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Nutritional Management Using Elemental Diet for Adult Patients with Severe Short Bowel Syndrome

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Summary. **This paper reviews the problems and methods in the treatment of patients suffering from short bowel syndrome (SBS) after removal of large parts of the small intestine. Twenty-eight patients with severe SBS received medical treatment at our department from 1966 through 1989. All patients who could pass through the first postoperative period with the help of intravenous hyperalimentation (IVH) received further IVH or enteral hyperalimentation at home to maintain nutritional condition and promote social rehabilitation.**

Six patients unable to receive hyperalimentation died from insufficient nutrition within 2 years after the intestinal resection. Seventeen (77%) of the 22 patients who received parenteral or enteral hyperalimentation at home survived and rehabilitated socially. Of five patients (23%) whose remnant small intestines were shorter than 70 cm, four died of pneumonia caused by malnutrition in spite of receiving parenteral or enteral hyperalimentation. The other died of senility 13 years after the operation.

The nutritional assessment indicated that the serum concentrations of albumin in those patients who died of malnutrition were significantly decreased compared with those of the survivers. Among many other nutritional parameters, only the percentage of AMC (arm muscle circumference) and serum concentrations of PA (prealbumin), RBP (retinol binding protein) and Zn showed statistically significant decreases from the normal range in the longer surviving patients. Among the causes of the nutritional deficiency of patients with SBS, statistically significant derangements of digestion and absorption of fat and protein were observed.

In order to ensure hyperalimentation at home for SBS patients the following measures are essential: 1) Patients whose remnant small intestine is shorter than 30 cm will need home parenteral nutrition (HPN) throughout life. 2) Although 2/3 of patients whose remnant small intestine is 30-70 cm in length gradually become able to tolerate natural foods. 1/3 will necessitate home enteral nutrition (HEN) using an elemental diet (ED) throughout life. 3) Patients with the small intestine longer than 70 cm will be able to take normal foods soon after their recovery from the first operative period.

The techniques of HEN using ED introduced in this paper have proved useful for the nutritional support of severe SBS patients whose remnant small intestine was 30-70 cm in length.

Introduction

The validity of hyperalimentation using intravenous hyperalimentation (IVH)[1] or an elemental diet (ED)[2] was initially confirmed by clinical experiences with a patient with severe short bowel syndrome (SBS) around 1968 in the USA. Thereafter, hyperalimetation has remained the most common method for maintaining the nutritional condition of patients with severe SBS and promoting their social rehabilitation.

In Japan, a group study for the evaluation of both home parenteral nutrition (HPN) and home elmental enteral hyperalimentaion (HEEH) started in 1986 and 1985, respectively, in order to improve the method of hyperalimentation for patients with severely disturbed intestinal function and promote its popularization.

This paper reports our clinical experiences of hyperalimentation, especially those of HEEH, in 28 adult patients with severe SBS, who were treated by us at our department and at our affiliate hospitals from 1966 to 1989.

Pathophysiology of patients with severe SBS

Those patients receiving massive resection of the small intestine recovered from the postoperative

nutritional deficiency state, and passed through the three stages of Pullan[3]: First, Immediate postoperative period; Second, Recovery and adaptation period; and Third, Stabilize period.

The following nutritional deficiencies were observed in patients with SBS able to recover from the First postoperative period. Protein-energy malnutrition (PEM) was the major manifestation of SBS, resulting from the malabsorption of three cardinal nutrients. In addition to this, symptoms due to severe deficiency of essential fatty acids, electrolytes and minerals including Na, K, Cl, Fe, Ca, Mg, P, Zn, Cu, Se and Cr, and vitamins, including B-complex, C, B_{12}, A, D, K and E, were observed in patients with severe SBS. These nutritional deficienies were confirmed by the Nutritional Assessment and absorption tests in patients able to survive for a long time by taking natural food or receiving nutritional support using ED or a low-residue diet (LRD). A statistically significant decrease was recognized in the percentage of AMC (arm muscle cirumference) and % TSF (tirceps skin fold), but not in % IBW (ideal body weight), as indicated by anthropometric studies (Table 1-A).

