Effect of different drinks on fluid and electrolyte losses from a jejunostomy[1]

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Summary: The effectiveness of 5 different solutions on the absorption of fluid and electrolytes was tested in 7 patients with a proximal intestinal stoma and large fluid losses, all of whom previously needed intravenous infusions to maintain balance. In 4 patients it proved possible to replace the intravenous infusions with an enteral supplement. The WHO glucose/electrolyte solution without added potassium (NaCl 3.5 g, $NaHCO_3$ 2.5 g, glucose 20 g/l) gave satisfactory results, though was slightly less effective than a solution containing more sodium in which maltose was substituted for glucose. Neither sucrose nor an oligosaccharide (Caloreen) gave an advantage over glucose in the formulations used. In 3 patients losses were so great, and absorption of sodium from oral solutions so small, that intravenous supplements had to be continued. These 3 patients could be distinguished from the other 4 by the fact that more than 250 ml emerged from the stoma during the 3 hours after a drink of 500 ml of glucose/electrolyte solution. In all patients a drink of water or tea led to a loss of sodium from the stoma; water should be restricted in such patients and replaced by a glucose/electrolyte solution.

Introduction

Colectomy with extensive intestinal resection, with or without disease in the residual bowel, can result in such diarrhoea that patients can only be maintained in fluid and electrolyte balance with intravenous supplements. Several patients have been described where the institution of water restriction and various oral glucose/oligosaccharide/electrolyte solutions enabled intravenous fluids to be discontinued (Griffin *et al.* 1980, 1982, Ward *et al.* 1981). The WHO cholera formula without potassium has been used in this way at St Mark's Hospital for some years. The object of the present study was to determine whether modification of its formula would improve the absorption of such a solution in this type of patient.

Methods

The subjects for the study were 6 women and 1 man (L) with extensive small intestinal resections and a terminal stoma (Table 1) who needed intravenous supplementation to maintain fluid and electrolyte balance. Intravenous supplements were continued during the test periods in 6 patients. All resections were for Crohn's disease, except in G who had developed radiation enteritis associated with treatment for carcinoma of the cervix. The subjects were studied on several occasions after an overnight fast. The following morning they were asked to drink a 500 ml bolus of test solution over 5 to 10 minutes and collect all jejunostomy effluent over the next 3 hours (6 hours for F). The composition of the test solutions is shown in Table 2. All solutions contained electrolytes and sugars in various proportions but designed to maintain isotonicity with blood (around 280 mosmol/l). The simplest solution (solution 1) was saline/glucose in which sodium chloride and glucose were present in approximately equimolar proportions. The second solution was designed to test the effect of replacing some of the

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Table 1. Clinical details of patients studied

Subject	Age (yr)	Small bowel remaining (cm)	Time since last resection (months)	Subsequent course
F	26	150	48	Repeated admissions with dehydration and subacute obstruction exacerbated by unsuitable diet. Fluid balance can be maintained with glucose/electrolyte mix
G	50	95	5	Transferred to oral glucose/electrolyte mix. Well at home on 21 by day and 21 by nasogastric tube at night
W	66	150	24	Transferred to oral glucose/electrolyte mix and discharged well
L	37	130	1	Transferred to oral glucose/electrolyte mix. Well at home on oral fluid restriction and 21 electrolyte mixture daily
P	45	60	3	Requires continuing i.v. fluids and feeding. Well at home on daily oral intake of 2.5l and i.v. intake of 5l
S	44	100	2	Requires continuing i.v. fluid and nutrition. Well at home on daily oral intake of 1.5l and i.v. intake 3l
B	17	150●	12	Required continuing i.v. fluids and nutrition. Died from severe ulcerating gastric and small bowel Crohn's disease

