Boletín Médico del
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RESEARCH ARTICLE

Usefulness and description of the intestinal bypass technique in children with short bowel syndrome: report of a Mexican cohort

Yunuen Rivera-Suazo[1] Eustorgio S. García-Cárdenas[1], Isela Nuñez-Barrera[1], América L. Miranda-Lora[2], Juan J. Bolaños-Pérez[1], Rosalinda López-Rodríguez[3], Norma Briseño-Chavarria[3], and Salvador Villalpando-Carrión[1]*

[1]*Departamento de Gastroenterología y Nutrición;* [2]*Unidad de Investigación Epidemiológica en Endocrinología y Nutrición;* [3]*Clínica Colorrectal de Heridas y Estomas. Hospital Infantil de México Federico Gómez, Mexico City, Mexico*

Abstract

Background: *Short bowel syndrome (SBS) is one of the most frequent causes of intestinal failure, needing parenteral nutrition to maintain an energy-protein and water-electrolyte balance. At the Hospital Infantil de México Federico Gómez (HIMFG), the formation of two stomas is a technique used for intestinal rehabilitation, where the use of residue through the bypass technique (BT) helps to maintain gastrointestinal functionality, water-electrolyte, and nutritional stability. This study aimed to describe the technique of using intestinal residue through BT as a treatment strategy in intestinal rehabilitation and its effect on the biochemical and nutritional status of pediatric patients with SBS.* **Methods:** *An analytical and retrospective cross-sectional study was performed in patients hospitalized at HIMFG with SBS who underwent BT during their hospital stay between 2019 and 2020 and then followed up for 8 weeks.* **Results:** *A total of 10 patients were included in this study, with a mean age of 24 months; 50% were female. BT was able to reduce the inflammatory process in the liver caused by the continuous use of parenteral nutrition; enteral caloric intake increased from 25.32 kcal/kg/day to 72.94 kcal/kg/day, but it was insufficient to improve their nutritional status.* **Conclusions:** *BT is a safe and effective alternative in intestinal rehabilitation in patients with SBS to stimulate trophism and intestinal functionality, allowing a progression of enteral feeding and a decrease in the hepatic inflammatory process that occurs in these patients with prolonged parenteral nutrition.*

Keywords: *Short bowel syndrome. Intestinal failure. Prolonged parenteral nutrition. Intestinal bypass technique. Pediatric population.*

Utilidad y descripción de la técnica de puenteo intestinal en niños con síndrome de intestino corto: reporte de una cohorte en México

Resumen

Introducción: *El síndrome de intestino corto (SIC) es una de las causas más frecuentes de insuficiencia intestinal que requiere del uso de nutrición parenteral para mantener un balance energético-proteico e hidroelectrolítico. En el Hospital Infantil de México Federico Gómez (HIMFG) la formación de dos estomas es una técnica empleada para la rehabilitación*

***Correspondence:**
Eustorgio S. García-Cárdenas
E-mail: eustorgiogarcia1@hotmail.com

Date of reception: 21-07-2023
Date of acceptance: 27-12-2023
DOI: 10.24875/BMHIM.23000110

Available online: 11-03-2024
Bol Med Hosp Infant Mex. 2024;81(1):23-30
www.bmhim.com

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intestinal, donde con el aprovechamiento de residuo mediante la técnica de puenteo (TP) se ayuda a mantener la funcionalidad gastrointestinal, equilibrio hidro-electrolítico y estabilidad nutricional. El objetivo de este estudio fue describir la técnica del aprovechamiento de residuo intestinal mediante TP como estrategia de tratamiento en la rehabilitación intestinal y su efecto en el estado bioquímico y nutricional de pacientes pediátricos con SIC. **Métodos:** *Se llevó a cabo un estudio transversal analítico y retrospectivo en pacientes hospitalizados en el HIMFG con SIC en quienes se realizó la TP durante su estancia intrahospitalaria entre 2019 y 2020.* **Resultados:** *Se incluyeron 10 pacientes en este estudio, con una edad promedio de 24 meses, y el 50% de sexo femenino. La TP logró disminuir el proceso inflamatorio hepático ocasionado por el uso continuo de nutrición parenteral; la ingesta calórica por vía enteral incrementó de 25.32 kcal/kg/día a 72.94 kcal/kg/día, pero fue insuficiente para mejorar el estado nutricional.* **Conclusiones:** *La TP es una alternativa segura y efectiva en la rehabilitación intestinal en pacientes con SIC para estimular el trofismo y funcionalidad intestinal, permitiendo una progresión de la alimentación enteral y disminución del proceso inflamatorio hepático que se presentan en estos pacientes con nutrición parenteral prolongada.*

