# 36

# SHORT-BOWEL **SYNDROME**

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hort-bowel syndrome (SBS) is a disorder characterized by decreased gastrointestinal (GI) mucosal surface area and shorter GI transit time. This can lead to malabsorption of macronutrients and micronutrients, electrolyte abnormalities, dehydration, and ultimately malnutrition. Table 36–1 lists common etiologies of SBS in children. The prognosis of SBS depends on several factors, including (1) the length and portion of small or large bowel resected, (2) the presence or absence of the ileocecal valve (ICV), (3) the adaptive and functional capacity of the remaining bowel, (4) the health of other organs that assist with digestion and absorption, (5) the bacterial overgrowth, and (6) the proportion of nutrition given enterally by 12 weeks of age.<sup>2</sup>

# Table 36-1. Common Causes of Short-Bowel Syndrome in Infants and Children

Necrotizing enterocolitis (NEC) Intestinal atresia Gastroschisis

Midgut volvulus

Crohn's disease

Tumors

Radiation enteritis

Ischemic injury

Intestinal pseudo-obstruction

Total intestinal aganglionosis

# Length and Portion of Small Bowel Resected

Normal small intestine length is approximately 217 ± 24 cm in infants 27 to 35 weeks' gestational age and 304  $\pm$ 44 cm in infants  $\geq$  35 weeks' gestational age (Figure 36–1). At term, mean length is reported to be 250 to 300 cm. Another 2 to 3 meters is added to its length during growth to adulthood. The large intestine is 30 to 40 cm at birth, growing to 1.5 to 2 meters in adult life.<sup>3</sup>

Loss of intestinal length can limit digestion by reducing the exposure of nutrients to brush-border hydrolytic enzymes as well as pancreatic and biliary secretions. Many studies have examined the relationship between length of residual small intestine and successful weaning from parenteral nutrition (PN). It appears that infants require approximately 10 to 30 cm of small intestine, with an intact ICV, to avoid lifelong dependence on PN. If the ICV is not present, 30 to 50 cm of small intestine is generally needed for successful weaning from PN.4,5

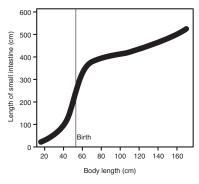


Figure 36-1. Intestinal elongation in utero through puberty. From: Montgomery RK, Grand RJ. Gastrointestinal development: implications for infant feeding. In: Walker WA, Watkins JB, Duggan C, editors. Nutrition in pediatrics. Hamilton (ON): B.C. Decker, Inc.; 2003. p. 323-40.

### **Portion of Bowel Resected**

The location of resected bowel has an impact on nutrient loss in SBS. Duodenal resection may result in iron or folate malabsorption. Calcium absorption may be impaired with proximal small bowel resection. The jejunum is the primary digestive and absorptive site for most nutrients with long, large villi, extensive absorptive surface area, highly concentrated digestive enzymes, and many transport carrier proteins. Loss of jejunum is also associated with reduction of cholecystokinin and secretin levels, which secondarily impair pancreatic and biliary secretion causing subsequent malabsorption of fat and fat-soluble vitamins.<sup>6</sup>

Loss of the terminal ileum results in malabsorption of bile acids. Steatorrhea and the formation of lithogenic bile may ensue. The terminal ileum is the primary site for vitamin B<sub>12</sub> absorption; therefore, resection can lead to B<sub>12</sub> deficiency. The ileum also secretes hormonal substances that slow GI motility in response to fat malabsorption. The antimotility effect of fat in the ileum is known as the ileal brake and is important in ensuring adequate fat absorption from the small intestine.7

Intestinal transit time decreases following small bowel resection. In the normal intestine, motility is rapid in the jejunum and slow in the distal ileum. Consequently, ileal resection reduces intestinal transit time more than duodenal resection. Gastric emptying is also more rapid following ileal resection but can be normalized if the colon is retained.<sup>8</sup> Colon resection is associated with delays in bowel adaptation and loss of energy from the absorption of short-chain fatty acids. 5,9,10 The colon also has an important role in the control of fluids and electrolyte losses: therefore, resection of the colon will decrease transit time further.

