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The Sir David Cuthbertson Medal Lecture

Clinical problems of a short bowel and their treatment

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Sir David Cutherbertson was a chemist before qualifying in medicine. During his first job as a clinical biochemist at the Royal Infirmary in Glasgow, a clinician asked him if he could help solve the problem of the non-union of fractures of the lower third of the tibia. He accepted this challenge and set up a six-bedded metabolic ward. There he performed careful balance studies on patients who had experienced trauma. It was from this work that he described an initial period of reduced metabolism and hyperglycaemia following injury (ebb period); this was followed by a period of increased metabolism and increased protein catabolism (flow phase). His work did not stop there. He went on to show that the magnitude of the N loss during the flow period could be reduced by giving protein and nutrient supplements (Widdowson, 1991).

The work presented here follows his example. I shall describe the clinical problems experienced by patients with a short bowel. With the use of balance studies the problems of water, electrolyte and energy absorption are demonstrated and appropriate treatments are evaluated.

WHAT IS A SHORT BOWEL?

Small-bowel length in normal subjects

Small-intestinal length has been measured surgically, radiologically and at autopsy. Bryant (1924) very carefully measured the small-intestinal length from the duodeno–jejunal flexure to the ileo–caecal valve at 160 autopsies. The mean small-bowel length was 6·2 m, with the mean for women being shorter than that for men. He showed a wide variation in normal human small-intestinal length from 3·0 to 8·5 m. The results he obtained are similar to those obtained at surgery (Backman & Hallberg, 1974; Slater & Aufses, 1991), but slightly longer than those obtained radiologically (Hirsch *et al.* 1956; Fanucci *et al.* 1984).

In a patient with a total small-intestinal length of 8·5 m a resection of 2·0 m will make little difference, but if the starting length is 3·0 m the same resection may cause major problems. Thus, it is important to refer to the residual length of small intestine rather than to the amount resected.

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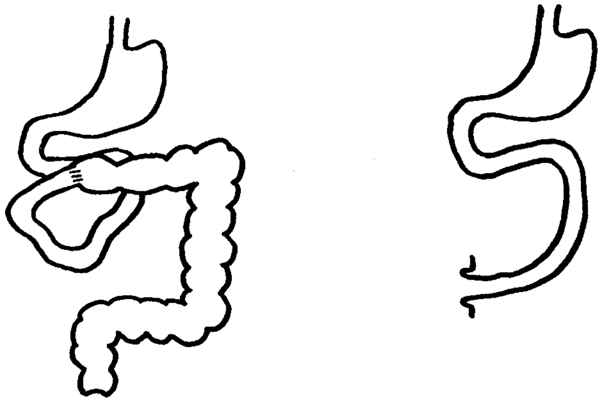

Fig. 1. The two most common types of patient with a short bowel.

Measurement of the length of a short bowel

If a surgical measurement of small-intestinal length is not available, the length may be determined radiologically from a Ba follow-through examination. This may be done using an opisometer with which the operator traces out the long axis of the bowel. Providing all bowel loops are seen on one film, and the residual bowel length is less than 2·0 m, there is a good correlation (r 0·72, $P<0·001$) between the mean of three such measurements and that obtained previously at surgery (Nightingale *et al.* 1991*a*).

Original small-bowel length in patients with a short bowel

In eleven of our patients with Crohn's disease the median length of small intestine resected was 1·20 (range 0·60–1·65) m and the amount remaining was 1·25 (range 0·9–1·85) m. This gives a calculated median original small-intestinal length of 2·40 (range 2·05–3·15) m. Even allowing for some shortening of the resected bowel specimens due to the Crohn's disease this suggests that these patients had an initial small-bowel length at the lower limit of the normal range.

I shall consider a short bowel to be a residual small-intestinal length of less than 2·0 m.

ANATOMICAL TYPES AND CAUSES OF A SHORT BOWEL

Most experimental work on animals has been done after they have had a jejunal resection, which is an uncommon situation in man. Most of the classical reports of patients with a short bowel are of those with a functioning colon remaining (Flint, 1912; Haymond, 1935; Booth, 1961; Simons & Jordan, 1969).

In current clinical practice two types of patient are commonly seen (Fig. 1). Some have had their colon, ileum and some of their jejunum resected and, thus, have a jejunostomy. Others have had their ileum and some of their jejunum resected, usually leaving a jejuno–colic anastomosis, but sometimes with preservation of the ileo–caecal valve (Nightingale *et al.* 1992*a*). The ileo–caecal valve is theoretically important as it regulates

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Table 1. *Details of eighty-four short-bowel patients*

	Jejunum–colon*	Jejunostomy
n	38 (26 female)	46 (31 female)
Age (years): Median	48	43
Range	7–70	16–68
Jejunal length (m): Median	0·9	1·15
Range	0–1·9	0·2–1·9
Diagnosis:		
Crohn's disease	16	33
Ischaemia	6	2
Irradiation	5	3
Ulcerative colitis	–	5
Volvulus	5	–
Adhesions	4	1
Diverticular disease	1	1
Desmoid	1	1

* Seven patients had a short length of ileum and an ileo–caecal valve; thirty-one patients had a jejuno–colic anastomosis.

the passage of small-bowel contents into the colon and prevents reflux of large-intestine contents back into the small bowel (Phillips *et al.* 1988); its preservation, however, may make little functional difference (Fich *et al.* 1992).