Palabras clave: *Síndrome de intestino corto. Insuficiencia intestinal. Nutrición parenteral prolongada. Técnica de puenteo intestinal. Población pediátrica.*

Introduction

Short bowel syndrome (SBS) is a complex condition caused by the anatomical or functional loss of part of the small intestine. This condition results in severe metabolic, electrolyte, and nutritional disturbances due to a reduction in the effective absorptive surface of the bowel[1]. According to Nightingale, a patient is considered to have SBS when the length of the intestine is insufficient to allow adequate absorption of nutrients, fluids, and electrolytes, which interferes with proper growth and development[2].

SBS is one of the most common causes of intestinal failure requiring parenteral nutrition to maintain energy-protein and water-electrolyte balance, a term introduced by Pironi et al.[3].

The term 'intestinal failure' was coined by Fleming and Remington in 1981 to describe a decrease in functional intestinal mass resulting in impaired digestion, absorption, or both[4]. The American Gastroenterological Association defines it as a condition resulting from obstruction, dysmotility, bowel resection, congenital defect, or disease associated with loss of absorption and characterized by an inability to maintain an adequate balance of fluids and electrolytes, proteins, and micronutrients[5].

The incidence of intestinal autonomy, defined as the ability of the gastrointestinal tract to be maintained without parenteral nutrition for more than three consecutive months, is estimated to range from 42% to 86% in cases of short bowel[6-8]. According to the Pediatric Intestinal Failure Consortium, in a study of 272 patients under 12 months of age with intestinal failure who received parenteral nutrition for more than 60 consecutive days, 44% achieved intestinal autonomy within 3 years, 26% died, and 23% required intestinal transplantation[7]. However, intestinal autonomy is not always achieved. Therefore, the introduction and combination of new intestinal rehabilitation therapies focusing on controlling and improving intestinal failure have enhanced intestinal adaptation and reduced the need for intestinal transplantation. These therapies include serial transverse enteroplasty, a surgical procedure to lengthen the intestine; optimization of total parenteral nutrition to prevent hepatopathy associated with intestinal failure through the use of omega-3 lipid emulsions and lipid minimization; and ethanol seals used to prevent recurrent catheter-related infections, sepsis, and bacterial overgrowth, as well as to treat intestinal dysmotility[9]. In patients with enterostomies, performing an enteral anastomosis can sometimes be challenging, which prolongs the use of the ostomy and affects the functionality of the distal bowel. At the Hospital Infantil de México Federico Gómez (HIMFG), we create two stomas in these cases to preserve gastrointestinal functionality proximally and distally. In addition, at HIMFG, we have experience in intestinal rehabilitation using the bypass technique (BT) to utilize the residuals and improve the patient's situation.

The nutrition protocol for these patients begins with total parenteral nutrition to meet their nutritional needs. Enteral nutrition is then initiated by continuous infusion, with the volume of formula increased as tolerated by the patient. Gastrointestinal status, hemodynamic and water-electrolyte balance, and stool output are monitored to decrease parenteral nutrition and increase enteral nutrition gradually. The ultimate goal is to provide all energy and nutrition through the enteral route, eliminating parenteral nutrition and continuous infusion of enteral nutrition[10].

This study aimed to describe the use of BT as part of the treatment for intestinal rehabilitation and its impact on the biochemical and nutritional status of pediatric patients with SBS.

Methods

An analytical and retrospective cross-sectional study was conducted by reviewing the records of pediatric patients treated at HIMFG diagnosed with SBS who underwent the BT between November 2019 and June 2020, with a follow-up of 8 weeks. The STROBE checklist was used for this cross-sectional observational study.

Inclusion criteria

We included patients under 18 years of age who met the following characteristics:

– Diagnosis of SBS, defined as insufficient intestinal length to allow adequate absorption of nutrients, fluids, and electrolytes, which interferes with proper growth and development.
– Presence of external shunting of the small intestine by two or more stomas, without metabolic or systemic complications that prevent the use of the enteral route.
– Patients undergoing bypass surgery as described below.

Exclusion criteria

Patients without complete clinical records, imaging studies, and reports, and those with infectious processes, water-electrolytic or metabolic alterations, or intestinal obstructions that prevented adequate intestinal transit during the BT. We used dependent variables such as anthropometry, indicators of nutritional status, biochemical parameters of hepatic and intestinal function, and data on intestinal functionality, and as an independent variable, the type of intestinal resection.