Serum concentrations of total protein (TP) and albumin (Alb) in patients not able to survive for long time after the intestinal resection showed a statistically significant decrease as compared to those of the survivors. Among the serum concentrations of TP, Alb, prealbumin (PA), retinol-binding protein (RBP) and transferrin (TF), only TP, PA and RBP showed a statistically significant decrease against the normal range. Deficiency syndromes of many electrolytes and minerals were observed. Even when the deficiency symptoms were not observed, serum concentrations of Zn showed a statistically significant decrease (Table 1-A). No significant decrease was observed in vitamins, lymphocyte count or purified protein derivative of tuberculin (PPD) value.

To summarize these nutritional deficiencies, two nutritional indices were calculated and both the prognostic nutritional index (PNI) of Buzby[4] and nutritional surgical risk index (NRI) of Sato[5] showed a statistically significant correlation with the length of the remnant small intestine of patients with severe SBS (Table 1-B).

A statistically significant correlation was found between the length of the remnant small intestine and digestion rate[6] as well as the absorption rate of ingested fat and protein assessed by an absorption test (Table 1-B). Such maldigestion of fat and protein, especially that of former, is thought to be a major cause of malabsorption in patients with an extremely short intestine of less than 70 cm.

Simultaneous resection of the ileocecal valve with or without an ascending colon could not change the results of the absorption test for fat and protein. However, it was found that the death rate of patients was higher by 10% in cases of ileocecal valve resection than in cases of it being intact. Of high importance and interest was the fact that 70 cm was the critical length of the remnant small intestine for determing whether or not patients could maintain nutritional condition with natural foods; in patients with the remnant small intestine shorter than 70 cm, the values of % TSF and PA came to show a significant decrease before the decrease in other parameters would occur (Table 1-C).

In regard to other causes of malabsorption of the nutrients, a shortening of the intestinal transit time was observed in almost all cases and gastric hyper secretion also recognized in about 50% of patients, which could be easily controlled by the administration of a H_2-receptor antagonist or proton-pump inhibitor.

Here, the authors would like to refer to the adaptation of the remnant small intestine. About a 20% increase in the absorption rate of fat and protein was recognized within 4-6 months after massive intestinal resection, even in patients with an extremely short remnant intestine of less than 70 cm. Since Flint,[7] there have been many reports that suggest a histological and physiological adaptation of the remnant small intestine, but the cause and mechanism of the adaptation remain obscure.

In this context, our recent experimental results from dogs suggest that an increase in the absorption of some major nutrients was caused by the mucosal adaptaion of their small intestine, i.e., by an increase in villous height and number of enterocytes brought about by the bile juice flow immediately after the massive resection. Interestingly, gastric and pancreatic juice could not induce these mucosal adaptations. Contrary to the widely accepted view pointing to a higher ability for mucosal adaptation of the ileum than that of the jejunum, however, no difference in the ability of the mucosal adaptation was recognized between the jejunum and ileum.

Enteral administration of an ED to animals after massive intestinal resection could induce a significant adaptive change in the mucosa of the remnant small intestine in an order similar to that of LRD and usual chow.

Rationality of the use of "Elental", the only available ED in Japan, for the nutritional support of patients with severe SBS is based on the characteristic features of the ED, including the following: 1) ED,

Table 1. Results of nutritional assessment and absorption test of 16 patients with SBS

A. Parameters showing significant decrease

parameters		P-value	n
Anthropometric study	% IBW	n s	15
	% AMC	$P < 0.05$	15
	% TSF	$0.05 < P < 0.1$	15
Serum concentration of proteins and minerals	TP	$0.05 < P < 0.1$	16
	Alb	n s	9
	PA	$P < 0.01$	14
	RBP	$P < 0.01$	14
	Tf	n s	14
	Fe	n s	16
	Zn	$P < 0.01$	16
Vitamines	B_{12}	n s	15
	FA	n s	15
Hemogram	lymphocyte count	n s	16
Delayed skin test	PPD	n s	13