Our patients with a short bowel were relatively young and it is interesting that the majority were female (Table 1); this may be because women start with a shorter length of normal intestine than men (Bryant, 1924). Crohn's disease was the most common cause in the two types of patient after a median of four resections in the jejunostomy group of patients and three in those with a retained colon. Surgery for inflammatory bowel disease, or its complications, resulted in a short bowel among the majority of patients with a jejunostomy, compared with less than half those with jejunum in continuity with their colon. Few patients with their colon remaining had retained their ileo–caecal valve.

METHODS OF PERFORMING BALANCE STUDIES

There are three possible ways to study intestinal balance in patients with a short bowel. The balance studies described here were all performed on patients with a jejunostomy. Many published reports describe balance studies in patients with a short bowel in continuity with the colon.

Test meal

In patients with a jejunostomy, Rodrigues *et al.* (1989) showed that over 90% of a non-absorbable marker in a liquid test meal was recovered from jejunostomy fluid in the 6 h after the meal.

Investigator-selected diet

For a 24 h balance study, the exact composition, amount and time that food and drink are taken by the patient, may be specified by the investigator. This is an experimental

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ideal but patients with a short bowel are fastidious eaters who feel full very quickly and such a study is difficult to perform in practice. Studies, however, may be done in which the proportion of nutrients is fixed (Nordgaard *et al.* 1994). For patients with a jejunostomy a 2 d collection is adequate but if the colon has been retained a 1 or 2 d run-in period will be needed to flush out the colon before 2 d of stool collections.

Patient-selected diet

This method was used in all our studies on patients with jejunostomies, and it can be used on those with a colon after a run-in period.

Patients each select a diet freely on the first study day when they eat and drink whatever is normal for them. On all subsequent study days they consume exactly the same food and drink, in the same amounts and at exactly the same times as on the first day. All our studies consisted of two paired control days and, if a therapy was given, two further test days. Anti-diarrhoeal drugs (codeine and loperamide) were continued, because stopping them abruptly may cause an acute withdrawal reaction. Daily intestinal output and a duplicate oral intake were collected.

The Na, K and Mg contents of a whole sample of diet or jejunostomy effluent were measured by flame photometry after acid-hydrolysis. Samples of the diet and jejunostomy effluent were freeze-dried and the energy contents of the samples were subsequently determined by bomb calorimetry.

WATER AND MINERALS

Water and sodium

Patients with jejunum in continuity with their colon. The colon has a large capacity to absorb Na and water (Phillips & Giller, 1973; Debongnie & Phillips, 1978). Ladefoged & Olgaard (1979) demonstrated the importance of this function in patients with a short bowel. They performed balance studies on eight patients with less than 2·0 m jejunum, two of whom had a colon. Five of the six without a colon were in negative Na balance whereas both of those with a colon were in positive Na balance.

We have clinically assessed seventy-one patients with less than 2·0 m jejunum and determined their clinical dependence on parenteral and oral Na and water supplements (Fig. 2). Thirteen of forty jejunostomy patients needed parenteral supplements (most of whom had less than 1·0 m residual jejunum) compared with four of thirty-one jejunum–colon patients (all four of whom had less than 0·3 m residual small intestine). In the jejunostomy group twenty-five of the remaining twenty-seven patients needed long-term oral Na supplements compared with only four among those with the colon remaining (Nightingale *et al.* 1992*a*).

Patients with a jejunostomy. Patients with a jejunostomy have major problems with water and Na losses through their stoma. We performed balance studies for 2 d on fifteen patients with jejunostomies. They were maintaining a satisfactory nutritional, fluid and electrolyte status (Nightingale *et al.* 1990). Six patients needed long-term home intravenous nutrition, three required intravenous fluids but maintained their nutrition with an oral diet and six maintained satisfactory nutritional status by taking oral fluid and nutrient supplements.

The intestinal output was mostly water (mean 92 (range 85–96) %) and there was a

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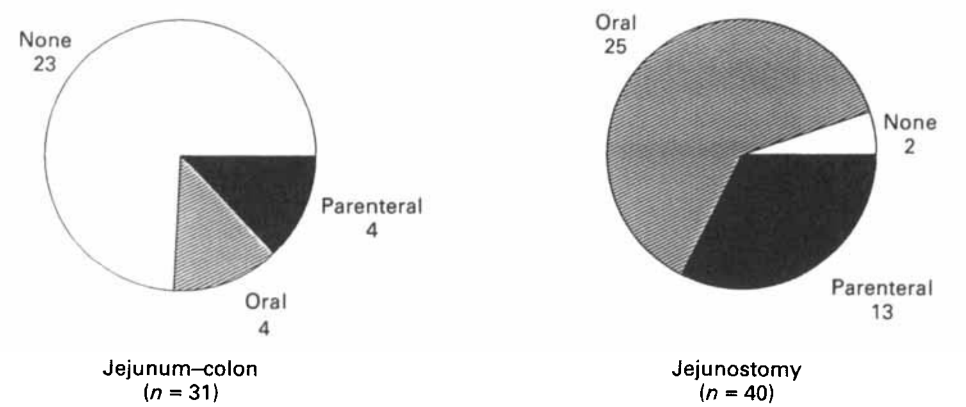

Fig. 2. The percentage of short-bowel patients with jejunum in continuity with the colon, and those with a jejunostomy, needing parenteral or oral sodium supplements.