For data collection, an electronic tool in Excel (TPeIC) was created with four sections: (a) identification card (age, sex, diagnosis, and hospital record); (b) birth data (gestational weeks, weight, height, and head circumference); (c) surgical data (pre- and post-operative diagnosis, length and location of bowel resection, length of residual bowel, and number of stomas, presence/absence of ileocecal valve); and (d) weekly evolution sheet with anthropometric, nutritional, and biochemical data. The anthropometric measurements (weight, height, brachial perimeter, and triceps fold) were taken as follows: for weight, a SECA® 20 kg digital scale was used, placed on a flat surface, and tared before the patient was placed unclothed; several measurements were taken until two coincident ones were obtained.

For standing patients, a digital ONROM® scale was used, with several measurements taken until two equal measurements were obtained; the measurement was taken in underwear or with the minimum amount of clothing, maintaining the same conditions for subsequent measurements. Length was measured in centimeters with a SECA® infantometer; for standing patients, a clinical scale was used with a BAME® stadiometer in centimeters. To obtain weight-for-height and height-for-age indicators, we compared them with CDC growth charts, adjusted for sex and age. Nutritional status was classified according to Waterlow parameters. Arm circumference was measured in centimeters with a HERGOM® anthropometric tape using the ISAK technique. The triceps fold was measured with a LANGE® plicometer in neonates and HARPENDEN® in pediatrics, using the ISAK technique. Frisancho constants and formulas were used for lean mass and adipose reserve indicators according to sex and age. Clinical, biochemical, and anthropometric data were collected from the case files. Finally, anthropometric and biochemical data and oral and enteral caloric intake were analyzed.

Bypass technique

Once the permeability of the distal bowel has been confirmed through a contrast study, BT involves infusing the contents of the proximal stoma through the distal stoma. The aim is to utilize the gastrointestinal secretions and enzymes, intraluminal absorption of nutrients to stimulate and maintain villous length, and hormonal regulation of intestinal adaptation, including hormone action on intestinal trophism[7,11].

An ostomy collection system is placed in the proximal stoma to store the proximal bowel contents to a minimum of 20 ml, an amount that can be infused through the distal stoma with a 20 ml syringe using a 3-5 cm latex or silicone tube (Fig. 1). This tube should be connected to a smaller caliber feeding tube for continuous administration with a venoclysis set in an infusion pump until the collected contents exceed 60 ml, delivering the same amount and rate to the distal bowel.

This infusion through the distal stoma must be slow and continuous < 1 h from collection to avoid bacterial proliferation. It does not require a sterile technique, and

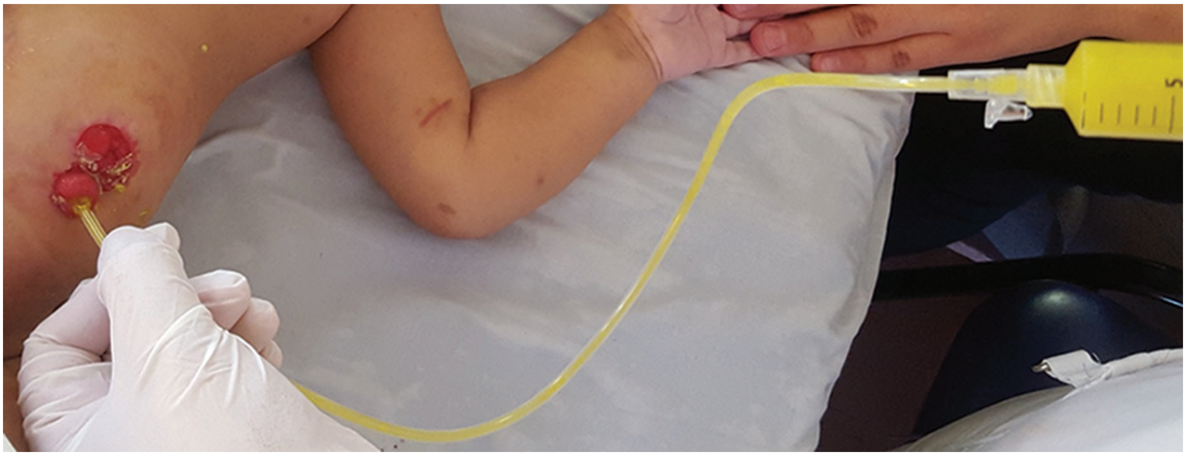

Figure 1. Application of bowel residue collected from the proximal portion of the bowel to the distal portion using a probe.

the process is repeated as many times as necessary to infuse all of the contents of the proximal stoma into the distal stoma as it is collected.

