Long-term Prognosis After Major Resection of Small Bowel in Early Infancy

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A previous report (Swain, Peonides, and Young, 1963) concerned the prognosis after resection of the small bowel for neonatal obstruction. 3 of the patients had had massive resections, and 2 of them, now aged 9 and 10 years, have been available for further study, together with 2 others now aged 2 and 3 years. Each had such a short length of small bowel remaining that it was at first doubtful whether it was adequate for survival and later for normal growth and development. Excised bowel is difficult to measure, while the total length of the bowel at birth varies between 250 and 300 cm. (Potts, 1955; Benson, 1955; Pilling and Cresson, 1957). The length of the remaining bowel is better for evaluating potential function than the percentage lost, but its measurement can only be approximate. Furthermore, experience has shown that the absorptive capacity of a very short segment of residual bowel may eventually develop so that it becomes adequate to supply the full needs of the growing child.

Benson, Lloyd, and Krabbenhoft (1967) consider that 25 to 30 cm. may suffice if the ileo-caecal valve is retained. 9 of their 10 patients, 7 of whom survived, had 100 cm. or less of remaining small bowel, and one had only 35 cm. After great difficulties with management during the early post-operative period, the later nutritional status of their surviving patients was normal by 3 years of age. Lawler and Bernard (1962) had previously reported an infant who had only 15 cm. of remaining small bowel after a massive resection at 6 weeks, and weighed 11.8 kg. at 18 months of age. More recently Rickham (1967) has reported good recovery in all of 7 neonates, with 40–75 cm. of remaining small bowel, 5 of whom are now 4–9 years old.

Modifications of Feeds Suitable for Early Months of Life

Experience gained in the present series has shown

that appropriate modifications in feeding may help to improve tolerance and absorption and thus the rate of growth and development at earlier ages; in principle, the fat, protein curd, and disaccharide content should be reduced, and their caloric equivalent replaced by predigested protein and monosaccharides. Mineral and vitamin supplements should also be given.

Easily assimilable feeds may be based upon diluted expressed breast milk, or cow's milk, and the calories augmented by predigested protein and monosaccharides (A and C—Table I). Minerals should always be added to diluted milk feeds and increased amounts given to infants with fluid stools, as in gastro-enteritis (Medical Research Council, 1952; Young and Rogers, 1954).

The oral multi-electrolyte solution used by Govan and Darrow (1946) containing Na 24, K 28, Cl 24, HPO_4 9, Ca 4, Mg 4 mEq/litre contributes suitable proportions of electrolytes, and if a concentration of this solution is available, appropriate amounts can be used with water for diluting breast milk or for making up dilutions of dried cow's milk so that at least as much sodium (approx. 30 mEq/l.) is provided as in undiluted cow's milk; this is known to be a 'safe excess' for normal infants. The additional supplements of sodium salts needed by those with fluid stools can be given as the chloride or lactate, but in these circumstances milk has usually to be withdrawn at first and glucose electrolyte solutions substituted. The concentration of sodium should be raised to 1/3–1/2 isotonic (50–75 mEq/litre) until dehydration has been relieved.

Proprietary powdered milk preparations are available which are easily reconstituted in water. However, Nutramigen (British Drug Houses), recommended by Burke, Kerry, and Anderson (1965) for infants with chronic diarrhoea, contains a high percentage of *sucrose*, and disaccharide-free milks, such as Galactomin (Trufood) and the low-lactose milk used by Clayton, Arthur, and Francis (1966), are high in *fat*, and unless diluted may be badly tolerated. Anderson (1966) suggested that in addition to manipulating the sugar content of

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TABLE I
Milk Feeds Suitable for Infants After Massive Resection

	Composition									
	Approximate g./l.			mEq/l.						
	Fat	Protein	Carbohydrate	Na	K	Cl	PO ₄	Ca	Mg	Calories/l.
<i>Milk mixtures for younger infants</i>										
A. Breast milk 50%, casein hydrolysate 2%, glucose or fructose 6%	20	20	96	3	6	5	5	8	2	640
C. Half-strength half-cream dried milk (1 in 16) Casein hydrolysate 2% Glucose or fructose 7%	10	37	97	13	20	16	26	30	6	630
<i>Milk mixtures for older infants</i>										
B. Separated machine skimmed dried milk (1 in 10) Glucose or fructose 5%	1	36	103	27	40	33	52	61	11	570
D. Mixed feeds: homogenized lean meat, egg yolk Vegetable and fruit <i>purées</i> with glucose		Variable		High						Variable
				High	High					Variable

Note: Additional mineral supplements are given to cover increased losses (see text). Vitamin supplements of C, B complex, and K are given intramuscularly to depleted patients and thereafter orally: A and D concentrates are added as soon as the baby begins to gain weight.

the feed, symptoms can usually be controlled by giving oral antibiotics when stasis is suspected, and that fat absorption can sometimes be improved by altering the fat in the diet to medium-chain triglycerides. Burke and Anderson (1967) believe that this change has an important place in the management of steatorrhoea after small bowel resection. In future it is intended to use these medium-chain triglycerides in appropriate cases.

