A study of malabsorption after resection of the entire jejunum and the proximal half of the ileum

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SYNOPSIS Biochemical, haematological, and radiological investigations are reported in a young child in whom nearly 80% of the small intestine was resected. The prognosis in a child after such extensive resection is probably better than in an adult, as natural growth can still occur with the expectation of greater adaptability as well as of increased length of the remaining segments.

The supreme role of the small intestine in digestion and absorption makes it an indispensable organ. Elaboration of the functions of its several parts is of considerable importance because of its involvement at different levels by a variety of diseases and anatomical lesions. Although special techniques (Borgström, Dahlqvist, Lundh, and Sjövall, 1957; Blomstrand, 1958; Cox, Meynell, Cooke, and Gaddie, 1958; Booth and Mollin, 1959) are now giving precision to the study of the physiology of digestion and absorption, it is by no means clear what proportion of normal absorption takes place in the ileum nor what its functional reserve is. For this reason observations on a unique patient who retains only the distal 22% of small intestine are recorded.

CASE REPORT

C.L., a boy, was born on 20 July 1958, whose birth weight was 3.4 kg. (7½ lb.). Progress and weight gains to 9.72 kg. (21 lb. 6½ oz.) at 10 months were normal. At this age operations for intussusception complicated by gangrene resulted in resection of the small gut from the duodenal-jejunal flexure to past the midpoint in the ileum. At the operations it was estimated that 134.5 cm. (78%) was removed leaving 38 cm. (15 in.) distally. Continuity was restored by gastro-ileostomy and the duodenal stump was closed. He made a good recovery after this remarkable surgery. Initially he had 10 to 14 loose motions daily which settled to seven to nine slightly formed ones at the age of 1 year by which time he had lost 1.36 kg. (3 lb.) in weight (Fig. 1). He was at that time a bright, underweight child with a protuberant abdomen. His diet was similar to that of a 6-month-old infant, and it was noted that milk feeds tended to pass

through quickly. He was subject to attacks of prostration with episodes of vomiting and diarrhoea.

It was at that stage, two months post-operatively, that our investigations began. His haemoglobin was 88% (12.8 g.), red and white blood cell counts were normal, reticulocytes 0.6%, and prothrombin time normal. Serum B₁₂ was 285 and 310 µg./ml. and B₁₂ absorption was 0.41 µg. after a dose of 1 µg. of Co⁵⁸B₁₂. Biochemical examination of capillary blood (Wilkinson, 1960) gave the following results: total plasma protein 6.3 g./100 ml. with a normal electrophoretic pattern apart from a moderate increase in gamma globulin, serum bilirubin 0.5 mg./100 ml., and plasma values for calcium 9.4 mg./100 ml., phosphorus 4.4 mg./100 ml., alkaline phosphatase 17 K.A. units/100 ml., bicarbonate 20 mEq./l., chloride 107 mEq./l., sodium 137 mEq./l., potassium 4.2 mEq./l., blood urea 47 mg./100 ml. The fasting blood sugar was 92 mg./100 ml. and at half-hourly intervals after 13 g. glucose (Poulton-Payne dosage: Wilkinson, 1960) was 118, 100, 78, 89, and 78 mg./100 ml.

A barium meal examination showed normal gastric emptying in the course of one and three-quarter hours by which time a little barium had reached the caecum. The ileum was still well filled at three hours and was clear at four hours. The ileum was considerably dilated except in the last few inches.

The first balance study (periods I and II) was carried out using a diet which closely resembled the one he had been having up to that time. The diet contained 980 calories, half of them derived from fat and the main constituents of it were baby foods and milk (2 pints). Although he had been losing weight steadily on this kind of food there was no change in his weight of 7.9 kg. during the balance period. Nevertheless, since his ideal weight for age would have been 10.3 kg. (Fig. 1) this diet was inadequate calorifically even if it had been totally assimilated. In order to recover the weight lost, which now amounted to 1.82 kg. (4 lb.) or nearly one fifth of

Patient's Age (mth.)	Weight (lb. oz.)	Other
At birth	7½	
10	21 6½	
12	18 6	Operation
13	17 6	
14	17 6	First balance study
15	18 6	Diet initiated
15½	19	
18	21 4	
19	22 4	
20½	23 6	Second balance study
22	24 5	
23	25 4	
25	27 4	

FIG. 1. Standard weight chart (Tanner, 1958)

what his weight had been at 10 months, his requirements were very much greater than those of a normal child.