#### Presence or Absence of the Ileocecal Valve

The ICV serves to regulate the flow of enteric contents from the small bowel into the colon. The absence of an ICV reduces GI transit and increases fluid and nutrient losses. In addition to decreasing intestinal transit time, loss of the ICV has other nutritional consequences. In the absence of the ICV, colonic bacteria may contaminate the small intestine, causing an inflammatory response that damages small bowel mucosa, resulting in an exacerbation of the malabsorptive state. Bile salts and B<sub>12</sub> may be deconjugated by the bacteria, further contributing to the malabsorption of fat and vitamin B<sub>12</sub>.

# Adaptive and Functional Capacity of the **Remaining Small Intestine**

Following intestinal resection, the remaining intestine has an ability to compensate, but this depends on the area of resection and other trophic stimuli. The ileum appears to be more able to adapt and compensate for loss of proximal small intestine. Intestinal adaptation refers to the gross anatomic and histologic changes that occur after significant intestinal resection (Table 36-2). These adaptive changes begin 12 to 24 hours after massive intestinal resection and will continue for more than 1 year after resection. 11 Villi lengthen, the intestinal absorptive surface area increases, and absorptive function gradually improves. The younger

# Table 36-2. Adaptive Changes in the Small Bowel Following Extensive Resection

Increased bowel circumference Increased bowel wall thickness Increased bowel length Increased villus height Increased crypt depth Increased cell proliferation and migration to villus tip infant is therefore at an advantage for improvements in bowel function over time when compared with adults due to the opportunity for further growth of intestinal length. Functional improvement does not immediately follow an increase in absorptive surface area. Digestive enzymes such as lactase, sucrase, and maltase are often decreased suggesting some functional immaturity.<sup>7</sup>

Enteral nutrition is an important stimulant of mucosal hyperplasia. This is thought to be a result of direct contact with epithelial cells; stimulation of gastric, pancreatic, and biliary secretions; and stimulation of the production of trophic hormones. 12 Much research has been directed at examining whether specific nutrients promote adaptation more than others.

# **Health of Other Organs That Assist with Absorption and Digestion**

Cholestasis and liver dysfunction can occur in patients with SBS, thereby affecting the absorption and utilization of nutrients. The major cause of death in children with SBS is PN-associated liver disease. 13 The relationship between PN use and cholestasis is likely multifactorial and includes the risk factors of sepsis, mucosal atrophy, and bacterial overgrowth. Every effort should therefore be made to reduce the risk of PN-associated cholestasis (Table 36-3).

# Special Aspects of Nutritional Therapy in Short-**Bowel Syndrome**

The goals of nutrition therapy in SBS are to maintain normal growth, promote intestinal adaptation, and avoid complications associated with intestinal resection and PN.

#### Fluid, Electrolytes, and PN

During the early postoperative phase, fluid and electrolyte balance is the goal of therapy. Large fluid losses are com-

Table 36-3. Steps to Reduce the Risk of PN-Associated Cholestasis

Method	Comments
Avoid overfeeding	90-100 kcals/kg usual energy parenteral requirement
Cycle PN off at least 2–6 hours per day	Promotes cyclic release of GI hormones
Aggressively treat and prevent infections	Meticulous CVC care; treat bacterial overgrowth
Push enteral nutrition	The ultimate goal of therapy

CVC = central venous catheter; GI = gastrointestinal; PN = parenteral nutrition.

mon and tend to be high in sodium content. Parenteral solutions with at least 80–100 mEq/L of sodium are often required to maintain sodium balance.

Meticulous attention needs to be paid to the fluid and electrolyte status of SBS patients. This includes daily weights, careful measurement of urine, stool, and ostomy losses, and laboratory monitoring of electrolytes. PN is indicated in the management of SBS until small bowel growth and adaptation permit growth on enteral nutrition alone.

Because daily variations in fluid loss are common, it is often advantageous to place the patient on a standard PN solution with fluid and electrolytes appropriate for age, size, and metabolic considerations and subsequently replace abnormal losses with a separate solution based on measurement of actual fluid losses. For example, ostomy fluid can be measured for sodium content and replacement fluid prescribed accordingly. When losses have stabilized, the additional fluid and electrolytes can be added to the PN.