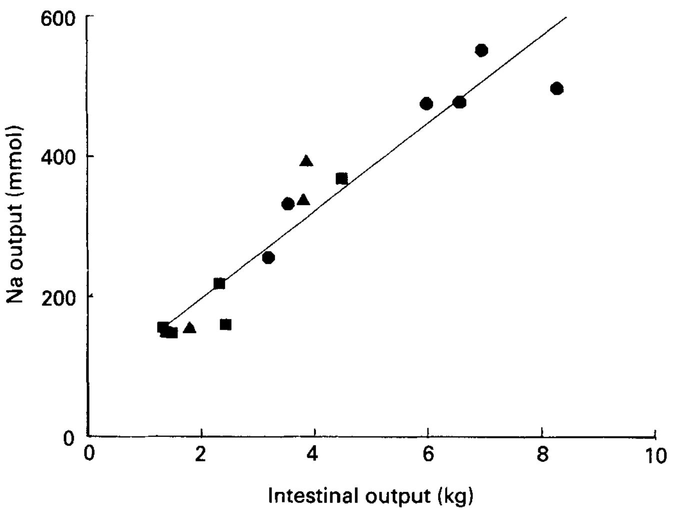

Fig. 3. Mean daily intestinal sodium output *v.* total intestinal output weight for fifteen patients with a jejunostomy. (●), Intravenous nutrition; (▲), intravenous fluid; (■), oral electrolyte supplements. r 0·96, P<0·0001.

good correlation between its weight and its Na content (Fig. 3). The mean jejunostomy Na concentration was 88 (range 60–118) mmol/l. The weight of stomal output was about 6–8 kg/d in those on parenteral nutrition and about 2 kg/d among those receiving oral supplements.

The mean daily oral intake minus the intestinal output (net intestinal balance) correlated with residual jejunal length. The patients who needed intravenous nutrition were in negative intestinal balance of about 2 kg and those who maintained satisfactory health on an oral regimen were in positive balance; those who needed intravenous fluid and electrolytes were in a precarious state of balance. The change from a net secretory state to a net absorptive state occurred at a jejunal length of about 1·0 m (Fig. 4). Results

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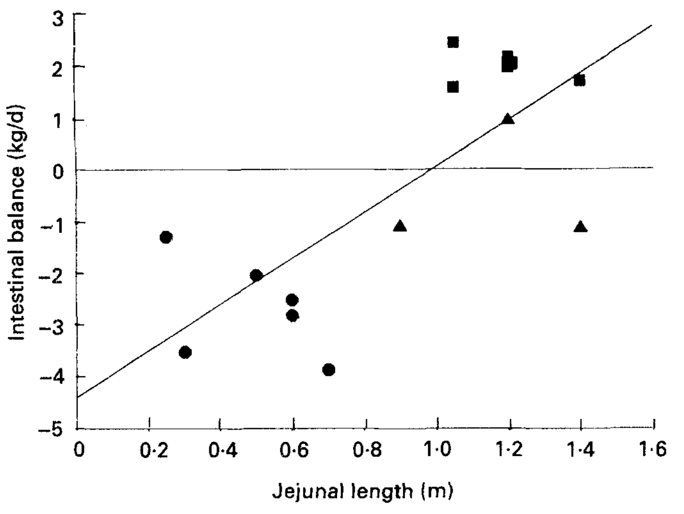

Fig. 4. Mean daily intestinal balance (oral intake minus intestinal output) *v.* jejunal length for fifteen patients with a jejunostomy. (●), Intravenous nutrition; (▲), intravenous fluid; (■), oral electrolyte supplements. *r* 0·75, *P*<0·005.

Table 2. *Classification of jejunostomy patients as 'secretors' or 'absorbers'*

	'Secretors'	'Absorbers'
Intestinal balance:		
Wet wt	Negative	Positive
Na	Negative	Positive
K	Either*	Positive
Energy absorption (%)	<50	>50
Jejunal length (m)	<1·0	>1·0
Therapy	Parenteral	Oral

* Negative if less than 0·5 m.

for Na balance correlated closely with those of total fluid output and the change from a net secretory to a net absorptive state was also observed when the jejunal length was about 1·0 m.

Thus, two patient groups can be identified in terms of water and Na balance; net 'secretors' in whom the oral intake is less than the intestinal output, and who tend to have less than 1·0 m residual jejunum; and net 'absorbers' who have an intestinal output which is less than the oral intake and who have more than 1·0 m of residual jejunum (Table 2). The jejunostomy output from a net 'secretor' increases during the daytime in response to food and decreases at night; thus, any drug therapy, that aims to reduce the output, must be given before food (Fig. 5).