Accordingly a diet high in protein and calories with low fat and roughage content in four main meals daily was instituted. Milk, because of its observed deleterious effects, was limited to 1½ pints daily and proteins were given in solid form (chopped meats). Improvement was immediate on this régime both in weight and wellbeing. Bowel motions were reduced to three formed motions and he quickly recovered his admission weight of 8.45 kg. before discharge. Subsequently, after his return home weight gains averaged 0.34 kg. (12 oz.) a month (Fig. 1) and he became an active and energetic boy.

He continued to do well except for an interlude at the time of the second balance study (period III) six months later. At that time less care was being exercised in regard to the fat and milk content of his diet. When these were again reduced, to the extent of avoiding all obvious fat and limiting the milk to a daily total not exceeding 1½ pints to be taken between rather than with meals, the stools returned to two daily of moderate size and the steady weight gains continued as before (Fig. 1). Investigations repeated after the second balance, that is nine

months after the operations, were as follows: total plasma protein 6.7 g./100 ml.; plasma calcium 9.5 mg./100 ml., plasma phosphorus 5.0 mg./100 ml., plasma alkaline phosphatase 15 K.A. units/100 ml., serum B₁₂ 445 µg./ml. Cell counts and blood film appearances were normal.

THE BALANCE STUDIES

Periods I and II were two months after the resection and period III was six months later, the patient's age being 12 and 18 months respectively.

The first balance study was carried out in hospital, the same diet being given each day. Food and fluids were prepared in double quantity by the hospital diet kitchen, half being sent to the laboratory for analysis and half being given to the child. All food and fluids refused by the patient were sent to the laboratory for analysis. Food was reduced to a uniform paste with a mechanical blender for analysis at the end of each metabolic period. Precautions were taken to exclude extraneous sources of calcium, and distilled water was used throughout. Carmine powder, 3 grains by mouth, was used as a stool marker at the beginning and end of each metabolic period. Stools were collected separately into parchment containers and bulked at the end of each period. Twenty-four-hour collections of urine were bulked at the end of each period. No urine or stool was lost.

The second balance study (period III) was performed at home with the cooperation of the mother. It was carried out in the same way as the first study, except that kitchen scales were used to weigh the food, the diet varied from day to day, and tap water was used (but an equal amount was analysed). During this study some urine was lost by bedwetting at night, but since the mother potted the child hourly she was able to assure us that the amount lost was very small. His weight during this study was 10.3 kg.

ANALYTICAL METHODS Wet ashing of samples of food, faeces, and urine was employed, using sulphuric acid and hydrogen peroxide for calcium and phosphorus, sulphuric acid for nitrogen, and nitric acid for sodium and potassium.

Nitrogen in food, faeces, and urine was determined by the standard micro-Kjeldahl procedure, phosphorus by the method of Briggs (1922), calcium by the method of Tisdall and Kramer (1921), and sodium and potassium by a single-cell, direct-reading flame photometer. Fat in food and faeces was determined by a slight modification of the wet extraction method of van de Kamer, Huinink, ten Bokkel, and Weyjers (1949).

The results of the metabolic studies are shown in Table I.

DISCUSSION

The wide-ranging and variable effects of extensive resections of small intestine have been discussed in many excellent studies and reviews in the last decade (Althausen, Doig, Uyeyama, and Weiden, 1950; Jackson and Linder, 1951, 1955; Berman, Habegger,