#### **Enteral Feedings**

Once the patient's fluid and electrolyte status has stabilized and postoperative ileus has resolved, a slow introduction of enteral feedings should be started. Mothers of newborns with SBS should be referred to a lactation consultant to encourage continued breastmilk production. Breastmilk has special immunologic and anti-infective properties that are especially advantageous to the infant having undergone intestinal resection. Breastmilk also contains growth factors, nucleotides, glutamine, and other amino acids that may play an important role in assisting intestinal adaptation.

If breastmilk is unavailable, the selection of enteral formula remains somewhat controversial. The choice of formula should consider age, functional anatomy of the remaining small bowel, and the capacity of digestion and absorption. 14,15 Premature infants have special needs that must also be considered (see Chapter 34, "Prematurity"). Studies suggest that complex nutrients, which require more work for digestion and absorption, tend to stimulate intestinal adaptation more effectively. However, limited mucosal surface area can lead to lactose, protein, and long-chain fatty acid malabsorption with the use of intact formulas. If this malabsorption is severe, fluid, electrolyte, and metabolic balance can be difficult to achieve. At the initial stage of feeding it is customary to use a protein hydrolysate formula or an amino acid-based formula that is lactose free and may include medium-chain triglycerides (MCTs) in order to facilitate absorption.

Protein is generally tolerated well and is least affected by decreased intestinal absorptive surface area.11 Intact protein contributes little to osmotic load. It appears that there may not be a significant absorptive advantage from the use of hydrolysate or amino acid-based formulas, particularly with older children. 16 However, infants and young children with bowel inflammation may be at risk of secondary intestinal allergic disease and therefore may benefit from the use of a hypoallergenic hydrolysate or amino acid-based formula. 14,17

MCTs are more water-soluble than long-chain triglycerides (LCTs) and are better absorbed in the presence of bile acid or pancreatic insufficiency. However, MCT fats have a slightly lower caloric density and exert a greater osmotic load in the small intestine. Studies suggest that LCTs have a trophic effect by stimulating gut adaptation after intestinal resection. 12 Although fat tends to be poorly absorbed in SBS, it is a dense calorie source relative to carbohydrate or protein. Considering the relatively greater adverse effect of carbohydrate on osmotic diarrhea, it is usually advantageous for patients with SBS to include at least moderate amounts of fat in their diets. A mixture of both LCT and MCT may be beneficial.

Carbohydrates may be poorly tolerated as they are broken down by GI bacteria into small, osmotically active organic acids that can exert a significant osmotic load in the distal small intestine and colon. Glucose may be absorbed without hydrolysis, but its small molecular weight increases solution osmolality. Carbohydrate can be given as glucose polymers to decrease the osmotic load. Lactose may be restricted initially after intestinal resection. In general, lactose-containing foods should only be restricted when intolerance is demonstrated or there is significant proximal small intestine resection.<sup>11</sup> Fiber supplementation may be helpful in the older child with SBS who has an intact colon. Some fermentation of the fiber will occur, producing trophic short-chain fatty acids (SCFAs), which are an important fuel for the colonocyte. Because SCFAs stimulate sodium and water absorption, a decrease in stool output and sodium losses may be expected as well.<sup>15</sup>

#### How to Feed

Continuous enteral feedings via a nasogastric or gastrostomy tube are advantageous in the patient with SBS because they permit constant saturation of carrier transport proteins,

thus taking full advantage of the absorptive surface area available. Older children and adults have a better capacity to regulate gastric emptying and therefore tolerate gastric bolus or oral bolus feedings better than do infants. Enteral feedings are slowly advanced by concentration then volume, and parenteral calories are decreased by rate or number of hours to maintain nutritional status, control fluid losses, and ensure intestinal adaptation. Once PN is discontinued, intravenous lipids can be continued in order to provide additional calories while enteral feeds are advanced. Small quantities of oral feedings should be introduced in infants 2 or 3 times a day to stimulate sucking and swallowing and minimize the risk of feeding aversion.