●Gastric resection and gastroduodenostomy

Table 2. Composition of electrolyte solutions tested in 46 of 56 studies

Concentration (mmol/l)	1 Saline Glucose	2 Saline Bicarb Glucose	3 Saline Bicarb Maltose	4 Saline Bicarb Sucrose	5 Electrolyte Glucose Caloreen
NaCl	90	60	72.5	72.5	76
$NaHCO_3$		30	42.5	42.5	9
KCl					12
Calcium gluconate					2.5
Glucose	110(20 g)	110(20 g)			110(20 g)
Maltose			55(20 g)		
Sucrose				55(20 g)	
Glucose oligosaccharide (Caloreen)					17.5(16 g)
Osmolality (mosmol/l)	279	284	269	275	294

In 10 other studies small changes were made as shown below and in Figures 1 and 2:
NaCl 76 mmol/l in solution 1 for W, 85 mmol/l for B
NaCl 42.5 mmol/l and $NaHCO_3$ 42.5 mmol/l in solution 2 for W and B, and one study on F
NaCl 115 mmol/l and $NaHCO_3$ 0 mmol/l in solution 3 for one study on G

chloride with bicarbonate. By replacing glucose with the disaccharide maltose, it is possible to give the same amount of glucose at lower osmolality, and thus increase the proportion of sodium in the solution (solution 3). The relative effects of the more readily obtainable sucrose (solution 4) and a mixture containing an oligosaccharide (solution 5) were also compared with the other drinks. Water and hospital tea, sweetened as requested by the subjects, were also tested. Subjects W and B took 20 polyethylene pellets with their solutions, while those tested by the other subjects contained polyethylene glycol (PEG 4000 2 g/l) as a nonabsorbable marker. The jejunostomy collections were weighed and stored at −20°C prior to analysis for sodium and potassium by flame photometry, chloride by coulometric titration and PEG by

Table 3. Water and electrolyte absorption and secretion in patients who were able to stop intravenous therapy (Group A)

	1 Saline Glucose	2 Saline Bicarb Glucose	3 Saline Bicarb Maltose	4 Saline Bicarb Sucrose	5 Electrolyte Glucose Caloreen	Water	Tea
Sodium: mmol	24.8	27.8	39.2▲	21.4	15.8■	−17.9●■	−29.5●■
(%)	(57.5)	(63.3)	(68.1)	(37.2)	(41.7)		
Potassium: mmol	−1.5	−1.4	−0.8	−1.1	3.5	−1.3	1.3
(%)					(58.9)		(43.3)
Chloride: mmol	25.2	13.7■	24.8	3.1	24.0	−14.5●	−20.8●■
(%)	(58.5)	(52.4)■	(63.2)	(8.5)	(61.5)		
Water: ml	316	343	348	173	273	312	223
(%)	(63.2)	(68.6)	(69.6)	(34.6)	(54.6)	(62.3)	(44.7)

●$P<0.01$: Sodium mmol Water < 1, 2, 3 : Tea < 1, 2, 5
Chloride mmol Water < 1, 2, 3, 5 : Tea < 1, 2, 5
■$P<0.05$: Sodium mmol 5 < 1 : Water < 5 : Tea < 3
Chloride mmol 2 < 1, 3 : Tea < 3
Chloride (%) 2 < 3
▲$P<0.02$: Sodium mmol 3 > 1

Table 4. Water and electrolyte absorption and secretion in patients who continued to require intravenous therapy (Group B)

	1 Saline Glucose	2 Saline Bicarb Glucose	3 Saline Bicarb Maltose	4● Saline Bicarb Sucrose	5 Electrolyte Glucose Caloreen	Water	Tea
Sodium: mmol	5.8	4.2	9.7	—	−2.9	−36.1	−36.5
(%)	(13.2)	(9.5)	(16.8)				
Potassium: mmol	−1.2	−1.6	−1.5	—	2.3	−1.4	0.3
(%)					(37.5)		(10.0)
Chloride: mmol	6.6	−9.3	−12.1	—	−7.8	−31.0	−44.0
(%)	(15.1)						
Water: ml	138.5	71.0	16.0	—	12.0	−7.0	−106.0
(%)	(27.7)	(14.2)	(3.1)		(2.4)		

●Solution not tested

the turbidometric method of Hyden (1956), modified to improve its stability and sensitivity (Malawer & Powell 1967, Boulter & McMichael 1970).

