganglion cells in newborns or premature infants because immature ganglion cells or ganglion cells in the neonatal period are similar to inflammatory cells (Ambartsumyan et al., 2020). In addition, multiple submucosal hypertrophic nerves ( $> 40 \mu\text{m}$ ) are not usually present in SRB from the aganglionic distal rectum of neonates with HD (Knowles et al., 2009). Therefore, it increases the difficulty of the pathological diagnosis in the neonatal period. To diagnose neonatal HD, auxiliary diagnostic methods such as immunohistochemistry and consultations with experienced pathologists are needed.

In our study, rectal mucosal biopsies that gained more than 2 specimens and had adequate submucosa were performed in all children before the operation. The surgical specimens were confirmed to have the absence of ganglion cells and/or had hypertrophic nerve fibers again in the final pathological examination. No misdiagnosis was found in any of the patients. Therefore, we recommend that TEPT be performed for HD in the neonatal period when using the expertise of experienced pathologists.

A contrast enema examination could be used to identify the level of aganglionosis, which generally describes a transitional zone including proximal dilatation with a spastic distal segment, but this is often not apparent in patients within the first few weeks after birth. In our study, the positive rate of contrast enema examination was 72.93%, which was similar to previous studies (Zhu et al., 2019). However, in our experience, surgeons could improve the diagnosis rate of HD by combining the medical history and

clinical manifestations with the imaging results. If the aganglionosis level cannot be confirmed before the operation, the operation will be more complicated; that is, a laparotomy or a laparoscopic-assisted seromuscular biopsy may be required to determine the extent of the intestinal excision. In 174 short-segments, the contrast enema examination results of 48 patients showed no transitional zone before the operation, but only 11 patients needed an abdominal approach or laparoscopic assistance during surgery. In the long-segment and TCA groups, no patients were diagnosed as having lower rectum or sigmoid colon disease before the operation, and all patients underwent seromuscular biopsy by laparoscopy or laparotomy and then radical surgery.

The patients in this study had an average operation age of 17 days and an average operation weight of 3375 g, of which 76% of the patients had diseases of the lower rectum and sigmoid colon, which was consistent with the general distribution of HD(Langer, 2013).

The TEPT procedure was first reported by Torre et al. in 1998(Torre-Mondragón and Ortega-Salgado, 1998). They described making a circumferential incision 10 mm above the dentate line in the rectal mucosa as the first step in a transanal mucosectomy. At the same time, Langer et al. described the transanal one-stage Soave procedure in 1999 [3] and started rectal mucosectomy from 5 mm proximal to the dentate line. All of them retained a long muscular rectal cuff from the incision position to the peritoneal reflex. However, some researchers thought that long muscular cuffs might be associated with obstruction, constipation, and enterocolitis(Arts et al., 2016), and some reports showed better results with a short muscle cuff or even no cuff, such as the Swenson procedure(Levitt et al., 2013; Rintala, 2003; Stensrud et al., 2015). Therefore, a muscular rectal cuff < 2–3 cm has been recommended by ERNICA(Kyrklund et al., 2020).

Since the advent of the TEPT procedure, our department has adopted and optimized the surgical methods based on our own experience. The mucosal incision is made 5 mm proximal to the dental line, and the submucosal dissection is continued proximally. The rectal muscular cuff used is 2.5-3 cm long. Then, it is separated upward along the rectum wall to the level of the peritoneal reflection and proximally. Because the operation is relatively simple, the operation time is shorter, and the impact on patients is less. We usually chose the colon that is close to the normal colon diameter and texture to excise (intraoperative frozen pathology confirmed the presence of ganglion cells). In the decision to select the extent of colon resection, to avoid the residue of the transitional segment, ERNICA recommends that in rectosigmoid HD, the colon should be transected at least 5 to 10 cm proximal to the first normal biopsy(Kyrklund et al., 2020). Then, we found that the compensatory dilatation of the proximal colon was mild, and the transitional segment was short in neonatal HD. This can avoid excessively excising the colon and thus affecting the long-term colonic function, which is especially advantageous in HD with a long level of aganglionosis.

On the other hand, in 40 patients who had sigmoid colon disease, the level of aganglionosis was located in the proximal sigmoid colon, near the junction of the sigmoid colon and descending colon. However, all of them underwent transanal surgery without laparotomy or laparoscopy, which might be related to the

shallowness of the pelvic cavity, the small volume of the abdominal cavity and the relaxation of the mesocolon in newborns. During the transanal surgery, the longest length of the colon pulled out through the anus was 28.5 cm. In our opinion, the majority of lower rectum and sigmoid colon HD patients, whose level of aganglionosis is below the junction of the sigmoid colon and descending colon, could undergo TEPT without a laparotomy or a laparoscopy in the neonatal period, and this technique is simple and efficient.

