

Serial Transverse Enteroplasty Allows Children with Short Bowel to Wean from Parenteral Nutrition

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Objective To analyze the effects of serial transverse enteroplasty (STEP) on parenteral and enteral calories in children with short bowel syndrome, and examine short- and long-term complications.

Study design A retrospective analysis of prospectively-collected data from a large single center cohort of patients undergoing STEP procedure was analyzed. Baseline demographic and clinical information, operative data, and short- and long-term complications were recorded. Detailed growth and nutritional data were obtained for 6 months prior and 12 months following STEP procedure.

Results Sixty-eight procedures were performed in 51 patients over a 68-month period. Median bowel length at first STEP was 51 cm with a median length gain of 54%. Repeat STEP patients had longer initial length (77 cm) and reduced length gain (20%). Operative times and blood loss were low, with few complications. Parenteral calorie requirement was stable or rising for 6 months prior to STEP, but decreased to median <20 kCal/kg/d at 1 year postop. Longer length gains were associated with higher risk of stricture formation. Seven children were transplanted, and 60% of nontransplanted children were enterally independent, with the remainder making ongoing progress; 48/51 children are alive at a median of 39 months follow-up.

Conclusions STEP is shown to be safe, well tolerated, and to have definitive benefit in reducing parenteral calorie requirements over the first year following the procedure. It has an important role in achieving enteral independence in children with short bowel syndrome. (*J Pediatr* 2014;164:93-8).

Options for managing pediatric intestinal failure have expanded rapidly over the past decade, paralleling development of multidisciplinary management teams. Nonsurgical advances in parenteral lipid minimization,¹ alternate lipid emulsions,² and central venous catheter management³ increasingly abrogate the development of intestinal failure-associated liver disease. Surgical lengthening procedures have been controversial as a method for improving enteral tolerance.

The serial transverse enteroplasty (STEP) procedure, described first in animal models⁴ and subsequently in humans,⁵ uses a series of alternating staple firings to reduce the effective luminal diameter of a poorly functioning dilated segment of intestine, in an attempt to improve ante grade motility and overall absorption.⁶⁻⁸ Initially greeted with skepticism,⁹ recent reviews have shown acceptable short-term morbidity and improvements in nutritional status.¹⁰⁻¹²

In this series of 68 procedures, we present detailed follow up of short- and long-term complications, growth measurements, and enteral and parenteral caloric intake in a series of children with short bowel syndrome. These data demonstrate significant reduction in total parenteral nutrition (TPN) leading to enteral independence following a STEP procedure.

Methods

We conducted a retrospective review of all STEP procedures performed in the University of Nebraska Medical Center intestinal rehabilitation program (IRP) between January 1, 2006 and August 1, 2011; this review was approved by the University of Nebraska Medical Center institutional review board. The 14 earliest patients in the series were included in a previous publication from our center.¹² This era was selected as having the most complete nutritional data for the cohort.

After identifying cases, we recorded basic demographic information and neonatal history. All operative notes from prior to transfer were examined to abstract estimates of small bowel length, colonic length, and presence of any residual ileum (no ileum, some ileum, or not determinable) at completion of the final surgery prior to transfer.

IRP	Intestinal rehabilitation program
IV	Intravenous
NEC	Necrotizing enterocolitis
PN	Parenteral nutrition
STEP	Serial transverse enteroplasty
TPN	Total parenteral nutrition

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The authors declare no conflicts of interest.

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STEP procedures were performed only when there was both clinical evidence of failure to progress on enteral feeds unresponsive to maximal medical management (including formula optimization, continuous vs bolus feeding, bacterial overgrowth treatment, motility management) and small bowel dilatation on contrast studies estimated to be greater than 3.5 cm in diameter (diameters were typically a minimum of 4 cm and often more). Cases were classified as a first STEP or a second or greater procedure, with same data recorded for all cases regardless of category. Patient weight, height, enteral calories administered from all sources per day, and parenteral calories per day (all values collected prospectively) were recorded at 52, 24, 12, and 4 weeks prior to STEP, at the time of STEP, and at 4, 8, 12, 24, and 52 weeks following the procedure, as well as the most recent values for each category. In some cases, the data from early and later time points were not available because of incomplete transfer records or noncompliance with follow-up appointments.

