Dilute elemental diet and continuous infusion technique for management of short bowel syndrome

Two infants with short bowel syndrome were successfully weaned from total parenteral alimentation by means of a continuous intragastric infusion through a gastrostomy of a dilute elemental diet. Each patient had received TPA for 9 and 3 months, respectively, and had failed to thrive while receiving other therapeutic formulas. Gradual transition to bolus feeding was accomplished in each infant after 2½ and 2 months, respectively. Our results demonstrate that a continuous infusion of a dilute elemental diet in large volumes can provide adequate calories for growth and maintain positive fluid and electrolyte balance.

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This report describes a new method of treatment of the short bowel syndrome. By using continuous intragastric infusion of large volumes of a dilute elemental diet, two infants were successfully weaned from total parenteral alimentation. These infants had received TPA for 9 and 3 months, respectively, and had not tolerated other therapeutic formulas.

An elemental diet was used because it requires minimal digestion for absorption and is almost completely absorbed in the upper small intestine. The diet was infused at a constant rate and at hypo- or iso-osmolar concentration to maximize use of available absorptive surface area, to minimize osmotic diarrhea, and to overcome delay in gastric emptying which commonly occurs when hypertonic formulas are given as bolus feedings.1, 2

Plan of treatment and management

Unflavored Vivonex (Eaton Laboratories, Norwich, N. Y.) standard nitrogen elemental diet was used. This diet derives 90.2% of its calories from glucose and glucose oligosaccharides, 8.5% of the calories from crystalline L-amino acids, and 1.3% of the calories from safflower oil. A full strength dilution furnishes 1 cal/ml and has an osmolarity of 500. The complete chemical composition of the diet has been published previously.3

The diet was continuously infused over a 24-hour period via a gastrostomy tube at a concentration of 166 mOsm/L and 0.3 Kcal/ml (one-third strength) using an IVAC (Ivac Corporation, La Jolla, Calif.) 500 peristaltic pump. Initial rate of infusion was 100 ml/kg/day. The volume infused was gradually increased over several days to provide adequate calories for growth. Maximal volume infused was 300 ml/kg/day. After three to four weeks of infusion at one-third strength dilution, the diet was advanced to one-half strength (250 mOsm/L, 0.6 Kcal/ml), and finally after another period of stabilization to two-thirds strength (332 mOsm/L, 0.6 Kcal/ml). Concentration of formula infused was increased when the infant gained weight steadily and reducing substances were absent or present in only trace amounts in the stools. The strength of formula and the amount infused were never increased at the same time.

Stool frequency and weight were recorded daily. Each stool was tested for reducing substances with a Clinitest (Ames Co., Elkhart, Ind.) tablet and for pH with nitrazine paper (pH range of 4.5 to 8). Each advance in concentration of diet was accompanied by increased stool frequency.
and increased reducing substances in the stools to 2 to 3%; pH of stools was always 5 to 6. After several days frequency of stools decreased and reducing substances in the stools disappeared.

Serum electrolytes were measured every other day. Hematocrit value, total protein, and serum albumin concentrations were determined weekly. A total of 400 IU of vitamin D was given daily to each infant because the formula is deficient in this fat-soluble vitamin. Vitamin B₁₂ was given intramuscularly once per month at a dosage of 100 μg. Fatty acids were not supplemented because deficiency of essential fatty acids does not occur when diets derive 1% of calories from linoleic acid.¹

**CASE REPORTS**

**Case 1.** C. C. was a 2,050 gm term female infant born with a small omphalocele. The infant developed bilious vomiting and abdominal distention at 10 hours of age. At surgery, atresia of the distal jejunum and ileum was present. A 50 cm atretic segment was resected, and an end-to-side ileojejunal anastomosis was performed. Postoperatively the infant received TPA for 8 months through a central venous catheter. Her weight increased from 2.05 kg to 5.54 kg (Fig. 1). During this period all attempts to feed the infant dilute proprietary formulas including Enfamil,* Pro-Sobee,* Pregestimil,* and Nutramigen* resulted in profuse diarrhea and transient weight loss.

At 8 months of age a small bowel biopsy was obtained at the duodenjejunal junction which showed a moderate-to-severe villous abnormality. However, the etiology could not be determined. At age 8½ months, because a glucose tolerance test was normal, feeding was reinitiated with one-fourth strength Pregestimil fed in volumes of 15ml every two hours for five days. Weight loss of 110 gm occurred even though TPA was given intravenously at a rate of 100ml/kg/day. Feeding with Pregestimil was discontinued, and one-half strength CHO-Free (Syntex Laboratories, Inc., Palo Alto, Calif.) with fructose was given orally for 9 days; the concentration was then increased to three-fourths strength. During the next 14 days, the volume of feedings was increased to 900ml per day, and TPA was reduced to 25ml/kg/day. Weight decreased by 165 gm. Stools became voluminous, watery, and contained 2 to 3% reducing substances. This feeding was discontinued.

A continuous infusion of elemental diet was then begun. During the next nine days the rate of infusion was advanced while the TPA solution was decreased. The infant gained 230 gm during this initial nine days of infusion (Fig. 1). During the next 21 days elemental diet infused was at 250ml/kg/day while the TPA solution was maintained at 100ml per day. Total weight gain during this time was 565 gm (Fig. 1).

The concentration of infusate was then increased to one-half strength. For the next 40 days the infusion was maintained at 250 ml/kg/day and weight gain was 400 gm (Fig. 1). Transition to bolus feedings every three hours of the one-half strength elemental diet was then started.

During the entire period of infusion measurements of serum concentrations of electrolytes, proteins, calcium, phosphorus, hemoglobin, and hematocrit values were normal.

