Food-based solutions are a viable alternative to glucose-electrolyte solutions for oral hydration in acute diarrhoea—studies in a rat model of secretory diarrhoea

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Abstract
A survey of acute diarrhoea and its treatment, in 3 groups of villages in south India, revealed that use of the World Health Organization oral rehydration solution (WHO-ORS) was poor or virtually non-existent and that several liquid foods were given to children during acute diarrhoea. The effects of the most commonly used, boiled and cooled supernatants of these liquid foods (rice (Oryza sativa)-water, ragi (Eleusine coracana)-water, arrowroot (Maranta arundinacea)-water), and tender coconut-water, and of the bicarbonate- and citrate-WHO-ORS on intestinal water transport were evaluated using a rat model of secretory diarrhoea. All solutions either decreased cholera toxin-induced net water secretion (arrowroot-water) or reversed it to net absorption. Ragi-water produced maximum net water absorption, significantly greater than the WHO oral rehydration solutions. WHO-ORS utilization is poor in some developing countries, and locally used food-based solutions could be used for maintaining hydration or correcting the dehydration due to acute diarrhoea once their effectiveness has been proved by clinical trials.

Introduction
Oral rehydration therapy has resulted in a dramatic decrease in mortality related to acute diarrhoea in all age groups (RAHMAN et al., 1979; LASCH et al., 1983). This observation prompted the World Health Organization (WHO) and the governments of many developing countries to increase availability to rural communities of prepacked powders to prepare oral rehydration solutions (ORS) (WHO, 1985). However, in populations where literacy rates are low and superstitions and misinformation about diarrhoeal disease widespread, these powders may not be adequately used despite easy availability (WALKER-SMITH, 1988).

In many southern Indian homes (both rural and urban) several food-based, home-prepared liquids are traditionally used during bouts of acute diarrhoea in the belief that they reduce the severity and duration of diarrhoea. Clinical trials have shown that food-based solutions are effective in maintaining hydration in, or correcting the dehydration due to, acute diarrhoea (PATRA et al., 1982; MEHTA & SUBRAMANIAM, 1986; BHAN et al., 1987). These liquids also have the advantage of providing nutrients. However, in a large country like India where there is tremendous regional diversity in food habits, it is important to identify liquid foods which are commonly used in a particular part of the country before advocating their use in the treatment of acute diarrhoea.

We therefore carried out a limited survey in a rural part of south India primarily to determine which food-based, home-prepared solutions are commonly used during acute diarrhoea. The effect of the 4 most commonly used liquid foods on intestinal water transport was then studied in a previously described rat model of secretory diarrhoea to provide a basis for considering the use of these solutions in clinical trials.

Subjects, Materials and Methods
Three groups of villages in North Arcot district of Tamil Nadu, India, were surveyed. These villages were selected because they were marked differences in their health education inputs. Most families in these villages were marginal farmers. Group A was relatively inaccessible and had no formal health teaching programmes. Group B had government-sponsored health teaching programmes which included information on oral rehydration therapy (ORT). Group C had similar government-sponsored health programmes and also intensive health teaching inputs by the Community Health department of the Institution. In A and C, WHO-ORS powder packets were available with resident village health workers whose job was actively to advocate their use in villagers.

In each group, the mothers of the first 3 households with at least one child under 5 years of age were asked the appropriate questions in the vernacular to determine (i) whether liquid foods were used during episodes of acute diarrhoea and (ii) the mother’s awareness and use of the WHO-ORS, or breastfeeding of children during acute diarrhoea, knowledge of the causes of diarrhoea, and the kind of treatment preferred (e.g., indigenous treatment, hospital-based treatment, etc.). Households for survey were selected by systematically visiting one house on one side of the streets to determine the age of the youngest child.