Almost as remarkably, in the long-segment and TCA, when the intestinal morphology might not be typical, we require a seromuscular biopsy to determine the transitional segment. Furthermore, the atypical pathology of some patients, such as patients who have immature ganglion cells and a normal nerve fiber plexus, makes the intraoperative pathological diagnosis more difficult. At this time, the surgeon needs to analyze the clinical manifestation and morphology of the intestine during the operation and verify the results repeatedly with the pathologist. We had experience in the long-segment, we took biopsy sections from the normal colon during the operation, but the results showed that there were no ganglion cells. After repeated confirmation by multipoint biopsies, it was finally confirmed that there were ganglion cells, which avoided excessively excising the colon, as well as a poor outcome.

As our study is a retrospective study, patients with long segment and TCA who underwent one-stage surgery in the neonatal period were selected, and they were in good condition. Therefore, for more serious patients, we need to choose the corresponding treatment plan according to the specific situation. In our patients, routine placement of an anal draining tube through the anastomosis was unnecessary, and anal dilation was performed for 1–3 months on an outpatient basis.

The incidence of complications within 6 months after operation was 11.8% (27/229), which was lower than the 15.6% complication rate found within one month after surgery in 182 patients in the neonatal period (< 31 days) noted by Mollie et al (Freedman-Weiss et al., 2019). Compared with other scholars' reports, the proportion of complications in our group was low. It has been reported that the incidence of postoperative enterocolitis in the neonatal period is 40.2% (Lu et al., 2017), which was not consistent with our experience. We believe that this may be related to the long preoperative colon enema time (5–7 days) in our hospital and the short muscular cuff we preserved, and more research is needed to support this view.

A total of 165 patients were followed up in this study, of which 106 children older than four years old took part in an interview about bowel function, and they were divided into two groups according to their age. There is no unified evaluation method for bowel function after surgery in HD. In the pediatric literature, several different questionnaires have been used, and only the BFS questionnaire has data from the normal population (Jarvi et al., 2010), so we chose the BFS and compared it with the literature using the same scoring criteria. In the lower rectum and sigmoid colon patients, the BFS was at a good level and increased with age. Although there was no significant difference, this might suggest that the defecation function may improve with age. Kristin et al. reported a survey of long-term bowel function after TEPT in 200 patients with rectosigmoid HD, and the mean BFS in nonsyndromic patients was 15.7. In contrast,

the BFS of our group was better. The bowel movements of most healthy infants changed from more frequent and loose stool to less frequent and formed stool. We hypothesize that this may be because infants undergoing surgery as newborns also went through that process, and the defecation system, the nervous system and muscular system were well developed, as well as the coordination between systems. This is our speculation, and more research evidence is needed.

In contrast, the BFS was lower in the long-segment patients. Among the 3 patients with TCA, 2 patients had fine bowel function (BFS = 18), and 1 patient had poor bowel function (BFS = 13), which was consistent with other reports(Kawaguchi et al., 2021). However, the number of children in our group was relatively small, and long-term follow-up is needed.

The frequency of fecal incontinence after TEPT varies considerably in the literature. In a recent retrospective population-based study of 103 patients with rectosigmoid aganglionosis who underwent TEPT, 29% reported fecal incontinence episodes of variable degree more than once a week after a median follow-up time of 15 years(Neuvonen et al., 2015). On the other hand, fecal incontinence was reported in only 12% of 281 patients who underwent endorectal pull-through after a mean follow-up time of 36 months(Kim et al., 2010), and in another study of patients undergoing endorectal pull-through, none reported fecal incontinence(Mattioli et al., 2008). In our study, soiling and fecal incontinence were also the main problems of long-term follow-up after the operation. A total of 73.6% (78/106) of the patients had no soiling or fecal incontinence during the follow-up, and the rest had a few of problems that occurred with a frequency of less than 1/week. Constipation only occurred in 2 long-segment patients, which was less than the proportion previously reported in the literature(Lu et al., 2017). We considered that constipation in the long-segment might be related to poor bowel function, which leads to insufficient intestinal peristalsis, resulting in stool retention.

Among all the follow-up patients, 6 children were poor in growth and development, and 22 children were above the normal level, which seemed to be basically consistent with the normal population distribution. Therefore, the one-stage TEPT in the neonatal period had no significant effect on the growth and development of HD children.

## **5. Conclusion**

TEPT performed by our department offers an improved method for the treatment of HD in patients during the neonatal period. Our data suggest that TEPT is effective and safe in the treatment of neonatal HD. Longer-term follow-up and controlled studies are needed to confirm these results in the future.

## **Declarations**

### **Author Contributions**

Jinshi Huang, Yanan Zhang, and Zhaozhou Liu designed the study. Zhaozhou Liu and Yanan Zhang wrote the main manuscript text. Shen Yang, Weihong Guo, Siqi Li, and Yingzi Li prepared table 1-6. All

authors reviewed the manuscript.

Conflict of interest☒ The authors declare no competing interest.

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