Results

The subjects have been divided into two groups depending on whether they could subsequently be maintained in fluid and electrolyte balance on oral fluids (Group A, subjects F, G, W, L) or continued to require intravenous supplementation (Group B, subjects P, S, B). The results of the jejunostomy collections are summarized in Tables 3 and 4 and illustrated in Figures 1 and 2. They show the net absorption or secretion of sodium, potassium, chloride and water from each test solution over the collection period in 56 studies where 80% or more of the marker was recovered (81% of the studies). Results have been compared by the paired

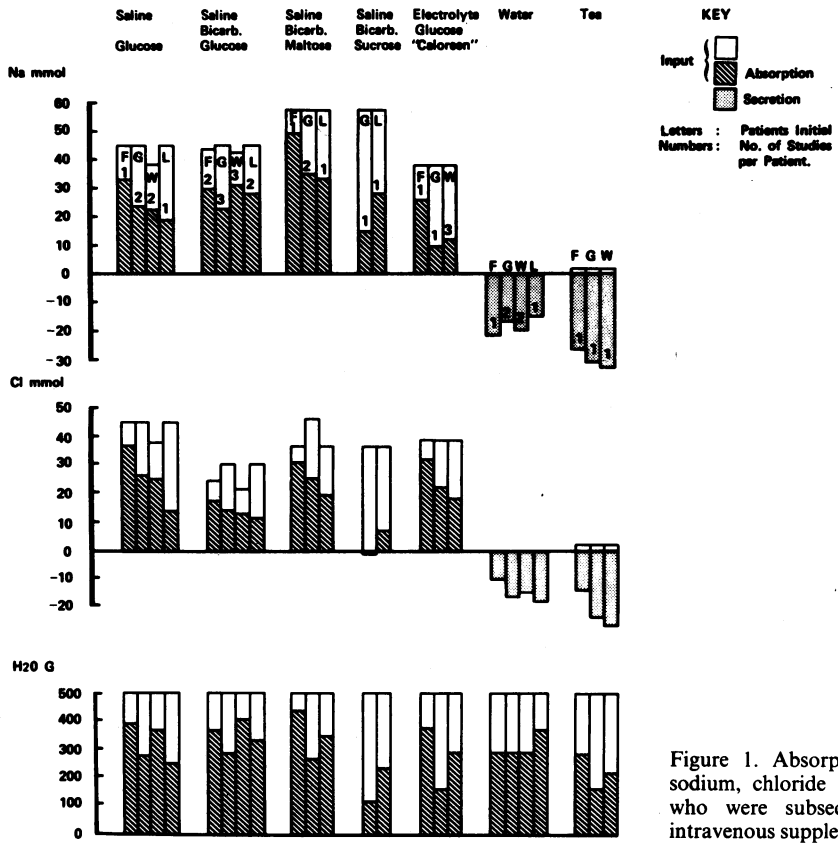

Figure 1. Absorption and secretion of sodium, chloride and water by patients who were subsequently able to stop intravenous supplements (Group A)

Student's *t* test where subject numbers permit. The statistical evaluation was confined to Group A, as Group B subjects absorbed insufficient of any solution to be clinically useful and continued to require parenteral support.

Water, sodium, chloride and bicarbonate
Group A
With or without bicarbonate: Mean absorption of sodium was 24.8 mmol (57.7%) from the 500 ml of saline/glucose solution, and 27.8 mmol (63.3%) from the solution where 30 mmol chloride had been substituted by bicarbonate (difference not significant). Chloride absorption was less from the bicarbonate-containing solution but water absorption was similar (68.6% versus 63.2%).

Glucose versus maltose: Substitution of an equal weight of maltose for glucose in the solution, with appropriate increase in sodium concentration to preserve isotonicity, resulted in a significant increase in sodium absorption to a mean of 39.3 mmol (68.1%) over the saline/glucose solution ($P<0.02$). Chloride absorption was greater with the higher chloride concentration, but water absorption was similar (69.6%).

