

Surgeon's perspective on short bowel syndrome: Where are we?

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Abstract

Short bowel syndrome (SBS) is due to a massive loss of

small bowel: the reduction of gut function is below the minimum necessary to maintain health (in adults) and growth (in children) so intravenous supplementation is required. Parenteral nutrition represents the milestone of treatment and surgical attempts should be limited only when the residual bowel is sufficient to increase absorption, reducing diarrhea and slowing the transit time of nutrients, water and electrolytes. The surgical techniques lengthen the bowel (tapering it) or reverse a segment of it: developed in children, nowadays are popular also among adults. The issue is mainly represented by the residual length of the small bowel where ileum has shown increased adaptive function than jejunum, but colon should be considered because of its importance in the digestive process. These concepts have been translated also in intestinal transplantation, where a colonic graft is nowadays widely used and the terminal ileum is the selected segment for a living-related donation. The whole replacement by a bowel or multivisceral transplant is still affected by poor long term outcome and must be reserved to a select population of SBS patients, affected by intestinal failure associated with irreversible complications of parenteral nutrition.

Key words: Parenteral nutrition; Bowel rehabilitation; Surgical rescue; Intestinal transplantation; Short bowel syndrome

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Core tip: Short bowel syndrome represents a surgical dilemma: parenteral nutrition is considered the gold standard of care and any surgical attempt must be limited by the universal principle "first do not harm." The surgical rehabilitation should be pursued when there are enough residual intestines to obtain a better bowel function: lengthening the intestine or reversing a loop of it with different techniques should have the only aim of slowing the transit while increasing the absorptive surface. When intestinal failure is associated to life-threatening parenteral nutrition complications, bowel transplantation should be considered as an option.

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INTRODUCTION

Short bowel syndrome (SBS) results from a reduced length of the small intestine. A "normal small bowel length," measured from the duodeno-jejunal flexure to ileocolic valve, is estimated at 250 cm \pm 40 cm at birth, and the growth is maximal during the first year of life^[1]. In adults, the small bowel length varies from 275 cm to 850 cm, with a mean of 350 cm \pm 60 cm, depending on the method used, radiologic, surgical, or per autopsy^[2]. The massive loss of small bowel represents the most frequent mechanism of intestinal failure, defined by the European Society for Clinical Nutrition and Metabolism as "the reduction of gut function below the minimum necessary for the absorption of macronutrients and/or water and electrolytes, such that intravenous supplementation is required to maintain health and/or growth"^[3]. Among children "the minimum necessary for the absorption" is a residual small bowel length of more than 25% of the expected for gestational age^[3], in adults SBS usually appears when the small bowel length is less than 200 cm (67% of the normal length)^[4]. Malabsorption and diarrhea represent the classical symptoms, associated to deficit of growth in the pediatric population. Wilmore *et al*^[5] first demonstrated long-term survival with parenteral nutrition (PN) in a child affected by SBS. Nowadays home PN represents the standard of care in patients affected by massive loss of small bowel with excellent long term results^[6-12]. PN does not replace physiologically the bowel function because uses the intravenous route to supplement nutrients and it could be affected by several life-threatening complications. Under this perspective, a surgical rehabilitation in case of SBS should be represented by: (1) the possibility to slow the transit and obtain an adequate absorptive surface of the remnant intestine through lengthening procedures and (2) whole replacement of the massive intestinal loss with a bowel transplant. It is worthwhile to analyze briefly the main reported studies on the issue in international literature, in order to develop an updated perspective under the surgical point of view.

OVERVIEW OF THE LITERATURE

SBS is mainly, but not only, a matter of length. In children, the massive resection of the small bowel could lead to a "very short bowel syndrome" (\leq 40 cm)^[13,14], "ultra-short bowel syndrome" (between $<$ 30 and $<$ 10 cm)^[15-17] or "no gut syndrome" (only the duodenum is left)^[18-20]. Adults with less than 200 cm but more than 75 cm of small bowel^[21] have a potentially functional intestine especially if the colon (and specifically the

ileocolic valve) is preserved in continuity. Among SBS patients, the role of the colon in the process of digestion has been demonstrated since the '90s^[22-25]. The presence of remaining colon is associated with a lower dependency on PN^[26,27] and there is agreement that the remaining small bowel after massive intestinal loss is supported by the colon (if in continuity) for completion of the digestion process. On the other hand, jejunum and ileum have different roles in digestion and ileum has probably a greater adaptive potential than jejunum^[28]. A remnant ileum (especially in continuity with the colon) could probably guarantee a faster weaning from PN. Clinical experience shows that patients with a jejuno-colonic anastomosis (SBS type II), even better with a jejuno-ileo-colonic anastomosis (SBS type III), have an improved absorption with time after a period of intestinal rehabilitation, whereas patients with end-terminal jejunostomy without colon (SBS type I) do not show that. When the colon is missing, among adults 115 cm of small bowel with an end enterostomy are considered the limit before SBS.