Potassium

None of thirty-one patients with a short bowel and a retained colon had a low serum K compared with three of thirty-nine patients with a jejunostomy. Balance studies in the

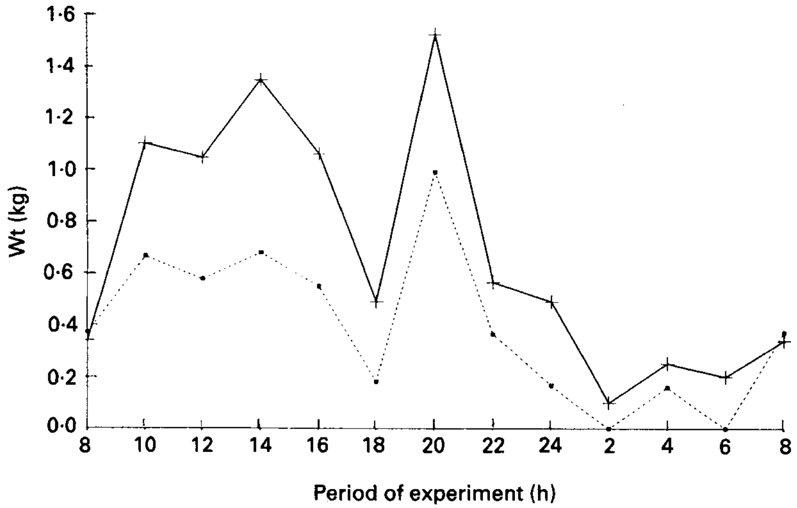

Fig. 5. Weight of 24 h oral intake (■ - - - ■) and jejunostomy output (+——+) measured every 2 h for a patient with 0·3 m residual jejunum.

jejunostomy patients showed that a negative K balance only occurred when the residual jejunal length was less than 0·5 m. A low K level in jejunostomy patients can reflect Na depletion with secondary hyperaldosteronism (Ladefoged & Olgaard, 1979) or Mg depletion.

Magnesium

Mg deficiency is common in patients with a short bowel and gives rise to a clinical syndrome characterized by fatigue, depression, irritability, muscle weakness, occasionally tetany, and if very severe, convulsions can occur (Selby *et al.* 1984).

Of our short-bowel patients who were not receiving parenteral nutrition, eleven of twenty-seven (41%) with a colon were receiving Mg or had low serum Mg levels compared with nineteen of twenty-eight (68%) with a jejunostomy. This suggests that the colon may absorb Mg. In those patients without a colon there was no correlation between Mg balance and residual jejunal length.

REASONS FOR THE HIGH OUTPUT FROM A JEJUNOSTOMY

Loss of normal secretions

The most important reason for the high volume of the stomal output is the failure to absorb the normal intestinal secretions which include (l/d) about 0·5 saliva, 2·0 gastric, 1·5 pancreatico-biliary secretions. Borgstrom *et al.* (1957) and Fordtran & Locklear (1966) have shown, using non-absorbed markers, that in most normal subjects a meal is still diluted by these secretions at a distance of 1·0 m from the duodeno–jejunal flexure.

Gastric acid hypersecretion

We have shown high serum gastrin levels both in the fasting state and after food in patients with a short bowel with and without a colon (Fig. 6). However, it is not known

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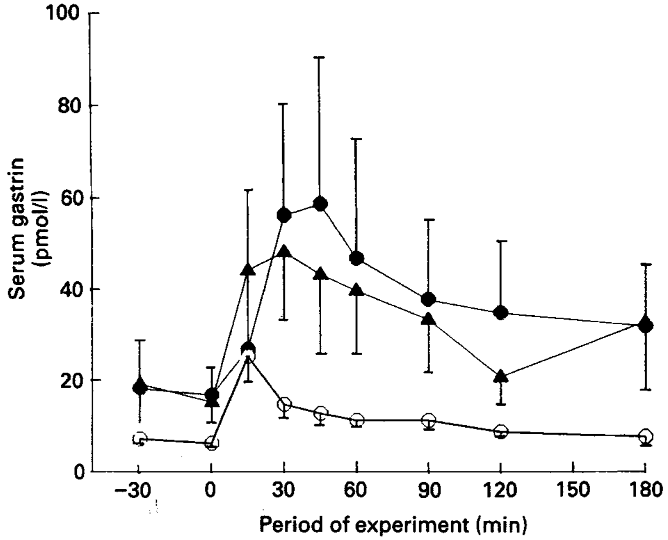

Fig. 6. Serum gastrin levels after a pancake meal in twelve normal subjects (○), seven patients with a jejunostomy (▲) and six patients with their jejunum in continuity with their colon (●). Values are means with their standard errors represented by vertical bars.

whether these gastrin levels result in gastric-acid hypersecretion in man. Hypersecretion can be shown in animals with denervated gastric pouches (Buxton, 1974) and may occur shortly after a resection in man if the colon has been preserved (Windsor *et al.* 1969).

Rapid gastric emptying of liquid

We had noted that rapid gastric emptying of liquid Ba occurred in patients with a jejunostomy. Thus, we went on to measure gastric emptying and compared patients with a short bowel and a preserved colon with those having a jejunostomy and no colon. A carefully validated dual-isotope meal was devised (Mather *et al.* 1991); the solid phase was a pancake (2·38 MJ; 570 kcal) containing resin microspheres of mean diameter 0·5 mm labelled with ^{111}In and the liquid phase was 195 ml orange juice containing ^{99m}Tc coupled to antimony sulphide colloid. Anterior and posterior scans were recorded at intervals over 6 h, and a geometric mean for the two scans was calculated. The data were corrected for overlapping of the energy spectra of each isotope and for radioisotopic decay. Twelve normal subjects, seven jejunostomy patients and six jejunum–colon patients were studied.