Operative times include the total time for all procedures, including central venous lines and gastrostomy tubes, and may thus be longer than true times for STEP procedures alone. Bowel lengths were directly measured in all operations after complete adhesiolysis of the small intestine, along the mid-portion of nonstretched intestine, from the ligament of Treitz, or a marked reference point on the distal duodenum, to the most distal point of the small intestine. Length was recorded again at the end of the procedure.

The STEP procedure was performed on all segments of intestine measuring greater than 3.5 cm in diameter when decompressed and laid out flat and unstretched. Often these segments were much greater than 4 cm. Alternating firings of an Endo-GIA 3.5 mm stapler (Covidien, Mansfield, Massachusetts) were employed, aligned in a mesenteric/antimesenteric fashion and taking care to not reduce luminal diameter below 2 cm between the medial edges of staple lines, although earlier in the series, in some cases diameter was reduced below this threshold. Representative diameter before STEP is highly subjective and variable along the length of the bowel, and was not recorded.

Postoperatively, children received full parenteral nutrition (PN) support (~90 kCal/kg/d). Enteral elemental feeds were initiated following return of bowel function (Neocate [Nutricia, Gaithersburg, Maryland] or Elecare [Abbott Nutrition, Columbus, Ohio]) at 20 kCal/oz and 2-5 mL per hour and were advanced as tolerated. Patients were discharged when tolerating some enteral feeds and appropriate outpatient care was available. After discharge, patients were followed in the IRP clinic with weekly outpatient visits. All complications occurring in the first 30 days after surgery were recorded as were the need for delayed intervention to repair strictures in STEP segments or to manage recurrent intestinal dilatation.

Nutritional status was maintained with enteral and PN to maintain height and weight Z-score, or where initially undernourished, to provide catch-up growth to at least the 5th percentile. Enteral calories were provided as continuous drip, with oral supplementation of formula and food when possible. Parenteral calories were weaned solely by ability to

maintain growth on an established curve after PN reduction, rather than by enteral intake.

Survival outcomes were classified as alive with or without transplant, or deceased with or without transplant. Nutritional outcomes were classified as requiring some parenteral calorie support, requiring intravenous (IV) fluids only, fully enterally independent, or fully orally independent. Follow-up data were analyzed to the most recent point of clinical contact.

Data were analyzed using SPSS v. 20.0 (IBM, Armonk, New York) and GraphPad v. 5.0 (GraphPad Software, San Diego, California). Summary data for normally distributed variables were expressed as means and SD, and variables with non-normal distributions were expressed using median and range. Group comparisons were made using Student *t* test for normally distributed data and the Kruskal-Wallis test and post hoc Dunnett Multiple Comparison test for non-normal data.

Results

From January 1, 2006 to August 1, 2011, 68 STEP procedures were performed (51 first-time STEPs and 17 redo STEPs) in 51 patients (Table I). In the study cohort, the commonest causes for bowel loss were gastroschisis (55%), atresia (24%), necrotizing enterocolitis (NEC) (16%), and volvulus (6%), compared with NEC (32%), gastroschisis (31%), atresia (14%), and volvulus (13%) in the IRP population overall. Median reported bowel length after completion of all neonatal surgeries was 30 cm (range 10-175 cm).

Operative data for the series is described in Table II. In the 51 children who underwent a primary STEP procedure, the median age was 1.0 years (range 0.1-12.7 years). The median bowel length before STEP was 51 cm (15-175 cm) and after STEP was 87 cm (31-270 cm), for a length gain of 54% (5%-130%). Operative time was just under 2 hours (115 min, range 65-257 min) and median blood loss was 0 mL (range 0-50 mL). Forty-eight children had a contrast study following the procedure around postoperative day 7; no leaks were seen. One-half of the children began feeds at or before postop day 8 (range 5-44) and were discharged from the hospital at a median of 14 days after surgery (7-61 days).

Table I. Descriptors of patient population

	Total STEPs	68 (51 patients)
Sex		
Male*		27 (53%)
Female*		24 (47%)
Gestational age (w) [†]		33.5 ± 2.9
Birth weight (g) [†]		2308 ± 802
Birth length (cm) [†]		40.6 ± 3.9
Diagnosis		
NEC*		8 (16%)
Gastroschisis*		29 (57%)
Intestinal atresia*		11 (22%)
Volvulus*		4 (8%)
Median length post initial surgeries (cm) [‡]		30 (10-175)

*Number (percent).

[†]Mean ± SD.

[‡]Median (range).

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