Maltose versus sucrose: Substitution of sucrose for maltose in the two subjects tested resulted in much less sodium absorption (21.4 mmol, 37.2%). There was little chloride absorption and water absorption was also less (34.6%).

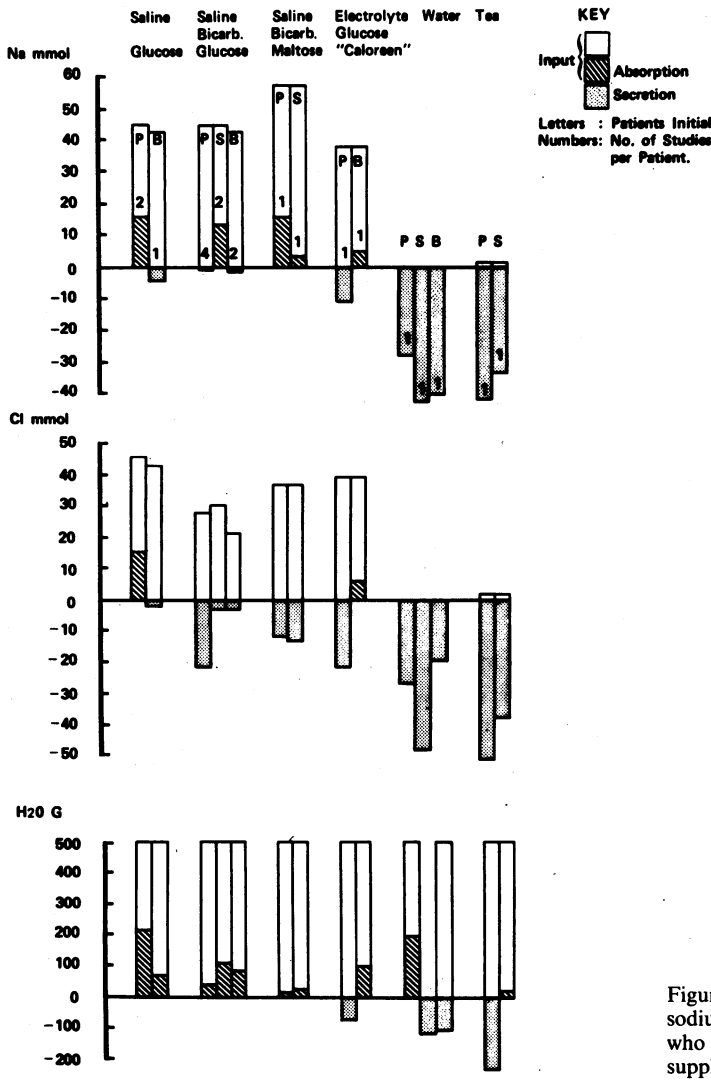

Figure 2. Absorption and secretion of sodium, chloride and water by patients who continued to need intravenous fluid supplements (Group B)

Addition of oligosaccharides: Addition of glucose oligosaccharide (Caloreen) in the formulation advocated by Griffin *et al.* (1982) resulted in absorption of only 15.8 mmol of sodium (41.7%) from 500 ml of solution, which was significantly less than from the saline glucose solution ($P<0.05$). Chloride absorption exceeded sodium absorption. Mean water absorption was 54.6%.

Water and tea: Ingestion of 500 ml of water or tea resulted in absorption of 62.3% of the water and 44.7% of the water in the tea, but a marked net loss of sodium and chloride in all subjects.

Group B

Group B subjects failed to absorb any of the solutions sufficiently well to be clinically useful, results ranging from a small net secretion to 17% absorption of sodium and 28% of water from the 500 ml ingested. Water and tea tended to result in a small net loss of water, but a large loss of sodium and chloride was produced by ingestion of 500 ml of both fluids in all subjects.