During the survey it became obvious that several food-based, home-prepared solutions, including coconut-water, were used during acute diarrhoea in the belief that they facilitated recovery. Several mothers were asked to prepare 3 of the most commonly used home-prepared, food-based solutions. These were rice (Oryza sativa)-water, ragi (Eleusine coracana)-water, and arrowroot (Maranta arundinacea)-water. Although the ingredients used to prepare the solutions were the same, different mothers used different

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amounts, so that some prepared a thick gruel while others added plenty of water and used only the resistant supernatant. The individual constituents were accurately weighed, the volume of water used was precisely measured and, where applicable, the time for which the suspension was boiled was noted.

**Perfusion studies in vivo**

In the laboratory, each of 3 food-based solutions was prepared as described by one of the mothers who used only the supernatant of dialysis and the rein feeds. These solutions were chosen because evaluation of their effects on intestinal water transport was possible in a perfusion system while that of gruels was not. The suspension was allowed to cool and the supernatant stirred through a Whatman filter (no. 4) to remove particulate matter. The filtrate constituted the perfusate of the test solution, to which polyethylene glycol was added as a non-absorbable volume marker.

**Steady state** All tests were run in pairs for the entire small intestine of 2 adult Wistar rats (200-250 g), of either sex, was carried out as previously described except that the infusion tube was introduced through the stomach to the proximal duodenum and a ligature tied about the pylorus. Secretion was induced by incubating the intestine with 75 μg of purified cholecystokinin (Sigma Chemical Company) in 2 h (Rostock et al., 1987). The flow rate was 9.5 ml/min, and a 50 min equilibration period was followed by three 10 min collections. Initially, an isotonic sodium chloride solution perfusion confirmed a net secretory state. This was followed by the perfusion of one of the test solutions (Table 1). Thus, in any one rat only 2 solutions were perfused.

**Analysis of samples**

Sodium and potassium in the perfusates were estimated by flame photometry and total carbon dioxide in a Corging 965 CO₂ analyzer. [1-Cl]polyethylene glycol was measured by liquid scintillation in a LKB 1214 Rack Beta counter (Wallace Oy, Finland). Osmolarity was measured in a Wescor vapour pressure osmometer (Essex, St. Louis, Ill., USA).

**Statistical methods**

Data are presented as the mean ± standard error (SEM). Differences in water fluxes are considered significant if *P*<0.05 by the unpaired Student's *t*-test.

### Table 1. Composition of perfusion fluids

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Sodium</th>
<th>Potassium</th>
<th>Total CO₂</th>
<th>Glucose</th>
<th>Osmolarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice-water</td>
<td>108</td>
<td>4-5</td>
<td>0-3</td>
<td>0-08</td>
<td>212</td>
</tr>
<tr>
<td>Spin-water</td>
<td>88</td>
<td>8-8</td>
<td>2-0</td>
<td>0-08</td>
<td>180</td>
</tr>
<tr>
<td>Lacto-consume</td>
<td>90</td>
<td>50</td>
<td>1-7</td>
<td>0-9</td>
<td>316</td>
</tr>
<tr>
<td>Orange-water</td>
<td>90</td>
<td>20</td>
<td>0</td>
<td>111-0</td>
<td>290</td>
</tr>
</tbody>
</table>

**Concentrations in mmol litre⁻¹; osmolality in mosmol. All solutions contained polyethylene glycol (4000).**

**Table 2. Type and place of treatment preferred in the three groups of villages**

<table>
<thead>
<tr>
<th>Type/place of treatment</th>
<th>Village group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Hospital-based</td>
<td>10</td>
</tr>
<tr>
<td>Mother clinic</td>
<td>NA</td>
</tr>
<tr>
<td>General practitioner</td>
<td>2</td>
</tr>
<tr>
<td>Indigenous treatment</td>
<td>14</td>
</tr>
<tr>
<td>Health workers</td>
<td>3</td>
</tr>
<tr>
<td>Home remedies</td>
<td>60</td>
</tr>
<tr>
<td>No treatment</td>
<td>29</td>
</tr>
</tbody>
</table>