Vitamin supplements should be continued after

the phase of obvious diarrhoea, since malabsorption often persists even when the child is gaining well, and he is then liable to become vitamin deficient (Case 1).

Table II shows that 3 infants had less than 100 cm. remaining small bowel, while one, Case 2, who also had a massive resection including areas of atresia, may be assumed to have been left with equally little small bowel.

The length of small bowel removed in cases with

TABLE II
Findings, Treatment, and Course in 4 Patients.

Case No.	Birthweight (kg.)	Age at Operation (days)	Operative Findings			Present Status		
			Findings at Operation	Site and Length of Bowel Resected	Site and Length of Remaining Bowel at Operation	Age (yr.)	Centiles	
							Weight	Height
1	2.7	1	Multiple ileal atresia	53 cm. + atretic areas mid gut	45 cm. jejunum 30 cm. terminal ileum	10	10	> 10
2	2.8	1	Volvulus and necrosis	65 cm. + areas of atresia including terminal ileum	Jejunum and proximal ileum only ? persistent dilatation at anastomosis	9	10	10
3	2	21	Volvulus and necrosis	90 cm. mid gut	52 cm. jejunum 13 cm. terminal ileum	3	> 25	50
4	3.4	3	Ileal atresia	20 cm. proximal and 53 cm. distal to ileal atresia including terminal ileum	80 cm. jejunum	2	90	25

multiple atresia is likely to be greater than the measured length, as the associated failure of circulation also arrests growth of the bowel. This probably explains why the measured residual plus resected bowel was less than the total expected for normal infants in 2 cases, while Case 3 was born with a short total gut length due to prematurity.

Few infants have such large resections as these 4 (Swain *et al.*, 1963). Such patients will suffer from intestinal hurry and malabsorption during the early months of life and must be treated accordingly. Case 1 was exceptional in the Queen Elizabeth Hospital Series in having no early diarrhoea. At the earlier assessment (Swain *et al.*, 1963), in which length of resected bowel was reported, it was supposed that his residual bowel was adequate, but further appraisal of his records (Table II) has shown that it was only 75 cm.

Clinical Course of Older Children

The later progress of 2 children, Case 1, who had no early setback, and Case 2, who failed to thrive during the first year with subsequent apparent recovery, will now be described.

Case 1. This child's satisfactory progress during early infancy may have been due to breast-feeding on which he doubled his birthweight in 3½ months. Thereafter he was seen regularly and had no setbacks, with parallel increments in weight and height for 4 years. Though he was then well (Swain *et al.*, 1963), his serum B12 and folic acid levels were only just within the normal range. Thereafter, his weight increment became less satisfactory, and later he lost weight. At 6 years of age he had no alimentary symptoms, but while on an unrestricted fat intake, fat excretion was high (13 g. and 12 g. daily). Vitamin B12 absorption and serum B12 levels were normal, but a positive Figlu test suggested folic acid deficiency, in keeping with his low-normal serum folate level of 5 mμg./ml. two years previously. Both steatorrhoea and folic acid deficiency might be expected in a child with a short residual jejunum-ileal segment. There was no evidence of anaemia; but though his height was above the 3rd centile, his weight was below this channel and his skeletal age was two years retarded, suggesting some arrest of growth and development.

Subsequently, easily assimilable high calorie and protein, restricted fat meals, and multiple vitamin supplements, high in folic acid, were advised. The child's appetite and vigour improved, and at 10 years, while still on the recommended low fat diet, fat excretion was only slightly raised (5·4 g. daily), though occasional relapses with greasy motions were said to be provoked by fatty meals. His height had reached the 10th and his weight was between the 3rd and 10th centile, but his skeletal age was still 2 years retarded.

Case 2. (J.B. as previously described by Swain *et al.* 1963). Her early severe alimentary intolerance was followed by some degree of malabsorption, but she made good clinical progress and it was therefore assumed that her appetite was compensating for the abnormal faecal output. Though most, if not all of her ileum including the terminal ileum had been resected at the age of 3 years, there was no evidence of B12 deficiency, and B12 absorption was in the low normal range.