**Case 2.** Patient S. J. was transferred to UCLA Hospital at one day of age because of bilious vomiting. She was born after a 34-week gestation. Barium enema after admission showed intestinal malrotation with malposition of the cecum. At surgery she had jejunal atresia with agenesis of the dorsal mesentery and a "Christmas tree" deformity of the distal small intestine.

Surgery consisted of a 70 cm resection of the atretic jejunal segment, with jejunoojejunostomy, appendectomy, and gastrotomy. At 4 days of age TPA was started using a peripheral venous catheter with 10% dextrose water, 3% casein hydrolysate, and Intralipid (Cutter Laboratories, Inc., Berkeley, Calif.). During the first month weight increased from 1.84 kg to 2.16 kg (Fig. 2). At age 5 weeks another 9.5 cm of jejunum was resected because of

*Mead Johnson & Company, Evansville, Ind.
small bowel obstruction. At age 8 weeks one-fourth strength Pregestimil at 15 ml every two hours was given orally. This resulted in watery diarrhea of low pH containing 2 to 3% reducing substances. TPA was continued but was stopped at 10 weeks of age because of obstructive jaundice (serum concentrations of total bilirubin 6.5 mg/dl, direct bilirubin 5.8 mg/dl, and alkaline phosphatase 400 IU/L).

At age 10 weeks one-fourth strength Pregestimil was fed through the gastrostomy by constant infusion at 15 ml/hour. The concentration was increased to one-half strength after two days. This regimen resulted in diarrhea of low pH which contained 2 to 3% reducing substances. After eight days of feedings with Pregestimil formula the infant's weight had decreased 100 gm.

The elemental formula was then initiated, but intravenous solutions of 10% dextrose and electrolytes were continued. During the next 29 days the patient gained 410 gm (Fig. 2). The concentration of elemental diet was increased to one-half strength and administered for a total of 27 days with a weight gain of 510 gm (Fig. 2). At 5½ months of age one-half strength elemental diet was given orally in gradually increasing amounts. Weight gain during this transition period was 270 gm (Fig. 2). Total volume of feedings decreased from 300 ml to 250 ml/kg/day. The infant was then given two-thirds strength diet at 200 ml/kg/day for 10 days prior to discharge.

Feeding of two-thirds strength elemental diet was continued until the patient was 13 months of age. She was then able to tolerate whole cow milk and is now fed a diet appropriate for a 16-month-old infant.

**DISCUSSION**

Our results provide evidence that a dilute elemental diet administered by continuous intragastric infusion in large volumes may be invaluable in treatment of the short bowel syndrome. Each of the infants had failed to tolerate oral feedings at a time when TPA was becoming increasingly difficult to maintain. With the use of a dilute elemental diet, a weight gain occurred for the first time without the use of TPA. Carbohydrate malabsorption was present after the elemental diet was begun but each infant maintained normal concentrations of serum proteins and electrolytes.

The only abnormality encountered in electrolyte concentrations during the infusion of an elemental diet was a transient metabolic acidosis probably secondary to loss of bicarbonate in stools in Case 2. This was corrected with supplemental bicarbonate therapy and did not recur when supplementation was discontinued.

Elemental diets have been used in adults with various gastrointestinal diseases, but there has been limited reported use in infants. Stephens and colleagues treated a premature infant with duodenal atresia, but this infant was unable to tolerate more than a 10% w/v solution of the elemental diet.

Weinberger and Rowe reported success with an elemental diet in two infants with the short bowel syndrome. However, they encountered problems with diarrhea and abdominal distention when the osmolarity of the formula was advanced to beyond isotonicity. Sherman and colleagues used an elemental diet in five infants 7 to 16 weeks of age with severe intractable diarrhea. These infants demonstrated an average weight gain of 17.0 ± 14.7 gm/day and a positive nitrogen
balance. Bell and associates\textsuperscript{12} attempted to use an elemental diet in an infant with massive small bowel resection when other therapeutic formulas had failed. The infant, however, had evidence of carbohydrate intolerance and failed to gain weight.

Theoretically, elemental diets should be useful in treatment of infants with short bowel syndrome because minimal bowel length is required for intraluminal digestion and minimal mucosal surface for digestion and absorption. In those diseases where disaccharidase deficiencies are present, glucose will still be actively transported. This may be particularly important in infants with protein-calorie malnutrition where disaccharidase deficiencies are known to occur.\textsuperscript{13} The L-amino acids do not require pancreatic proteases for intraluminal hydrolysis or the oligopeptidases of the brush border of the small intestinal mucosa for further digestion.

Most elemental diets are low in fat content or contain medium-chain triglycerides instead of long-chain triglycerides. Thus the need for bile salts and pancreatic lipase is minimal.

The main disadvantages of using previously available elemental diets in infancy relate to the osmolarity of the formulas. Most elemental diets have an osmolarity of approximately 800 to 1,000 mOsm/L at full strength. When the diet is given at a hypertonic osmolarity, gastric retention and osmotic diarrhea commonly occur.\textsuperscript{1} Stephens and associates\textsuperscript{3} commented that standard nitrogen Vivonex formula may not contain adequate protein for growth. The amino acid content of this formula compares favorably with the data accumulated by Foman and colleagues for requirements in normal infants. One cannot apply these data to sick infants but our data and the studies of Sherman and associates\textsuperscript{3} would support the concept that this diet does provide adequate protein for growth.

Since the elemental formula used in this study does not contain the recommended daily allowances of vitamin D and folic acid required for infants less than 12 months of age,\textsuperscript{10} daily supplementation is necessary.

Elemental diets may be useful in the management of short bowel syndrome of infancy. These diets may enable the clinician to discontinue the use of TPA sooner and provide adequate nutrition in infants who might otherwise be unable to tolerate any other therapeutic formula.

**REFERENCES**