At the end of the procedure, the tube is removed with strict attention to abdominal symptoms such as pain, bloating, and vomiting. For clinical follow-up, the technique's functionality is evaluated with the fecal output, whose volume should be less than the initial infusion of the distal stoma, translating the absorption of nutrients and fluids. An increase in rectal output would indicate clinical instability or intolerance to the procedure.

Statistical analysis

Descriptive analysis of the participant characteristics was performed using frequencies for dichotomous variables and medians, minimums, and maximums for quantitative variables. For these variables, tests of difference of medians were performed. The p-value was calculated using Friedman's test.

Ethical considerations

As this was a retrospective documentary investigation without intervention or intentional modification of variables, the study was considered free of risk, and informed consent was not obtained. The confidentiality of the data and the anonymity of the participants were maintained. Due to its nature, the study has no ethical implications.

Results

Over a period of 7 months, ten patients met the selection criteria. There was no gender predominance (50% female and 50% male). The mean age at surgery was 24 months. The pathologies causing SBS were intestinal malrotation and volvulus (4/10), necrotizing enterocolitis (2/10), intestinal atresia (1/10), gastroschisis (1/10), and others (2/10) (Table 1). In 8/10 patients, more than 100 cm of bowel was resected, while in two patients, the length was not recorded, only the site (Table 1).

The initial nutritional diagnosis was acute malnutrition in 70% of the patients and stunted growth due to short stature in 30%. At the end of the study, 20% were found to be eutrophic: 50% had weight/height harmony despite short stature, and 30% had acute malnutrition. It should be noted that one of the patients had four stomas, and the length of the residual intestine was unknown, so the limitation of intestinal absorption in the presence of BT should be considered (Table 1).

Basal lean tissue reserve was 69.19%, with no significant improvement, and fat tissue reserve was 67.68% (Table 2). Liver function tests showed a decrease in aspartate aminotransferase (AST) and alanine aminotransferase (ALT) levels: (154 U/L vs. 69 U/L) and alanine aminotransferase (ALT): (131 U/L vs. 79 U/L). When compared, the p-value was 0.03 for AST and 0.04 for ALT (Table 3).

The caloric intake of parenteral nutrition decreased by 25% on average from baseline (79.36 kcal/kg/day to

Table 1. Demographic and clinical characteristics of the patients

Patient	1	2	3	4	5	6	7	8	9	10
Age (months)	2	3	157	3	154	170	2	1	1	4
Gender	Female	Female	Male	Male	Female	Female	Male	Male	Male	Female
Diagnosis	Gastroschisis	NEC	Not Specified	Intestinal volvulus	Intestinal volvulus	Not specified	Intestinal volvulus	Intestinal atresia	NEC	Intestinal volvulus
Length Resected	Not Specified	> 100 cm	> 100 cm	> 100 cm	> 100 cm	> 100 cm	> 100 cm	> 100 cm	> 100 cm	Not Specified
Resection Site	Duodenum-jejunum	Multiple Segments	Ileum	Ileum	Ileum	Ileum	Multiple segments	Ileum-colon	Multiple segments	Multiple segments
IVC	+	+	+	+	+	+	-	-	+	+
Stomas	2	2	2	2	2	2	2	2	2	4
Initial feeding	Mixed	Mixed	Mixed	Mixed	Mixed	TPN	TPN	Mixed	Mixed	Mixed
Feeding at 8 weeks	Enteral	Mixed	Mixed	Enteral	Mixed	Mixed	TPN	Mixed	Mixed	Mixed
Initial nutritional status	Low birth weight	Low birth weight	Severe acute malnutrition	IUGR	Mild chronic malnutrition	Compensated chronic malnutrition	Low birth weight	Low birth weight	Low birth weight	Severe acute malnutrition
Nutritional status at 8 weeks	Growth delay	Growth delay	Moderate acute malnutrition	Eutrophic	Compensated chronic malnutrition	Eutrophic	Growth delay	Growth delay	Growth delay	Severe acute malnutrition

IUGR: intrauterine growth retardation; IVC: ileocecal valve; NEC: necrotizing enterocolitis; TPN: total parenteral nutrition.