She is now 9, and continues to thrive and lead a normal school life. Her weight and height are on the 10th centile and her skeletal age matches her chronological age. Though she is free of symptoms and often has only one stool daily, the faecal output (total weight and fat) varies and is usually excessive on a somewhat restricted fat intake. She has shown no evidence of B12 or other vitamin deficiency (B12 190 μμg./ml., serum folate 13·1 mμg./ml.). Her mother has been advised to select easily assimilable foods and to use low-fat milk.

Though physical recovery from very severe retardation in the first year seems to be complete, her school record suggests that her mental ability is less satisfactory, her IQ being only 71 and reading age 5 years 10 months at age 9. Previously her IQ on the Merrill-Palmer Scale had been assessed as 84 and 95 at 3½ and 4½ years, respectively. Help with her reading in a small group at school has now been advised. The effect of severe undernutrition during infancy on subsequent brain growth and intellectual development, or of long periods in hospital on her emotional development, may have contributed to her present poor performance (Stoch and Smythe, 1963, 1967).

Clinical Course of Younger Children

Case 3 (Fig. 1). Her feeds were at first supplemented by intravenous infusions, but when full amounts of undiluted breast milk were being given 8 days later (8 feeds giving 300 calories daily), she had severe diarrhoea, becoming grossly dehydrated and developing hyperelectrolytaemia (serum sodium 170 mEq/l.). After further intravenous infusions for rehydration, the plan of regrading the feeds was based on the use of the mixture A (diluted expressed breast milk), with additions of glucose, casein hydrolysate, and sodium and potassium salts (Table I). Though fluid stools persisted, the feeds were increased using skimmed milk (mixture B) to satisfy hunger, and she began to gain weight slowly. During the third month, the half-cream dried milk mixture C (Table I) was gradually substituted for A with no ill effects, and at 3 months when about 450 calories per day were being given the baby gained weight regularly, though her bulky foul stool output was still a cause for concern. *Purées* of meat, vegetables, and fruit with glucose were added to the diet with benefit. At one stage, during the sixth month, a course of neomycin was prescribed, with apparent improvement in the stool output, while Celevac (methylcellulose), which absorbs water and is given to reduce diarrhoea and prevent excessive fluid loss without interference with absorption, gave no apparent benefit. During the seventh month the separated milk mixture B replaced

FIG. 1.—Case 3. Post-operative treatment.

the half cream mixture C, and egg yolk was given and well tolerated. She stayed in hospital until she was considered fit for adoption aged 7 months. By that time the losses in the stools had diminished.

Unexpectedly, this child has had no alimentary symptoms during the subsequent $3\frac{1}{2}$ years. At 18 months her adopting mother discontinued dietary restrictions and she has continued to thrive, enjoying the family meals (3 per day). The feeding habits of this family are judged to be suitable for her. Her weight has remained on the 25th, while her height is on the 50th centile. She has no evidence of anaemia. The parents assess her mental ability as higher than that of their own child at the same age, and he is now doing well at school.

Case 4 (Fig. 2). The difficulties in managing the early post-operative phase occurred during the second week, when she lost weight precipitately when feeds of undiluted expressed breast milk were given. After rehydration by intravenous infusions, the diluted breast milk mixture with salt supplements (A) was given and tolerated, but the baby did not gain weight on 340 calories daily. Her faecal output was judged to be excessive in 6 motions daily. At 6 weeks, when her weight was still stationary, the faecal fat output was high (fat globules on microscopy ++), and therefore the separated dried milk B was gradually substituted for A, but at 8 weeks, when equal amounts of the two milks were used she became dehydrated, more fluid being lost in her stools. After rehydration with glucose

FIG. 2.—Case 4. Post-operative treatment.

electrolyte mixture orally, the breast milk mixture was again prescribed, and as the volume was increased she gained weight slowly. However, an attempt to introduce the half-cream dried milk mixture C was unsuccessful, leading to a diarrhoeal crisis at 3½ months of age. After rehydration, a third attempt to achieve tolerance using the breast milk mixture was successful. Small amounts of more concentrated feeds were given 3-hourly using undiluted breast milk, augmented with 2% casein hydrolysate and 3% glucose, the fluid intake being augmented at mid-point between feeds with a 7½% glucose-electrolyte mixture, with 2% casein hydrolysate, so that the total daily intake was similar to the breast milk mixture A. 2·5% fructose was added to the mixture allowing the caloric intake to be increased towards 400, and the baby began to gain weight again within a month. Some separated fat-free milk was substituted at 5 months, and *puréed* meat, vegetables, and fruit were added at 5½ months, but full feeds of separated milk at 3-hourly intervals (8 feeds) were not given until 8 months.