TABLE 1

RESULTS OF METABOLIC STUDIES DURING THREE PERIODS

	Period I ¹	Period II	Period III
Nitrogen			
Intake	22.6	22.6	52.4
Urinary excretion	9.0	7.9	27.0
Faecal excretion	4.3	4.5	11.5
Total excretion	13.3	12.4	38.5
Balance	+9.3	+10.2	+13.9
Mean daily balance	+2.3	+2.6	+2.8
Phosphorus			
Intake	4.2	4.2	6.4
Urinary excretion	0.4	0.5	1.9
Faecal excretion	1.0	1.1	2.5
Total excretion	1.4	1.6	4.4
Balance	+2.8	+2.6	+2.0
Mean daily balance	+0.7	+0.7	+0.4
Calcium			
Intake	3.8	3.8	5.4
Urinary excretion	0.02	0.03	0.15
Faecal excretion	1.7	1.2	3.5
Total excretion	1.72	1.23	3.65
Balance	+2.1	+2.6	+1.8
Mean daily balance	+0.5	+0.6	+0.4
Fat			
Intake	194.0	194.0	158.8
Faecal excretion	48.4	53.2	128.0
Balance	+145.6	+140.8	+30.8
Percentage absorption	75	72	19
Sodium			
Intake	91	91	353
Urinary excretion	29	48	232
Faecal excretion	11	12	25
Total excretion	40	60	257
Balance	+51	+31	+96
Mean daily balance	+13	+8	+19
Potassium			
Intake	203	203	256
Urinary excretion	30	15	139
Faecal excretion	52	50	72
Total excretion	82	65	211
Balance	+121	+138	+45
Mean daily balance	+31	+34	+9

¹Periods I and II were four days and period III was five days. Results for nitrogen, phosphorus, calcium, and fat are given in grams, and for sodium and potassium in milliequivalents.

and Billings, 1953; Pilling and Cresson, 1957; Pullan, 1959). Early reports were more concerned with the extent of the resection whereas the emphasis is now on the nature and function of remaining segments. The present patient is exceptional in having no jejunum at all, and a duodenum which is now an appendage to the stomach.

Radiological examination three months after his operations showed considerable dilatation of the ileum, a finding which is usually reported as confined to the jejunum in those patients who retain a segment of the latter. Intestinal transit times were not unduly increased, but because there are many factors which influence the passage of barium as well as a wide normal variation, the exact significance of these times is elusive. However, this examination did suggest that possession of the ileo-caecal valve and

of terminal ileum was controlling the rate of passage through the remaining small gut.

Because detailed studies have rarely been done on children when the demands for growth and nutrition are proportionately so much greater there was a special interest in our study of this patient. It was noteworthy that he made such a good post-operative recovery after a quick succession of operations at the age of 10 months when he was extremely ill with gangrene and perforations. Although losing weight rapidly at first, he was able to maintain his bodily equilibrium to the extent that two months later all haematological and biochemical investigations were within the range of normal, apart from evidence of mild dehydration.

As expected, since the ileum is the main site of B₁₂ absorption (Booth and Mollin, 1959), the serum B₁₂ levels and Co⁵⁸B₁₂ uptake were normal (Mollin, Booth, and Baker, 1957). The glucose tolerance figures were within the range of normal in our experience with the method used and the stool fat at that time was 12-13 g. daily. This combination of normal B₁₂ and glucose absorption with high stool fat gives an additional pattern to three types described by Booth (1960) in association with distal resections.

The balance study of two consecutive periods (I and II) shows great uniformity at a time of relative stability for the patient in respect of previous diet and constant weight at the time of the study. Although the diet was unsuited to his needs, due to high fat and milk content, he retained 75% of 48.5 g. of fat. A nitrogen intake of 5.66 g. was less than desired in his case, but approximately normal for his 'ideal' weight of 10.3 kg. equivalent to 3.5 g. of protein/kg. (League of Nations Report on the Physiological Basis of Nutrition, 1936). The study showed a positive balance of 40 to 45% equivalent to 1.5 g. of protein/kg. daily and normal urinary and faecal excretion of nitrogen. There was an excellent positive balance for calcium, phosphorus, sodium, potassium, and chloride in spite of the quite inadequate sodium chloride intake. From these results it was clear that he could absorb adequate protein, minerals, and electrolytes as well as a moderate amount of fat. Although we did not know of any comparable study the malabsorption was less severe than expected from reports in the literature, and we attributed this to the efficiency of absorption in the ileal segment.

Six months later we expected increased efficiency of absorption to account for his striking clinical recovery (Fig. 1 and case report), but period III coincided with a short episode of increased steatorrhoea. This event was partly due to laxity about fat, but more particularly to the excessive milk

allowance in an otherwise adequate diet. The ritual of frequent 'potting' to ensure the collection of all excreta undoubtedly promoted intestinal hurry since the stools returned to normal almost immediately afterwards. Although this second study represents an isolated incident certain valid inferences can be drawn from it. In particular it supports the view that there is a high correlation between severity of the steatorrhoea and degree of malabsorption of the other dietary constituents in such cases (Pietz, 1956). On this occasion it mainly affected the absorption of calcium and phosphorus, since 78% of the protein intake in period III was absorbed compared with 80% in the first study. The study confirmed the clinical observation of the deleterious effect of an excessive intake of milk because the intake of fat during period III was only 66% of that pertaining to periods I and II, whereas the child had been given a greatly increased amount of milk.