The most significant findings were of rapid early liquid gastric emptying in the patients with jejunostomy, the rate being fastest in those with the shortest lengths of residual jejunum. This contrasted with those who had a retained colon, in whom gastric emptying was normal. Thus, in the absence of much of the small intestine, the colon was acting as a brake to gastric emptying. The head of the liquid part of the meal, which represents less than 5% of the total radioactivity, arrived very rapidly in the caecum of these patients but not in normal subjects. It seems possible that the arrival of this liquid in the colon activated a braking mechanism which slowed subsequent gastric emptying (Nightingale

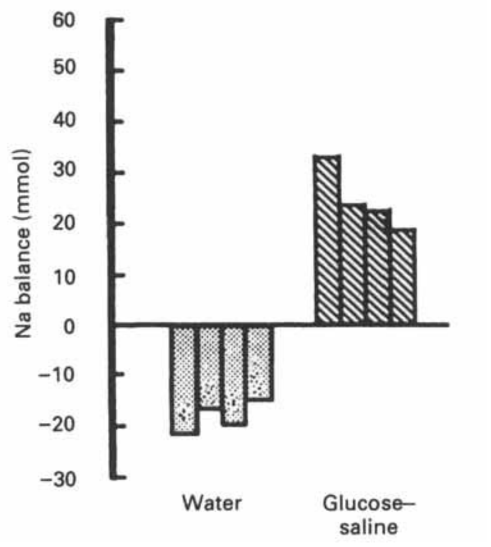

Fig. 7. The effect of drinking 500 ml tap-water (▨) or a glucose–saline (9 g NaCl/l) solution (▧) on intestinal sodium balance in four patients with a jejunostomy. (Adapted from Newton *et al.* (1985).)

et al. 1993). This colonic braking mechanism could be neural or humoral. We measured the serum levels of twelve different gastrointestinal peptide hormones during the gastric emptying study. The most interesting results were the levels of peptide YY in the two patient groups. Peptide YY is produced by the terminal ileum and colon (Adrian *et al.* 1985); it delays gastric emptying and small-bowel transit (Allen *et al.* 1984; Savage *et al.* 1987). The peptide YY levels were low in the jejunostomy patients and this may have contributed to the rapid emptying. Very high peptide YY levels were found in patients with a retained colon and at such levels gastric emptying of liquid is delayed (Savage *et al.* 1987). Peptide YY may be responsible for the colonic braking mechanism (Nightingale *et al.* 1992*c*).

TREATMENT OF THE HIGH OUTPUT FROM A JEJUNOSTOMY

Drink little hypotonic fluid

Jejunal mucosa is naturally leaky and rapid Na fluxes occur across it. When four patients with a jejunostomy drank 500 ml water, Newton *et al.* (1985) showed that all four had a net loss of Na in the effluent. When the patients drank 500 ml of a glucose–saline (90 mmol Na/l) solution all patients achieved positive Na balance. Water taken orally thus washes Na out of the upper intestine when a jejunostomy is present (Fig. 7).

Drink a glucose–saline solution

There is coupled absorption of glucose and Na in the jejunum. Much work has been done to determine the optimum Na and glucose concentrations of a replacement solution. Spiller *et al.* (1987) perfused 250 mm jejunal segments with seven different amino acid–carbohydrate solutions and found that, if the initial Na concentration of the

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perfusing liquid was more than 90 mmol/l, net Na absorption occurred. Rodrigues *et al.* (1988) showed, in jejunostomy patients, that Na balance was improved if an oral isotonic solution of NaCl and glucose contained 90 or 120 mmol Na/l, but that 60 mmol/l was ineffective.

We studied Na balance in six patients with a jejunostomy. When 1 litre of tap-water was given in addition to a normal diet, three patients were in negative Na balance. When NaCl capsules (fourteen, each 500 mg; 120 mmol) were taken with food, or when 1 litre of a glucose–saline solution (120 mmol Na/l) or a glucose-polymer–saline solution (120 mmol Na/l) were sipped during the day, Na balance was positive in most cases. The salt capsules caused nausea and vomiting in two patients. Substitution of a glucose polymer for glucose allowed 481 kJ (115 kcal) more energy to be absorbed each day without adversely affecting Na absorption (Nightingale *et al.* 1992*b*).

The World Health Organization (WHO) cholera solution has a Na concentration of 90 mmol/l (Avery & Snyder, 1990). It is important to note that this concentration is needed for patients with a jejunostomy, and that it is a much higher concentration than needed for treatment of infective diarrhoea. The WHO cholera solution is usually made up as 3·5 g NaCl, 2·5 g $NaHCO_3$, 20 g glucose. Sodium citrate, 2·9 g, may be substituted for bicarbonate as some patients then find the solution more palatable.

Drug therapy

Drugs used to reduce jejunostomy output act principally by reducing intestinal motility or secretions. Loperamide and codeine phosphate mainly reduce intestinal motility. As the enterohepatic circulation, through which loperamide circulates, is disrupted, loperamide may need to be given in higher doses than normal.