Table 2. Anthropometric indicators

Weekly follow-up	Weight (kg)	Z-score weight	Height (cm)	Z-score height	Lean tissue reserve (%)	Fat tissue reserve (%)
Basal	3.21	–2.01	44.7	–1.97	69.19	67.68
	(3.8-49.5)	(–4.49-0.05)	(45-145.5)	(–5.15-0.58)	(50.9-86.5)	(32.5-106.6)
Week 2	2.86	–1.91	40.4	–1.83	69.69	66.75
	(3.8-40.5)	(14.11-0.1)	(47-145.5)	(15.06-0.70)	(39.37-86.6)	(38.5-106.6)
Week 3	11.13	–2.14	45.4	–1.67	67.15	71.78
	(2.7-51.25)	(–3.93-0.13)	(52-145.5)	(– 4.69-0.70)	(49.4-90.2)	(50-106.2)
Week 4	36.61	–2.22	39.5	–2.22	73.71	71.75
	(2.73-51.6)	(–4.83-0.16)	(52-145.5)	(–4.6-0.7)	(53-90.3)	(52.5-107.5)
Week 8	37.1	–2.56	50.8	–2.56	72.19	66.16
	(2.64-50.6)	(–4.9-0.03)	(53-145.5)	(–4.14-0.62)	(49.8-94.18)	(45-110)
p-value	0.098		0.099			

Values expressed as mean, minimum and maximum respectively.

Table 3. Evolution of liver enzymes

Liver enzyme	Basal	Week 2	Week 3	Week 4	Week 8	p-value*
AST (U/L)	154 (27-947)	91 (33-278)	67 (32-217)	117 (39-465)	69 (17-252)	0.033
ALT (U/L)	131 (23-741)	113 (35-351)	86 (15-269)	148 (19-493)	79 (11-325)	0.043

Values given as means, minimum and maximum respectively.
*p-value Friedman's test.
ALT: alanine aminotransferase; AST: aspartate aminotransferase.

Table 4. Amount of kilocalories administered by enteral and parenteral nutrition

Daily caloric intake and mode of nutrition	Basal	Week 2	Week 3	Week 4	Week 8	p-value*
EN kcal/kg/day	25.32 (2.17-82.63)	34.87 (0.10-96.6)	28.90 (24.70-73.86)	40.59 (0.37-89.39)	72.94 (49.90-134.83)	0.034
PN kcal/kg/day	79.36 (38.80-143.50)	76.88 (46.47-108.12)	72.81 (45.10-109.60)	75.59 (43.95-113.34)	59.62 (31.87-76.50)	0.66

Values given as means, minimum and maximum respectively.
*p value Friedman's Test.
EN: enteral nutrition; PN: parenteral nutrition.

59.62 kcal/kg/day). Moreover, the caloric intake of enteral nutrition increased by 28% from baseline (25.32 kcal/kg/day to 72.94 kcal/kg/day), with a p-value of 0.034. The energy density of the enteral formulas varied between 0.67 and 0.95 kcal/ml (Table 4). In 80% of patients, the BT was performed at a capacity of 100%, while in the remaining 20%, output of 20% of the capacity was achieved. At the end of the follow-up period, 90% of the patients received 100% of the achieved output, while the remaining 10% received 70% output.

Discussion

After bowel resection, the remaining bowel attempts to compensate and maintain nutritional homeostasis through physiological, cellular, and molecular mechanisms. This adaptation begins as soon as the resection is performed and can last between 1 and 3 years[6,8,12].

This is the first study to report the BT procedure with residue recovery as an alternative treatment in the intestinal rehabilitation of pediatric patients. With this intestinal rehabilitation technique, an improvement in nutritional status was demonstrated in 50% of the patients; 20% (n = 2) became eutrophic patients and 30% improved weight for height, remaining in compensated chronic malnutrition. There is little evidence regarding malnutrition in patients with SBS. However, it is known that it is difficult to maintain proper growth and development in a child whose intestine has a reduced absorptive surface and a decrease in digestive enzymes and transporter proteins. This may explain the variations in the percentages of lean and adipose tissue reserves seen in our patients since the limitation of nutrient absorption is reflected in tissue synthesis. In a series of three cases with SBS presented by Galiano et al., it was found that only two patients had an adequate weight/height gain, while one remained below the mean value[13].

In our series, eight out of ten patients received mixed nutrition (enteral and parenteral) at the beginning of treatment; one patient received enteral stimulation until week 4, and another was dependent on parenteral nutrition without being able to initiate enteral nutrition. With this technique, a progression of enteral nutrition was achieved with a consequent decrease in parenteral nutrition, suggesting that this technique reduces the duration of parenteral nutrition, with a consequent reduction in associated complications.