The rate of advancement of enteral feeds should be determined by multiple factors, including stool or ostomy output, gastric residuals, and signs of malabsorption. We have employed the advancement guidelines in Table 36–4. It is acceptable for infants to have 5 to 10 watery stools per day, as long as reducing substances are less than 1.0% and stool pH is above 5.5. Reducing substances greater than 1% or stool pH below 5.5 may indicate excessive carbohydrate malabsorption. If intolerance occurs soon after an increase in rate or concentration of the formula, a return should be made to the previously tolerated rate or concentration. Once tolerance is established, advancement can be attempted again. Frequent setbacks are not unusual. Enteral feedings may eventually be transitioned to oral/bolus feedings or oral/bolus and nocturnal feedings to allow more freedom from the feeding pump. Oral feedings should consist of small, frequent meals. Solid feedings should be initiated at developmentally appropriate stages. Some suggest that protein- and fat-containing solids, such as meats, may be a better choice for the initial solid food introduced in order to avoid the osmotic effects of carbohydrate.<sup>18</sup>

# Enteral Feeding Advancement in the Infant with Short-Bowel Table 36-4. Suggested Guidelines for Syndrome

Functioning ostomy (if applicable)?

No contraindications?

Day 1: Breastmilk (full strength) or Pregestimil (20 cal/oz) @ 10-20 mL/kg/d continuously<sup>†</sup> for 24

- Paralytic or drug-induced ileus Grossly bloody stools or ostomy output or radiologic changes of intestinal ischemia

- Shock or poor perfusion due to cardiac or respirator Bilious or persistent vomiting (defined as more than Clinical suspicion of obstruction or ileus (severe abd

- †Bolus feeds may only be offered as follows:
  1. Infant is developmentally able to feed by mouth (PO)
- 1 hour's worth of continuous feeds may be offered PO QD TID after 5 days of continuous feeds; during this
- time, tube feeds should be held More than 1 hour's worth of continuous feeds may be offered PO once the infant has reached full volume of feeds by continuous route or at least 7 days have passed on the feeding advancement protocol

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# Table 36-4. Suggested Guidelines for Enteral Feeding Advancement in the Infant with Short-Bowel Syndrome, continued

Feeding Advancement B.

Principle 1: Quantify feeding intolerance primarily by stool or ostomy output and secondarily by reducing substances. Reducing substances should be measured twice daily Principle 2: Tolerance assessed no more than twice per 24 h. No more than one advance per 24 h period Principle 3: Ultimate goals: 150–200 mL/kg/d

Principle 4: If ostomy/stool output precludes advancement at 20 cal/oz for 7 days, then increasing caloric density 100-140 kcal/kg/d

the formula can be performed Principle 5: Isocaloric reductions in PN support should be undertaken simultaneous with feeding advancement

< 10 g/kg/d or < 10 stools/d  $\rightarrow$  advance rate by 10–20 mL/kg/d 10–20 g/kg/d or 10–12 stools/d  $\rightarrow$  no change > 20 g/kg/d or > 12 stools/d  $\rightarrow$  reduce rate or hold feeds<sup>‡</sup> Stool output If < 10 g/kg/d If 10-20 g/kg/ If > 20 g/kg/d

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lleostomy output If < 2 g/kg/h  $\rightarrow$  advance rate by 10–20 mL/kg/d If 2–3 g/kg/h  $\rightarrow$  no change If > 3 g/kg/h  $\rightarrow$  reduce rate or hold feeds<sup>‡</sup>

< 1%  $\rightarrow$  advance feeds per stool or ostomy output = 1%  $\rightarrow$  no change > 1%  $\rightarrow$  reduce rate or hold feeds<sup>‡</sup> Stool reducing substances If < 1%  $\rightarrow$  advance feeds pe If = 1%  $\rightarrow$  no change If > 1%  $\rightarrow$  reduce rate or ho ω.

absent  $\to$  advance feeds per stool or ostomy output present  $\to$  reduce rate or hold feeds<sup>‡</sup> Signs of dehydration If absent → advance fer If present → reduce ra 4.

Gastric aspirates 5

< 4 times previous hour's infusion  $\to$  advance feeds > 4 times previous hour's infusion  $\to$  reduce rate or hold feeds<sup>‡</sup>

G-tube = gastrostomy tube; IVF = intravenous fluid; J-tube = jejunostomy tube; NG = nasogastric; NJ = nasojejunal; NPO = nothing by mouth; PN = parenteral nutrition; QD = every day; TID = three times a day. #Feeds should generally be held for 8 h, then restarted at <sup>3</sup>/<sub>4</sub> the previous rate.

Excess fluid and electrolyte losses may continue to complicate the management of SBS patients on enteral feedings, particularly in patients with high-output jejunostomies. Oral rehydration solutions with a sodium concentration of 75–90 mEq/L should be used to replace losses (see Chapter 26, "Gastrointestinal Diseases," for a list of commercially available oral rehydration solutions).