B. Parameters showing significant correlation with the length of the remnant small intestine

Parameters		P-value	n	
			fat	protein
Absorption test of protein and fat	Malabsorption	$p < 0.05$	12	9
	Maldigestion	$p < 0.05$	6	4
Serum concentration	Alb	$0.05 < 0.1$	6	
Nutritional index	PNI (Buzby)	$0.05 < P < 0.1$	6	
	NRI (Sato)	$P < 0.05$	10	

C. Parameters showing significant decrease at the point of 70 cm of the remnant small intestine

Parameters	<70 cm	$\geqq 70$ cm	P-value	n
% TSF	28.15 ± 8.39	68.16 ± 30.93	$P < 0.05$	15
PA (mg/dl)	20.49 ± 4.76	30.78 ± 7.49	$P < 0.05$	14

Table 2. Method of long-term nutrition and the number of deaths before and after the hyperalimentation of patients with SBS

Remnant small intestine (cm)	Cases	Method of nutrition	No. of deaths	
			Before Hyperalimentation	After Hyperalimentation
> 70	17	natural food	4*1/4	0/13
30 ~ 70	7	1/3 HEEH	1/1	2*2/6
		2/3 ED → LRD → natural food		
< 30	4	HPN	1/1	3*3/3

*1 Two of 4 patients died of causes unrelated to SBS (recurrence of cancer).
*2 Two patients died of causes unrelated to SBS (cerebral bleeding and senility).
*3 Two of 3 patients died of pneumonia.

a nutritionally complete diet contains, as the nitrogen source, 17,611 g/100 g of pure amino acid mixture, the ratio of essential and non-essential amino acids being 2 : 3; it further contains 79.3 g/100 g of dextrin as carbohydrate, 0.657 g/100 g of lipids (0.636 g soy bean oil and 0.021 g of lecithin), 2.02 g/100 g of electrolytes and minerals and 1,646.9 ppm of many vitamins. One hundred grams of the ED yielding 375 kcal, can provide more energy (over 40 kcal/kg BW/day) than a regular diet or a LRD without severe abdominal complications even in patients with an extremely short intestine. 2) The pH value of the ED solution is adjusted to 6 and therefore does not stimulate the exocrin pancreas, except for causing a slight increase in serum immunoreactive insulin (IRI), immunoreactive glucagon (IRG) and glucagon-like immunoreactivity (GLI); serum immunoreactive secretin (IRS) showed no remarkable change. 3) The ED can promote the mucosal adaptaion on the remnant small intestine. 4) The ED does not induce diarrhea owing to its very low fat content, even if it has a slight tendency to increase diarrhea by relatively high osmotic pressure (760 mosm/L) at the concentration of 1 kcal/ml of the solution. 5) Marked reduction in portal blood flow, which is considered a cause of hepatic failure by IVH, may be prevented by enteral administration of the ED.

Clinical course and results of treating patients with SBS

From our clinical experiences of 28 patients with SBS (Table 2), we were able to conclude two important factors which would influence the prognosis of the SBS patients: one was the length of the remnant small intestine, and the other was whether patients could receive intensive hyperalimentation by a skillful clinician over a long time.

In our hospital, patients in the First postoperative period were generally treated by intravenous low calorie infusion before 1968, and later by IVH. By IVH, almost all patients could tolerate severe disturbances in the balance of water, electrolytes and major nutrients and were able to enter the Second period.

Four of the 6 patients who could not receive hyperalimentation in the Second and Third periods died of malnutrition within 2 years after the intestinal resection indifferent of the length of the remnant small intestine. Two others died of causes unrelated to SBS (recurrence of cancer).

Contrary to the above mentioned 6 patients, prognoses in the 22 patients who could fortunately be treated with hyperalimentaion were influenced by whether they could receive a zealous enforcement of hyperalimentation by skillful clinitians. In these cases the method of hyperalimentaion was decided by the extent of the length of the remnant small intestine.

Among these 22 patients, 13 whose remnant small intestine exceeded 70 cm in length gradually recovered from SBS and were socially rehabilitated with the temporal aid of IVH and/or the ED (including HEEH) and the LRD.