Somatostatin (or its analogue octreotide), H2 antagonists or proton-pump inhibitors may be used to reduce gastrointestinal secretions. The H2 antagonists and proton-pump inhibitors reduce gastric acid secretion. Somatostatin and octreotide reduce both gastrointestinal motility and exocrine secretions.

The differentiation between ‘secretors’ and ‘absorbers’ becomes relevant in drug therapy as net ‘secretors’ respond most to anti-secretory drugs and net ‘absorbers’ to drugs that reduce intestinal motility.

We gave 50 μg intravenous octreotide twice daily (0·5 h before breakfast and supper) to six net secretors (Nightingale *et al.* 1989). The intestinal output reduced in all (Fig. 8) but not enough to allow the parenteral fluids to be stopped. In contrast there was an increased stomal output when two absorbers were given 100 μg subcutaneous octreotide three times a day before each meal. Oral omeprazole (40 mg/d), a proton-pump inhibitor, similarly reduced the stomal output (Fig. 8) in net ‘secretors’ when absorbed, but had little effect upon the output in net ‘absorbers’ (Nightingale *et al.* 1991*b*). The H2 antagonists cimetidine and ranitidine have a similar effect (Jacobsen *et al.* 1986).

Mg supplements

Treatment of Mg deficiency can be difficult especially in patients without a colon. Few of those patients (two of twelve) without a colon and who were receiving oral Mg supplements achieved a normal serum Mg level, although the levels were higher than before treatment. We have used MgO, 12 or 24 mmol daily, given in gelatin capsules

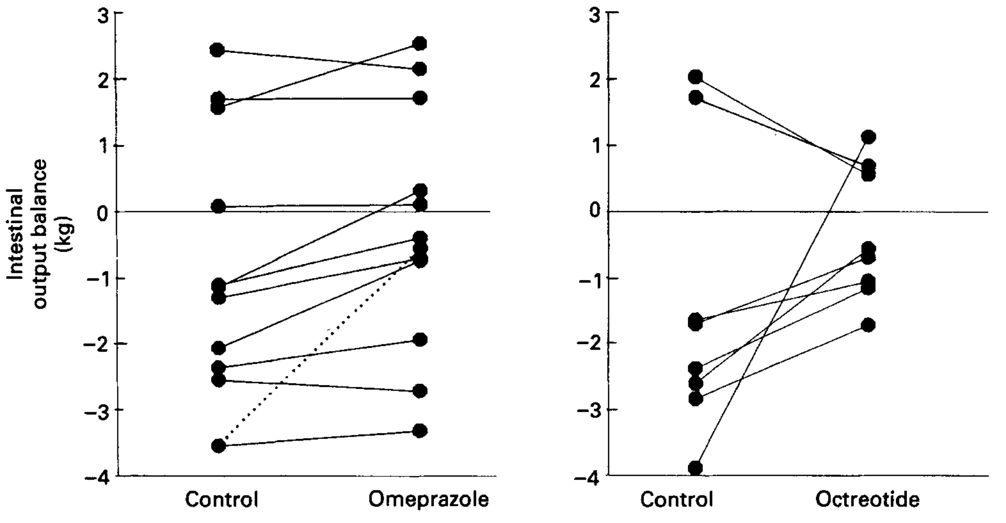

Fig. 8. Net intestinal output balance (kg) after oral omeprazole or injections of octreotide. (. . . . .) The effect of intravenous omeprazole on one patient.

each containing 4 mmol. These are taken during the day or at bedtime as a treatment for clinically overt Mg deficiency or for asymptomatic low serum Mg levels. If this supplement does not bring the Mg level into the normal range, oral 1-α-hydroxycholecalciferol (2–6 μg/d) may be given (Selby *et al.* 1984).

MACRONUTRIENTS

Patients with jejunum in continuity with their colon

Patients who have a short bowel and retained colon are usually well immediately after the surgery but during the ensuing months may insidiously lose weight and present severely malnourished. This presentation contrasts with those who have a jejunostomy, who present immediately after surgery with fluid and electrolyte imbalance due to the high output from the jejunostomy. In patients with a retained colon there are two important questions to consider. Does the colon salvage macronutrients (especially carbohydrate) and what is the effect of fat in the diet?

Does the colon salvage macronutrients? It has been estimated that the normal human colon can absorb up to 2·26 MJ (540 kcal)/d by bacterial fermentation of carbohydrate to short-chain fatty acids (Ruppin *et al.* 1980). Messing *et al.* (1991) performed balance studies for 3 d on ten patients with less than 2·0 m jejunum (one had no residual colon) and found that a mean of 79% of carbohydrate, 61% of protein and 53% of fat were absorbed. This suggested that, in these patients, the colon could salvage carbohydrate, probably by fermentation. There is further confirmation of this from a study by Nordgaard *et al.* (1994) who gave a diet of 10·5 MJ (2500 kcal)/d to fourteen patients with a short bowel of whom eight had a retained colon. Three diets, all of which contained 20% energy as protein but different proportions of fat and carbohydrate, were given

Table 3. *Percentage energy absorbed by short-bowel patients with or without a colon, consuming diets of different composition for 4 d (from Nordgaard* et al. *1994)*

Composition of diet		Percentage energy absorption	
Carbohydrate (% energy)	Fat (% energy)	Short bowel with colon (*n* 8)	Short bowel no colon (*n* 6)
60	20	69	55
40	40	61	52
20	60	49	48

each for 4 d (Table 3). The results showed that as more carbohydrate was given to those with a retained colon more was absorbed and little was detected in the stool.