In period III the stool fat had more than doubled to 25.6 g. a day so that only 19% of 32 g. of dietary fat was retained. At the same time an abnormal amount of nitrogen was lost in the stools (2.3 g. or 22% of intake) in association with the increased intake of 10.5 g. However, the percentage of protein absorbed (78%) was very satisfactory, and although there was a positive balance of only 26% due to the greatly increased urinary nitrogen the net nitrogen retention was maintained at a level equivalent to 1.5 g. of protein/kg. of his 'ideal' weight (11.7 kg.) for age at 18 months. Calcium and phosphorus lost in the stools was more than doubled but the total absorbed was similar to that absorbed in periods I and II. The percentages of sodium and potassium taken up were also greatly reduced, but the more normal urinary outputs, together with increased total intake, suggests a satisfactory equilibrium. The reduced percentages of intake absorbed in period III suggested exceptional intestinal hurry due to the unusual conditions of the study and cannot be regarded as representative of his 'normal'. These findings show the vulnerability of such a patient to injudicious changes of diet and routine as well as the very worth while measure of function achieved by a small segment in such adverse circumstances. Since period III, with stricter adherence to diet, he has continued his steady weight gains (Fig. 1), and stools have returned to his usual one to two formed motions of normal size.

The diet which produced such an excellent clinical response and control of his motions without any additional measures whatever is essentially similar to the recommendations of the authors quoted. The special features which we wish to emphasize are limitation of milk intake and avoidance of liquid protein concentrates. The natural tendency

of parents, nurses, and dietitians to revert to milk and an infant type diet in the belief that food of that kind is more easily assimilated must be resisted. A child of 1 year is quite capable of taking a more solid adult type diet provided it meets his nutritional requirements and that meat, etc., is suitably cut up. Our régime consisted of four main protein-containing meals a day, with snacks and 4 oz. milk drinks from the ration between rather than with meals. The widest possible choice of foods is encouraged, eliminating only the well-known sources of fat and roughage. This has proved both a manageable and expensive diet (but much less costly than various alternatives), and seems to be well suited to the patient's requirements.

Development and attainments have not been retarded and his striking weight recovery in 12 months brought him near to the 50th percentile again at the age of 25 months (Fig. 1). Because the length of the gut is said to increase at least twofold with body growth (Pilling and Cresson, 1957), further improvement and an increasing margin of safety in small intestinal function can be anticipated.

SUMMARY AND CONCLUSIONS

Biochemical, haematological, and radiological investigations are reported, together with detailed metabolic studies on a child two and eight months after resection of 78% of the small intestine. The findings are considered in the light of an anatomical situation where the distal half of the ileum is required to subserve all the remaining functions of the mesenteric small intestine.

The distal half of the ileum appears to be capable of undertaking a substantial amount of the function of the small gut. In this patient B_{12} and glucose were normally absorbed, associated with a raised excretion of fat, giving a distinct pattern of malabsorption. His absorption of protein, minerals, and electrolytes was adequate.

Dilatation and adaptation of the ileum to subserve a role similar to more proximal segments appears to occur in man in a manner similar to the jejunal dilatation reported after distal resections. In addition retention of the terminal ileum and ileocaecal valve is probably especially advantageous after extensive resections in controlling transit times and thereby promoting more efficient absorption.

The impaired absorption of the dietary constituents involved in the malabsorption appears to correlate more closely with the severity of steatorrhoea than with the fat intake when the total absorbing surface of the small intestine is reduced by resection.

Excellent weight gains, together with effective

control of the motions, were achieved with diet alone. The essentials of diet are high protein and calorie, and low fat and roughage content. The need to give protein in solid form and to limit the milk intake has been stressed. Four main meals daily were found to be well suited to this patient's requirements.

The prognosis in a child after such an extensive resection is probably better than in the adult, because natural growth is still occurring, with the expectation of greater adaptability as well as of increased length of the remaining segments.

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