Two of 6 patients whose remnant small intesine measured 30-70 cm died of causes unrelated to SBS (one was cerebral bleeding and the other was senility) at 1 and 13 years after intestinal resection, respectively. In contrast, 4 of the 6 surviving patients were finally able to take natural foods after a long period of enteral feeding of the ED (including HEEH) and/or the LRD. Of these, one 28-year-old man, whose clinical course will later be mentioned in detail, had to continue to keep nutritional condition on HEEH for about 15 years after massive intestinal resection leaving a remnant small intestine of 30 cm (Fig. 1 and Case 2 of Fig. 2).

We recently have come to believe that 2/3 of patients with a remnant small intestine of 30-70 cm might gradually be able to tolerate natural foods within 6-12 months after the resection, but the remaining 1/3 cannot adapt to natural foods and must continue to receive enteral administration of the ED throughout life to maintain good nutrition and achieve social rehabilitation.

As for patients with the remnant small intestine of less than 30 cm, it has become apparent that they should be treated with IVH as long as they live. In our affiliated hospitals, despite the fact that they had received hyperalimentation with IVH and/or ED, all 3 patients with the remnant small intestine of less than 30 cm (one 22 cm and two 20 cm) died of pneumonia at 3, 6 and 17 months, respectively, after they were discharged from our department. Pneumonia appears to be one of the major causes of death of patients with severely depleted nutritional conditions.

Thus, we tentatively conclude that the shortest length of the remnant small intestine which can support a patient's nutritional condition by enteral hyperalimentation is 30 cm.

Techniques of HEEH for patients with severe SBS

As almost all patients do not accept the oral intake of an ED because of its unpalatability, the administration of ED should be done through the feeding

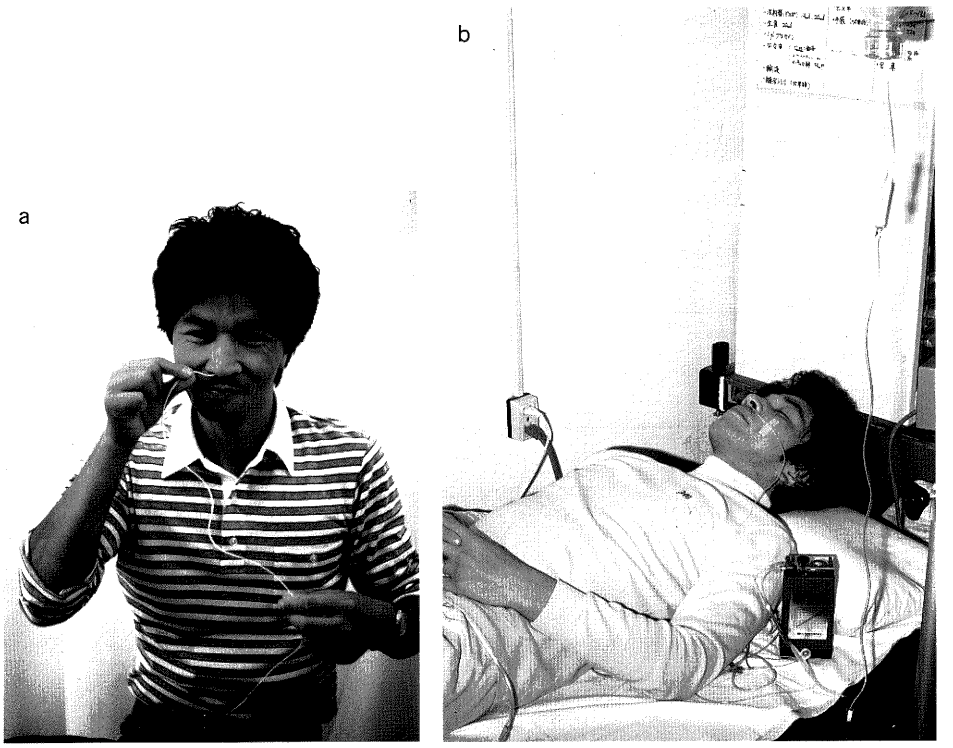
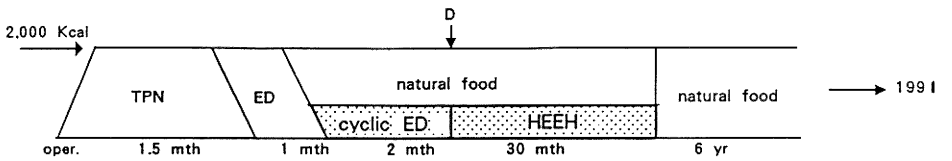
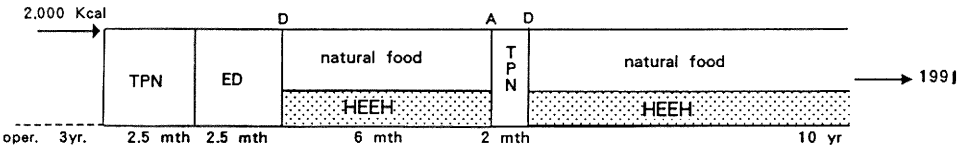