While it would appear that giving a diet high in carbohydrate would be beneficial to patients with a retained colon, this can cause D-lactic acidosis in rare cases (Editorial, 1990). Usually the lactic acid produced by man is the L(+) isomer. Abnormal bacterial colonization of the colon can result in a metabolic acidosis due to formation and absorption of the D(−) isomer which cannot be metabolized. The resulting D(−) lactic acidosis may cause a syndrome of ataxia, blurred vision, ophthalmoplegia and nystagmus. This syndrome can be induced by an oral carbohydrate load (especially mono- and oligosaccharides) and is probably worse if thiamine deficiency coexists. Treatment is with broad-spectrum antibiotics or giving a diet high in polysaccharides but low in mono- and oligosaccharides (Mayne *et al.* 1990).

The effect of fat in the diet. Unabsorbed long-chain fatty acids derived from dietary triacylglycerols cause problems in the colon. They make diarrhoea worse by reducing water and Na absorption (Ammon & Phillips, 1973) and increasing the colonic transit rate (Spiller *et al.* 1986). They may reduce the absorption of nutrients by inhibiting bacterial metabolism and may be bactericidal (Knapp & Melly, 1986; Thompson *et al.* 1990). They increase the stool losses of Ca and Mg (Booth, 1961), and they increase oxalate absorption. In classical studies Booth (1961) showed that as more lipid was given so more was absorbed and the percentage absorbed remained constant. This is similar to the finding of Nordgaard *et al.* (1994).

Thus patients with a short small intestine anastomosed to the colon need a large total energy intake with a diet high in carbo- hydrate (polysaccharides), but relatively low in lipid and oxalate. Parenteral nutrition is only rarely needed, but should be considered if less than 0·5 m jejunum remains.

Patients with a jejunostomy

Those patients who need parenteral nutrition absorbed less than 35% of their oral energy intake; those maintained on oral supplements absorb 50–60% of their dietary energy intake (Nightingale *et al.* 1990). Thus, it appears that a reduction of absorptive capacity by two-thirds necessitates bypassing the gut with parenteral nutrients to supplement oral intake. A reduction in absorptive capacity by up to half means that a person has to eat twice as much as normal to absorb adequate energy. Most patients are able to achieve this by simply eating more food. One way of increasing the energy intake is to give a nocturnal nasogastric tube feed to utilize the shortened gut throughout the 24 h.

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Are small molecules absorbed better than large molecules? McIntyre *et al.* (1986) performed balance studies on seven patients with less than 1·5 m jejunum ending as a jejunostomy. They compared a diet of small peptides, oligosaccharides and medium-chain triacylglycerols, with one of whole protein, polysaccharides and long-chain triacylglycerols. The two diets were of the same osmolality and total energy content. Percentage absorption of N, energy and fat were equal, as were stomal losses of Mg and Ca.

The effect of fat in the diet. In another study, McIntyre *et al.* (1986) showed that as fat in the diet was increased the proportion absorbed remained constant. Increased dietary fat and, thus, raised fat excretion did not affect the stomal output, did not increase Mg and Ca losses, and did not make the output offensive, so this diet was socially acceptable. Nordgaard *et al.* (1994) showed that the proportions of lipid and carbohydrate absorbed by patients with a jejunostomy were similar, unlike patients with a colon in whom there is preferential carbohydrate absorption (Table 3).

Patients with a jejunostomy, like those with a colon, need a large total energy intake; a polymeric, iso-osmolar high-fat diet with added salt can be recommended.

RENAL STONES

In our studies renal stones caused symptoms in nine of thirty-eight (24%) patients with a short bowel and residual colon but in none of the forty-six patients with a jejunostomy and no colon (Nightingale *et al.* 1992*a*). The stones were diagnosed at a median time of 22 (range 2–67) months after the resection; analysis of the stones from three patients showed them to consist of calcium oxalate.

It has been shown that after an ileal resection there is increased colonic absorption of dietary oxalate (Dobbins & Binder, 1977). Two mechanisms may explain this. First, Ca and oxalate usually form an insoluble complex in the colon which is passed in the stool. If free fatty acids are present in the colon they preferentially bind the Ca, so the oxalate becomes soluble and, thus, can be absorbed giving rise to enteric hyperoxaluria (Earnest *et al.* 1974). Second, unabsorbed bile salts in the colon increase the colonic permeability to oxalate (Dobbins & Binder, 1976).

Treatments to prevent renal stones rely on a low-oxalate (Chadwick *et al.* 1973), fat-reduced diet (Andersson & Jagenburg, 1974). Oral Ca supplements (Barilla *et al.* 1978), Ca-containing organic marine hydrocolloid (Lindsjo *et al.* 1989) and cholestyramine, which binds bile salts (Smith *et al.* 1972) may also be used.