SURGEON'S PERSPECTIVE

In SBS the remaining small bowel may dilate. This is important for surgeons in order to lengthen the intestine, tapering it. It has been shown that the extent of dilation is associated with the bowel length, and both are related to enteral autonomy^[29]. Two surgical procedures are popular in order to lengthen the bowel: Bianchi and Serial Transverse Enteroplasty Procedure (STEP). The Bianchi procedure, summarized by Bianchi in 1997^[30], is also known as longitudinal lengthening and tailoring (LILT). The small bowel mesentery is separated as two leaves with a GI anastomosis stapler to create a tunnel, and then the two resulting small bowel segments of smaller diameter are connected with an end-to-end anastomosis in an iso-peristaltic fashion. In the STEP, first described by Kim in 2003^[31], the dilated small bowel is narrowed by serial transverse applications of the GI stapler from opposite directions, creating a new lengthened small intestine (zig-zag channel). This procedure does not require an intestinal anastomosis and the mesenteric vascular supply is untouched. Since its first description, STEP has become a widespread procedure, sometimes repeated on the same patient (re-STEP) to obtain a longer intestinal segment. Bianchi and STEP procedures have been performed at first in children and more recently also in adults^[32-35]. Most of the studies are on STEP: while enteral autonomy (median time: 21 mo) is eventually possible in some patients^[36], improved enteral tolerance can be achieved in a majority^[37,38]. STEP can be performed on shorter intestinal segments or intricate segments such as the duodenum, which is technically not feasible for Bianchi procedure, and it seems to have a lower mortality but an overall progression to transplantation^[39]. The spiral intestinal lengthening and tailoring procedure is a new

surgical technique based on a spiral shape incision of the dilated intestine (at 45°-60° to its longitudinal axis), and re-tubularization in a longer but narrower fashion. It does not alter the orientation of the muscle fibers like STEP, offering minimal mesenteric handling compared to Bianchi procedure. It has been reported in a 3-year-old girl^[40] where, 6 mo after the procedure, PN was weaned off. Another manuscript described the technique in a 10-month-old child^[41] showing at 1-year follow-up a growth on the 15-25th centile on 82% oral calories and 18% PN, passing 2-3 daily stools. Three children with "no gut" syndrome and dilated duodenum underwent a novel surgical procedure of "duodenal lengthening" combined with a technical modification of STEP^[18]: duodenal tapering was performed with sequential transverse applications of an endoscopic stapler on the anterior and posterior wall of the duodenum, avoiding bilio-pancreatic injury. Two patients weaned PN off at 12 mo post-surgery and the last one's PN caloric requirements decreased by 60%. The surgical rescue of "no gut" syndrome has been reported in adults as well. Bueno *et al*^[20] demonstrated the feasibility of lengthening a dilated duodenum in a patient where his mega-duodenal stump was tapered by STEP, restoring his digestive continuity through an end-to-side duodeno-colonic anastomosis. After 24 mo of follow-up, the time on daily PN was shortened from 24 to 9 h and the volume and calorie requirements were reduced by half.

Since lengthening procedures slow the bowel transit time, a "reversed anti-peristaltic segmental bowel loop" has been proposed with the same aim: this procedure can be indicated in patients with an adequate remnant bowel length. Median oral autonomy was described up to 100% ± 38% with a lower amount of parenteral calories, as well as PN dependence^[42]. In another report^[43] 56% of patients improved their enteral autonomy.

The different graft types used in intestinal transplantation are the isolated small bowel, combined liver-intestine, multivisceral and modified multivisceral ones^[44]: liver-containing grafts have shown the longest survivals. Apart from cadaveric donation, living-related intestinal transplantation has been pursued especially in a pediatric setting^[45]: terminal ileum represents the used graft, because of technical feasibility and its greater adaptive potential than jejunum^[28]. Short term results of intestinal transplantation have recently improved in terms of survival and digestive autonomy, due to advances in surgery and immunosuppression. Immunosuppressive therapy has evolved significantly over the past 20 years: the tacrolimus-based therapy as maintenance, preceded by induction with anti-thymocyte globulin or an interleukin-2 blocker, is the main used protocol worldwide. A "secondary" agent like steroids, azathioprine, mycophenolate mofetil or an mTOR inhibitor is recommended after an episode of rejection. Innovative cross match strategies and optimizing organ allocation could improve the long-term outcome, but the main causes of death and graft loss remain sepsis

Table 1 Surgical rehabilitation of short bowel syndrome

SBS surgical rehabilitation
Lengthening procedures
Bianchi
STEP
SILT
Duodenal lengthening
Reversed anti-peristaltic segmental bowel loop
Intestinal transplantation

SBS: Short bowel syndrome; STEP: Serial transverse enteroplasty procedure; SILT: Spiral intestinal lengthening and tailoring.

and rejection. Challenges for long-term results are chronic rejection and immunosuppressant-related complications^[46,47]. According to Intestinal Transplant Registry reports^[44], 1611 children were transplanted worldwide between 1985 and 2013, with an overall patient survival rate of 51%. In the 2014-2016 Scientific Registry of Transplant Recipients^[48], the 6 American centers that in 2016 performed 10 or more intestinal transplants in adults reported a 1-year graft survival from 61% to 83% and a 3-year graft survival from 29% to 73%. In an earlier report from 2008 to 2010, the 1-year graft survival in adults was 71%, illustrating the relatively modest gains achieved^[47]. Intestinal transplantation should be suggested to a very select subset of SBS patients with severe and irreversible complications of PN and no hope of intestinal rehabilitation. In conclusion, among SBS patients the surgical rehabilitation (Table 1) of the remnant bowel must be performed to slow the intestinal transit time increasing at the same time the absorptive surface: only in cases of irreversible intestinal failure with PN life-threatening complications, intestinal transplantation could represent a therapeutic option even if still encumbered by suboptimal long term results.

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