Fig. 1. Technique for home elemental enteral hyperalimentation (HEEH). Fig. 1-a shows nasal self-intubation of the ED tube. Fig. 1-b shows infusion of ED solution into the stomach with the help of an infusion pump at night



Case 1. An 81-year-old man with a remnant small intestine of 74 cm.



Case 2. A 28-year-old man with a remnant small intestine of 30 cm.

Fig. 2. Two successful cases of HEEH for severe SBS

tube. Thus, techniques of enteral administration of an ED at home were developed recently by our group and by Dr. Matsueda et al.[10] Patients with severe SBS are taught the technique for 2 or 3 days just before discharge.

The technique we employ is as follows: after nasal self-intubation of the ED tube a siliconated silastic tube of 6F with a stainless steel tip into the stomach, patients dissolve the ED (Elental) at a concentration of 1 kcal/ml for infusion into the stomach at night with the aid of an infusion pump at a speed of less than 120 ml/h (Fig. 1-a, b).

Contrary to this nasal self-intubation, the recent trend is to place a gastrostomy tube at the time of the

massive intestinal resection, or by the technique of the percutaneous endoscopic gastrostomy (PEG) in patients unable to receive gastrostomy at the time of intestinal resection.

As to the efficacy of an infusion pump, it is recommendable to use an infusion pump for enteral infusion of the ED through a naso-gastric tube or a gastrostomy tube for patients who had received the massive intestinal resection. The infusion pump is very useful in the following points: 1) to infuse the ED solution constantly to avoid diarrhea, 2) to control the speed and volume of the ED solution, and 3) to avoid temporal stop of infusion by kinking of the tube.

By means of the above introduced methods, patients can obtain 1/3 to 1/2 of their daily energy needs (about 40 kcal/kg BW) from HEEH at night using the above mentioned technique, and, if necessary, remaining 2/3 to 1/2 from natural foods taken during the day. We would like to stress the effect of taking natural food along with the HEEH even if it is very low in fat, as this is important to satisfy the demand for "eating" by the patients, to supplement some nutrients which are lacking in the ED, and to induce adaptaion of the mucosa of the remnant small intestine. In this instance, we also wish to stress that fat must be eliminated from natural foods for those patient with a short intestine of less than 70 cm, in order to avoid severe abdominal disturbances, contrary to the view of Jeejeebhoy et al.[11] Because of the low amount of fat in the ED and in the natural food supplied to the patient, temporary intravenous infusion of fat emulsion is necessary to avoid a deficiency syndrome of essential fatty acids.

Two successful cases of HEEH

Case 1 (Fig. 2-a): An 81-year-old man received massive small intestinal resection, leaving a remnant small intestine of 74 cm because of intestinal obstruction due to postoperative adhesion. As shown in Fig. 2-a, the patient could successfully pass through the First period with the help of IVH for about 1/2 months and succeeding enteral administration of ED for a month. The patient was taught the technique of HEEH for week before his discharge. In the course of HEEH, he was able to obtain 1/3 of his daily energy needs from HEEH at night and 2/3 from natural food taken during the day, adequately maintaining his nutritional condition. After about 6 months of HEEH, he gradually became able to dispense with the help of the supplemental administration of ED, obtaining all his energy need from natural foods.