GALLSTONES

The prevalence of gallstones in our patients was very high, though most were asymptomatic, occurring in 43% of those with a jejunostomy and 44% of those with the small bowel anastomosed to the colon (Table 4). The stones were more common in men. Analysis of stones from such patients shows that they are not pure cholesterol stones, as might be expected because of the enteric loss of bile salts, but of mixed composition including bile pigment. Such stones probably result from gall-bladder stasis with the formation of biliary sludge and then calcium bilirubinate stones. This explanation would explain the male predominance, as calcium bilirubinate crystals occur more commonly in men with biliary sludge than women (Lee *et al.* 1992) and would also explain the

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Table 4. *Prevalence of gallstones amongst eighty-four short-bowel patients*

	Jejunum–colon (*n* 38)	Jejunostomy (*n* 46)
Cholecystectomy		
Pre-resection	3	4
Post-resection	2	1
Ultrasound		
Stones	10	12
No stones	19	23
Not followed*	4	6
Prevalence (%)	44	43

* Not included in the prevalence calculation.

observation that gallstones after an ileal resection are often calcified (Heaton & Read, 1969). Experimentally an ileal resection in prairie dogs causes the formation of calcium bilirubinate crystals and pigment stones (Pitt *et al.* 1984).

Cholecystokinin injections to prevent gall-bladder stasis (Doty *et al.* 1985) or prophylactic cholecystectomy are not currently advised as most of these gallstones are asymptomatic.

LONG-TERM OUTCOME

Nutritional status

Most short-bowel patients with and without a colon are well nourished. An assessment of seventy-one patients at a median of 5 years after their last bowel resection showed that only thirteen (18%) were malnourished, with a body mass index of less than 19 kg/m^2. There was no significant difference between the body mass indices of those with and those without a retained colon.

Social problems

Patients with a jejunostomy and no colon have to cope with a stoma and a high stomal output, and they have a high dependency on treatment. If they omit 1 d of therapy they are likely to become dehydrated and Na-depleted. Patients with a short bowel and a retained colon may have severe diarrhoea which can be fatty, malodorous and unpleasant. They are, however, less dependent on treatment which can often be stopped for several days with no ill effect.

Rehabilitation

Despite the disabilities, most patients were well rehabilitated. Among our seventy-one patients, twenty-five of forty patients with a jejunostomy were at full-time work or looking after home and family unaided, compared with twenty-five of thirty-one of those patients with their colon; twelve jejunostomy patients were at part-time work or looking

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after home and family with help, compared with three patients with a colon. Only two jejunostomy patients and three patients with a retained colon were unable to work or help at home but they coped with their own treatment and went out occasionally. One patient with a jejunostomy and a hemiplegia was housebound and needed help with treatment (Nightingale, 1993).

POSSIBLE FUTURE THERAPIES

Diet

Special nutrients to improve absorption have not yet given encouraging results but a greater physiological understanding may lead to an advance.

Drugs

Drug therapies in the future are likely to be directed at improving absorption and reducing the stomal output in patients with a jejunostomy. Absorption may be improved by slowing the rate of transit, stomal output can also be decreased by reducing secretions but not enough to impair digestion. Possible treatments of this type include an oral somatostatin analogue and peptide YY agonists.

Growth factors

Marked ileal adaptation after jejunal (with or without colon) resection occurs in animals. In patients with a retained colon the evidence for structural (Porus, 1965; Weinstein *et al.* 1969) and functional (Dowling & Booth, 1966) jejunal adaptation is scarce. Jejunal adaptation in patients with a jejunostomy may not occur (O'Keefe *et al.* 1992).

Therapy using growth factors may try to maximize intestinal adaptation; for example, epidermal growth factor has been used in children to treat microvillus atrophy (Walker-Smith *et al.* 1985). Aminoguanidine which inhibits diamine oxidase (*EC* 1.4.3.6), so reducing polyamine breakdown, has shown some potential in animals (Rokkas *et al.* 1990).

Intestinal transplantation

Small-intestine transplantation cannot currently be recommended for most patients as it is a life-endangering procedure and most patients with a short bowel have a good quality of life. It has not been determined whether Crohn's disease recurs after a transplant. In future, advances are likely to occur that make small-bowel transplantation a good option for some patients.

CONCLUSIONS

Two types of patient with a short bowel can be distinguished, those with a jejunostomy and those with jejunum in continuity with a functioning colon. There are some important differences between the problems experienced by each group (Table 5). Jejunostomy patients have major problems with water, Na and Mg balance. Both types of patient have problems with macronutrient absorption, though this probably occurs less in those with a

Table 5. *Summary of the problems of the short-bowel syndrome*

	Jejunum–colon	Jejunostomy
Water and Na loss, Mg deficiency	Rare	Common
Nutrient malabsorption	Common	Common
Renal stones	24%	Rare
Gallstones	44%	43%
Social	Common	Very common

colon as some carbohydrate is salvaged. Renal stones occur in those with a colon (24%), gallstones are common in both groups (43% jejunostomy, 44% jejunum–colon) and social problems occur in both groups. With modern therapy, the nutritional status and rehabilitation of most patients with less than 2·0 m small bowel remaining is good.

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