Predictors have been sought to assess bowel autonomy, with residual bowel length being a primary determinant of bowel function and the most consistent indicator. It has been suggested that a residual bowel length of 35 cm is associated with a 50% chance of not requiring parenteral nutrition[14]. A residual length > 40 cm significantly decreases the likelihood of continuing to require parenteral nutrition. However, a residual length of only 15-40 cm has been associated with intestinal adaptation when resection occurs in term neonates[15].

There are other factors associated with prognosis and evolution, such as the extent and portion of the resected segment, the associated diagnosis, the functionality of the residual bowel, the presence of an ileocecal valve, the age of the patient at the time of resection, and the presence of a stoma versus primary closure[16]. Regarding the latter, at 8 weeks after initiation of treatment with the bypass technique, 50% of the population underwent surgical closure. At 12 weeks of follow-up, 80% of the patients were reconnected, and at 16 weeks, only one patient had a stoma. Other important factors include the presence of cholestasis secondary to parenteral nutrition[15,17]. In this regard, at biochemical level, we found that AST and ALT levels were significantly reduced, suggesting that bypass may be a protective factor against the development of hepatopathy associated with prolonged use of parenteral nutrition.

To evaluate the functionality of the technique, we quantified fecal output, which should be less than that infused through the distal stoma. To date, there are no published studies to determine normal stool output in patients with SBS and stomas. This is because the proximal stoma output may correspond to an output that exceeds oral, gastric, or transpyloric intake, as endogenous gastric, pancreatic, biliary, and intestinal secretions constitute a significant portion of both stoma and fecal output. In this context, the proximal output may be 3 or 4 ml/kg/h despite an intake of only 1 or 2 ml/kg/h. Therefore, the amount of nutrients administered enterally should be given as a continuous infusion at a slow but controlled flow rate, for example, 1 ml/kg/day. In addition, stoma and rectal volumes should be monitored to keep them at < 40-50 ml/kg/day. This is because higher outputs put the patient's water status at risk and may require water and electrolyte replacement[9,18,19].

In our study, the initial average proximal output was 32.37 ml/kg/day, increasing to 52 ml/kg/day at the end of the study. The initial average fecal output was 9.91 ml/kg/day, increasing to 11.5 ml/kg/day at the end of the study. This represents an absorption of 78% of the initial infusion. These results are consistent with those published by Aragón et al., in which the average fecal output in stable children with SBS was 31.5 g/kg/day[10].

There are therapies aimed at promoting and achieving intestinal sufficiency through dietary modifications and pharmacological interventions. Enteral nutrition is the most important stimulus for intestinal adaptation[16] because it stimulates the secretion of gastrointestinal hormones and gastric and pancreatic secretions. It also causes direct stimulation of enterocyte hyperplasia through the interaction of the intestinal epithelium with intraluminal nutrients[20,21]. In addition, enteral nutrition stimulates bile flow and intestinal motility, reducing the risk of bacterial overgrowth and providing a protective effect against cholestasis[22]. At histologic level, this translates into hyperplasia of the intestinal epithelium; such hyperplasia includes increased microvilli height and crypt depth, as well as intestinal elongation and dilatation[23,24].

The use of residuals with the BT as an alternative treatment in intestinal rehabilitation aims to achieve intestinal adaptation by early transition from parenteral to enteral nutrition. The goal is to maintain adequate nutritional status and limit morbidity and mortality.

In conclusion, intestinal rehabilitation with residue utilization and BT can help to achieve greater intestinal autonomy and adaptation, morphologically and functionally. This is achieved by favoring intestinal tropism and allowing the use of the absorptive capacity of the residual intestine, reducing the risk of malnutrition and maintaining an adequate water-electrolytic balance.

This procedure also helps to maximize enteral nutrition early and reduce the use of parenteral nutrition. This may reduce the risk of developing hepatopathy associated with prolonged use of parenteral nutrition.

The use of residue by the BT may also improve the nutritional status of patients and help to optimize the weight/height ratio.

The main limitations of this study are the sample size, its descriptive nature, and the retrospective analysis of cases. However, the study represents a starting point for future work on managing these patients.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. This study involved a retrospective review of medical records, for which approval was obtained from a formally constituted review board (Institutional Review Board or Institutional Ethics Committee).

Conflicts of interest

The authors declare no conflicts of interest.

Funding

No funding.

Acknowledgments

The authors would like to thank the health-care professionals and academic staff involved who made this work possible.

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