Case 2 (Fig. 2-b): A 28-year-old man had to receive massive small intestinal resection because of mesenterial arterial thrombosis, leaving a remnant portion of 30 cm in length. After repeated admission to a hospital to receive IVH for 3 years after the resection, the patient met one of us and learned the technique of HEEH, by which he became able to abandon IVH. He could obtain 1/3 of his daily energy needs (about 2,000 kcal) from HEEH at night at home and 2/3 from fat-free natural foods supplied at his work during the day, though he required receiving a temporary supplementary intravenous infusion of fat emulsion at the hospital. He has been able to maintain a good nutritional condition by HEEH for a long time of more than 10 years to date, during which time he has gotten married and fathered a son.

Present state of HEEH for SBS in Japan

Our clinical experiences indicate the following conditions are essential in ensuring successful HEEH in patient with an extremely short intestine: 1) Patients should always be allowed to seek advice from physicians. 2) An infusion pump is available in order to avoid diarrhea when ED is administered, 3) Supplementary intravenous administration of fat and some electrolytes are given in cases of severe diarrhea, 4) Patients with the remnant small intestine of less than 30 cm should receive HPN throughout life.

The number of cases of HEEH in adult patients with severe SBS increased to 12 cases by the end of 1990 in Japan, and this was 3% of 392 cases of HEEH. This number will increase according to the development and the popularization of the technique of HEEH until homotransplantation of the small intestine becomes possible in Japan.

REFERENCES

1) Dudrick SJ, Wilmore DW, Vars HM, Rhoads JH: Long-term total parenteral nutrition with growth, development and positive nitrogen balance. *Surgery* **64**: 134-142, 1988.
2) Thompson WR, Stephens RV, Randall HT, Bowen JR: Use of the "Space Diet" in the management of a patient with extreme short bowel syndrome. *Amer J Surg* **117**: 449-459, 1969.
3) Pullan JM: Massive intestinal resection. *Proc Royal Soc Med* **52**: 31-37, 1959.
4) Buzby GP, Mullen JL, Matheus DG, Hobbe CL, Rosato EF: Prognostic Nitritional Index in gastrointestinal surgery. *Amer J Surg* **139**: 160-167, 1980.
5) Sato M, Yamasaki T, Shirasawa K, Kidokoro T: Nutritional and immunological assessements of

patients with gastrointestinal cancer—nutritional sugical risk index and cancerous cachexia index. In: Ogoshi S, Okada (eds) Parenteral and Enteral Hyperalimentation. Exerpta Medica, Amsterdam-New York-Oxford, 1984, p 7-25.

6) Hatakeyama K, Koyama S: Differntial diagnosis of maldigestion and malabsorption of fat. II. Comparing of ^{131}I-triolein with ^{14}C-triolein in normal, pancreatic juice-deficient, short bowel and bile-deficient dogs. *Jap J Surg* **11**: 272-276, 1981.

7) Flint JM: The effect of extensive resection of the small intestine. *Bull Johns Hopkins Hosp* **23**: 127-144, 1912.

8) Tilson MD: Pathophysiology and treatment of short gut syndrome. *Surg Clin North Amer* **60**: 1273-1284, 1980.

9) Koyama S, Hatakeyama K, Yamadera Y, Muto T, Aiba T: Postoperative effects of an elmenal diet on the malfunction of the digestive tract. In: Ogoshi S, Okada A (eds) Parenteral and Enteral Hyperalimentation. Exerpta Medica, Amsterdam-New York-Oxford, 1984, p 163-175.

10) Matsueda K, Umeda N, Shimojo E, Sakagami R, Takazoe A, Mori K, Hoshino E, Muraoka A, Shoda P, Kobayashi T, Yamamoto S, Kurosawa K, Oda T: A long-term follow up of new home-hyperalimentation for short bowel syndrome and its therapeutic application in inflammatory bowel disease. In: Ogoshi S, Okada A (eds) Parenteral and Enteral Hyperalimentation. Exerpta Medica, Amsterdam-New York-Oxford, 1984, p 205-216.

11) Jeejeebhoy KN, Ahmud S, Kozak G: Determination of fecal fats containing both madium chain and triglyceide and fatty acid. *Clin Biochem* **3**: 157-163, 1970.