Subsequently, her mother lived in hospital to learn to manage this feeding pattern and to deal with any setbacks, and the baby was allowed home at 9 months still weighing only 5 kg. Thereafter, she made regular progress despite occasional diarrhoeal episodes, which her mother had learnt to treat by withholding milk and giving the glucose-electrolyte mixture. Improvement in bowel function during the subsequent months allowed accelerated weight gain so that she reached the 3rd centile at 1 year of age. At this time three meals per day were given, and she continued to have one or two stools daily. There has been no evidence of anaemia or vitamin deficiency, and both folic acid and B12 levels were normal at 2 years. Complete checks on absorption are planned before school age. Her physical and mental progress are in keeping with the growth charts. Her height was 82 cm. (> 25th centile) when her weight was 13·1 kg. (> 75th centile) at 2 years of age. She was walking at 1 year and 7 months.

Discussion

The records of three of these cases illustrate the early difficulties likely to be encountered in the management of infants with only short lengths of small bowel. Only Case 1 had an uneventful recovery after operation. It may be that he received enough milk from the breast to allow normal growth despite losses from the bowel, for much of the fat which contributes a high proportion of the caloric intake is likely to have been lost due to grossly deficient areas of absorption. Increasing amounts of undiluted expressed breast milk were not well tolerated by two other cases, each developing a diarrhoeal crisis (Cases 3 and 4). Careful introduction of modified feeds during the post-operative phase might be expected to avoid the early complications.

None of these cases at first received the modi-

fications of the feeds with electrolytes added that are recommended in Table I, and after diarrhoeal crisis and regrading on diluted breast milk Case 4 relapsed as the skimmed milk (mixture B) was substituted. Even when the fat was reduced, full concentrations of the usual cow's milk mixture were not well tolerated. This child had serious relapses, not gaining on her required volume of the diluted breast milk feeds at 3-hourly intervals either. She only began to improve when half this volume of more concentrated feeds was given every 3 hours, and the volume augmented by clear fluids containing glucose, fructose, and predigested protein given between the milk feeds. This scheme was based upon the supposition that small volumes of milk might be retained long enough for absorption in her short bowel, while the clear fluids given separately might be absorbed mainly from the stomach. Though her management was so difficult in the early months, she apparently outgrew her intolerance of food and was doing well on only 3 meals daily by 1 year.

After a catching-up phase of accelerated gain in weight and growth, the health of both Cases 3 and 4 is now completely satisfactory (Table II), so that their parents have to be persuaded to give them vitamin supplements and bring them to hospital. They compare favourably with other children of their age, but are still too young for formal assessment of intelligence. The later progress of Case 2, though satisfactory on physical examination, is now a matter of concern as she is duller than her elder sib and has reading difficulties. During the first year of life she suffered from severe undernutrition but of no greater degree than Case 4, though she was not discharged from hospital until she was 4 months older, and aged 13 months. She was somewhat slower than Case 4 in reaching her milestones for walking and talking.

Both the older children have persistent malabsorption when put to the test, and it is probable that Cases 3 and 4 would also have steatorrhoea if given a high fat intake, and would be susceptible to vitamin deficiency.

The explanation for the recovery of bowel function in children with so little remaining small bowel is not well understood. Evidence from experimental work in dogs (Flint, 1912), in puppies (Clatworthy, Saleeby, and Lovingood, 1952), and in piglets (McCance and Wilkinson, 1967) points against compensatory growth in length, and towards hypertrophy and hyperplasia. Booth *et al.* (1959) and Dowling and Booth (1966, 1967) showed that the proximal and distal small intestine of the rat responded differently to resection. When the

jejunum was removed the ileum showed marked hypertrophy, the villous height and small bowel diameter being increased, these changes being slight but significant in the jejunum after ileal resection. These changes have been extensively reviewed by Dowling (1967).

The present results, in agreement with previous reports, show that the intensive care given to these infants initially and continuous treatment in hospital for several months, is amply rewarding, for they seldom have handicaps of which they need to be aware in later childhood. However, it is obvious that their health should be supervised in a centre where their bowel function can be studied, dietary advice given, and any untoward symptoms, or retardation in their growth and development, investigated.

Summary

Observations are recorded on the progress of each of 4 children who had less than 100 cm. of small bowel remaining after resection for neonatal obstruction, their present ages being 3, 4, 9, and 10 years.

Plans are outlined for the management of feeding during the early months, based upon experience in treating the severe intolerance due to malabsorption.

The physical growth and development of all 4 children has reached the normal range, but one child who had a long phase of undernutrition and growth retardation during infancy appears to be somewhat mentally retarded at 9 years.

The apparent recovery of bowel function in our patients has also been reported by other workers. A degree of malabsorption has persisted in the older children, the younger having not yet been put to the test. This malabsorption jeopardizes nutrition, and therefore arrangements for long-term care are essential.

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