## **Experimental Nutrients in SBS**

Research has focused on attempts to increase the absorptive capacity of the remaining bowel with the use of hormones, intestinal growth factors, and diet modification. Growth hormone has been shown to stimulate small bowel growth in rats and an increase in lean body mass in adult short bowel patients. 19,20 One study of growth hormone in children with SBS did not demonstrate an overwhelming positive effect,<sup>21</sup> although a subset of such patients might benefit from growth hormone therapy. Glutamine has received attention because of its role as an energy source for enterocytes and colonocytes. The role of glutamine in gut adaptation in humans remains controversial with supportive data on both sides.<sup>22,23</sup> A combination of growth hormone, glutamine, and dietary modification (high carbohydrate, low fat, added fiber) has been proposed as a regimen to enhance bowel adaptation,<sup>24</sup> but subsequent trials did not support its efficacy. 25,26 Hormonal therapy with other trophic factors such as glucagon-like peptide 2 (GLP-2) is also likely to be tested.<sup>27,28</sup> To date, the number of clinical trials is limited. particularly in pediatric patients, and results are inconsistent and remain controversial.<sup>29,30</sup>

# **Metabolic Complications of SBS**

In patients with steatorrhea, long-chain fatty acids (LCFAs) combine with magnesium and calcium contributing to increased stool losses, making calcium unavailable for the

formation of calcium oxalate. Unabsorbed bile salts in the colon are thought to increase mucosal permeability to oxalate. These two factors combine to increase enteric oxalate absorption, which in turn increases the risk of oxalate renal stones. 10 Dietary oxalate restriction and oral calcium supplementation may help in the prevention of calcium oxalate renal stones.11

There is an increased presence of gallstones both among patients with ileal resection and those without an ICV.10 It is assumed that precipitation of cholesterol occurs due to the low concentration of bile salts in bile as a consequence of ileal resection causing an interruption of the enterohepatic circulation.<sup>31</sup>

Gastrin secretion is increased, probably because of the loss of the normal feedback mechanism. This results in excess gastric acid, which alters luminal pH of the small bowel and adversely dilutes or inhibits pancreatic lipase or trypsin activity. Hyperacid secretion impairs carbohydrate and protein digestion and absorption, micellar formation, and fat lipolysis, and the impairment process results in malabsorption and diarrhea.<sup>32</sup> Acid blockers can be used to decrease gastric acid and improve absorption.

In SBS, overgrowth of bacteria in the small intestine results in deconjugation of bile acids and maldigestion. Bacterial overgrowth should be suspected whenever patients with SBS experience growth regression, require additional calories, or lose weight. An additional complication of bacterial overgrowth is a neurologic syndrome associated with d-lactic acidosis characterized by headache, drowsiness, stupor, confusion, behavioral disturbance, ataxia, blurred vision, opthalmoplegia, and nystagmus. 10,33 d-Lactic acidosis should be suspected when there is an acidosis with an unexplained anion gap. Bacterial overgrowth can be treated with broad-spectrum antibiotics.

Once patients are off PN, SBS patients are at risk of vitamin and mineral deficiencies. More common deficiencies are the fat-soluble vitamins A, D, and E. As vitamin K is synthesized by bacteria in the colon, a deficiency may occur in patients without residual colon or those on broadspectrum antibiotics. 11 Patients with ileal resection should be monitored carefully for vitamin B<sub>12</sub> deficiency. Zinc deficiency is common in patients with intestinal stomas. Iron deficiency can result from the loss of duodenal-jejunal absorptive area. Selenium absorption may also be impaired. Bone mineralization density should be monitored.<sup>34</sup> Attention should be paid to vitamin D status as well as the provision of appropriate calcium and phosphorus to promote bone health. Calcium supplementation may also be required to minimize oxalate absorption. Supplementation of vitamins and minerals should be based on individual need. Oral replacement may require several times the recommended daily requirements (see Chapter 5, "Nutritional Requirements: Dietary Reference Intakes").

#### Summary

The nutritional management of SBS is a multistage process that may take years. Aggressive use of enteral nutrition to stimulate intestinal adaptation as well as recognition and treatment of possible complications can significantly improve prognosis.

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