Potassium

In both groups of subjects, there was a small secretion of potassium with all the solutions except those containing the ion (solution 5, and tea, K = 6 mmol/l), where there was a small net potassium absorption.

Discussion

As can be seen from the length and type of residual small bowel, the subjects who took part in this study had jejunostomies rather than ileostomies and such patients present a major and continuing problem in the maintenance of fluid and electrolyte balance. Their numbers are small but patients with ileostomies and less extensive small intestinal resections may suffer similar but less severe or intermittent problems, which can be treated along the same lines.

Physiological principles can be used to devise an electrolyte solution which should be well absorbed by the residual proximal small intestine in these patients, but such a fluid – if it is to be clinically acceptable in the long term – must also be palatable, easy to prepare and preferably cheap.

Potassium was not included in most of the fluids tested as the subjects did not have clinical evidence of potassium deficiency, probably because the potassium concentration of intestinal fluid is low and urine loss not great when normal sodium balance is maintained. Potassium salts make the solution less palatable and add to the osmolality.

Human intubation studies have shown that fluids entering the jejunum become isotonic with plasma and acquire a similar sodium concentration by equilibration with intestinal secretions (Fordtran & Locklear 1966, Phillips & Summerskill 1967), suggesting that the optimum sodium concentration for an electrolyte solution should be either close to that of plasma or greater, while preserving isotonicity. Ingestion of fluids with low sodium concentrations, which are not completely absorbed, would lead to a net loss of sodium from a jejunostomy. This has been very clearly demonstrated in the present study where all subjects were in negative sodium balance after drinking 500 ml of water or tea. This supports the suggestion of Griffin *et al.* (1980, 1982) that such fluids are detrimental to these patients and should be restricted.

Solutions of sodium chloride are poorly absorbed in the jejunum (Fordtran *et al.* 1968, Sladen & Dawson 1969), but there appears to be a transport mechanism for sodium bicarbonate absorption (Phillips & Summerskill 1967, Fordtran *et al.* 1968), presumably primarily to absorb the bicarbonate load secreted by the pancreas. Jejunal bicarbonate absorption is greatest at concentrations above that of plasma but can occur against a concentration gradient down to 5 mmol/l (Phillips & Summerskill 1967), probably by sodium/hydrogen exchange (Turnberg *et al.* 1970*b*). In the ileum, by contrast, luminal fluid equilibrates at a bicarbonate concentration of around 40 mmol/l (Phillips & Summerskill 1967), with probably exchange of chloride for bicarbonate (Bucher *et al.* 1944, Turnberg *et al.* 1970*a*). These findings would suggest that including bicarbonate in an electrolyte solution in a concentration of 30–40 mmol/l should be beneficial. However, from his perfusion experiments with different anions, Fordtran (1975) concluded that, for maximal absorption, the only anion in an oral glucose electrolyte solution should be chloride.

The ability of glucose to stimulate sodium, chloride and water absorption in the human jejunum, first demonstrated by Schedl & Clifton (1963), was soon applied to the treatment of cholera (Hirschorn *et al.* 1968, Pierce *et al.* 1968, 1969). Perfusion of a 30 cm segment of jejunum suggested optimal sodium absorption with a glucose concentration of 56–85 mmol/l (Sladen & Dawson 1969), while in the treatment of cholera a glucose concentration of 160 mmol/l was superior to 40 mmol/l (Pierce *et al.* 1968). Further studies of infective secretory diarrhoeas led Nalin *et al.* (1978) to suggest that a 2% glucose concentration (110 mmol/l) is optimal for promoting salt and water absorption; the standard WHO electrolyte solution contains this, with a sodium concentration of 90 mmol/l. Neither situation is directly applicable to our patients, but the WHO formula concentrations of glucose and sodium seemed a reasonable compromise within the bounds of isotonicity (solutions 1, 2).

Other jejunal intubation studies have shown that the glucose disaccharide, maltose, is absorbed as well as (McMichael *et al.* 1967) or possibly better (Jones *et al.* 1980) than glucose itself. By substituting glucose with an equal weight of maltose, the sodium concentration of the electrolyte solution could be raised to 115 mmol/l while preserving isotonicity (solution 3). For comparison, we tested the cheaper disaccharide sucrose (glucose/fructose), which has been extensively and effectively used in the treatment of infective secretory diarrhoeas (Nalin *et al.* 1978, Palmer *et al.* 1977), although more unabsorbed sugar may be present in the diarrhoeal stools when sucrose is substituted for glucose (Palmer *et al.* 1977, Suprapto *et al.* 1975) and fructose has been shown to promote less sodium absorption than glucose in jejunal intubation studies (Fordtran 1975). A weight-for-weight substitution of sucrose for maltose enabled the sodium concentration in the electrolyte solution to remain at 115 mmol/l (solution 4).

Substitution of maltose for glucose (solution 3) resulted in similar water absorption, but more sodium absorption, probably associated with the higher sodium concentration in the solution. The increase was insufficient to be of clinical significance and would not justify the considerable cost of using maltose in an oral electrolyte solution. The poor absorption of the sucrose-containing solution (solution 4), with very little chloride absorption, suggests that most sodium absorption was taking place in association with bicarbonate and that sucrose is an unsatisfactory substitute for glucose in this situation.

Larger glucose polymers such as rice powder have been successfully used in treating cholera (Molla *et al.* 1982), while jejunal intubation studies have shown glucose oligosaccharides to be well absorbed and effective promoters of sodium absorption (Jones *et al.* 1980). In their study of one jejunostomist, Griffin *et al.* (1982) found that intestinal perfusion of a solution containing both glucose and glucose polymer (Caloreen) resulted in more sodium and water absorption than occurred from those containing either alone, although the glucose concentrations in the two glucose/electrolyte solutions tested were unlikely to be ideal (35 and 210 mmol/l). The complicated solution they advocated contained 105 mmol/l of free glucose with added Caloreen, necessitating reduction of the sodium concentration to 76 mmol/l to preserve isotonicity. This (solution 5) was tested to provide a direct comparison with the much simpler glucose/electrolyte/bicarbonate solutions.

The solution containing glucose polymer (Caloreen) resulted in significantly less sodium absorption and a tendency to less water absorption than the simple glucose/electrolyte solution, perhaps because of the lower sodium concentration and the osmotic load produced by rapid hydrolysis of glucose polymer known to be produced by pancreatic amylase (Fogel & Gray 1973). In their demonstrations of the efficacy of glucose polymer in promoting sodium and water absorption, the effect of amylase was eliminated by Jones *et al.* (1980) in their jejunal intubation study with a proximal occlusive balloon, and minimized by Griffin *et al.* (1982) by their administration of the 750 ml of test solution to their patients by slow intestinal infusion over 90 minutes.

Our studies, which have attempted to approximate to the clinical situation, suggest that the simple WHO formula without potassium chloride (NaCl 3.5 g, $NaHCO_3$ 2.5 g, glucose 20 g/l) is a reasonable compromise, on theoretical and experimental grounds, in the search for an ideal replacement fluid for patients with a high output intestinal stoma. In practice, the solution is relatively palatable, cheap and simple for patients to prepare at home from household ingredients with a set of measuring spoons (available from Teaching Aids at Low Cost, Institute of Child Health, 30 Guildford Street, London WC1N 1EH).

In the most severely affected patients, however, we found no oral electrolyte solution to be usefully absorbed. Although these patients had no radiological evidence of active small intestinal disease, it is possible that there was some dysfunction at cellular level resulting in a secretory disturbance, with the consequent inability to absorb sodium and water. Review of the results shows that these patients could be identified when ingestion of 500 ml of glucose/electrolyte solution after an overnight fast resulted in a 3-hour stomal output in excess of 250 ml. This simple test can thus provide evidence of whether a patient is likely to be stabilized with an oral glucose electrolyte solution or will need continued intravenous supplements.

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