*More than one place of treatment was indicated by some mothers.*

**Results**

13% and 35% and 67% of mothers from villages A, B and C respectively were aware of the WHO-ORS but only 39% of mothers from group C alone said they would use it. 54% of mothers from C and 90% from A had no ideas about the cause of diarrhoea. Infectious agents were not considered an important cause of diarrhoea. Most mothers preferred treatment that was available at home (traditional remedies including liquid food or the fluid which could be delivered at home (health workers and mobile clinics). Hospital-based treatment was seldom sought (Table 2). Mothers in all 3 groups of villages continued to breast-feed their child during a diarrhoeal episode. Rice-water, ragi-water, arrowroot-water and tender coconut-water were the most commonly used liquid foods used during acute diarrhoea.

**Perfusion in vivo**

Net water secretion was reliably induced in all rats during isotonic sodium chloride perfusion following cholecystokinin incubation. Figure 1. Since the rates of net water secretion following the isotonic sodium chloride perfusions were statistically similar in each group, irrespective of the solution subsequently perfused, these data have been pooled and compared with the effects of the food-based solutions on net water transport (Figure 2).

All test solutions either decreased the degree of net water transport.
water secretion or reversed it to net absorption. Rapid water production maximized net water absorption, which was significantly greater than that achieved by the other solutions including the bicarbonate and the citrate-Who ORS. Tender coconut-water and the WHO oral rehydration solutions produced comparable rates of net water absorption (Figure).

Discussion

Despite extensive and vigorous campaigns to popularize the use of the WHO-ORS in developing countries, the present survey shows that the WHO-ORS is underutilized by some rural communities despite easy availability. The need for acceptable and effective alternatives to glucose-electrolyte solutions, both for maintaining hydration and for correcting dehydration in acute diarrhoea. Our survey showed that a variety of liquid foods is used during acute diarrhoea. These include several cereal-based preparations as well as tender coconut-water, which is readily available in this part of the country. Evaluate the effect of these food-based solutions on intestinal water transport is a logical step before embarking on clinical trials of their efficacy, especially because clinical trials are tedious to carry out and require large numbers of patients to derive meaningful data.

Rat intestinal perfusion in vivo provides an easy means of evaluating the effect of ORS on intestinal water transport (Rostov et al., 1987). It is possible to use rat intestinal perfusion because the effect of various substances on intestinal water transport in humans and rats is similar. For instance, isotonic sodium chloride produces little or no net water absorption, whereas sucrose, bicarbonate and acetate stimulate water absorption (Rostov et al., 1986, 1989). Glucose, bicarbonate and acetate stimulate net water absorption (Rostov et al., 1986, 1989). Clinical trials appear to reflect differences in osmolality of, or in the degree of sodium, bicarbonate and polysaccharide concentrations in these food-based solutions cannot be determined from the present study. The limitations of using a perfusion system in deriving the electrolyte concentrations for use in ORS need to be emphasized. Net sodium absorption in the perfusion system does not occur at sodium concentrations <110 mmol/l in animals (Rostov et al., 1987) or in humans (Spiller et al., 1987). Our clearly the optimum sodium concentration for use in ORS cannot be derived from intestinal perfusion studies. Similarly, net intestinal bicarbonate secretion occurs during perfusion with bicarbonate-free solutions (Rostov & Mathan, 1988). Clinical trials have, however, shown that bicarbonate-free solutions are as effective as bicarbonate-containing solutions in correcting the acidosis due to acute diarrhea (Khalil & Ahmed, 1984; Rostov, 1984; Pressly, 1988). Electrolyte concentrations for ORS need to be derived from published clinical trials and not from intestinal perfusion studies. Nevertheless, the present intestinal perfusion studies do suggest that the food-based solutions may be useful in maintaining the hydration and correcting dehydration in acute diarrhoea. In the rice-based solutions have already been extensively field-tested and found to be at least as effective as glucose-electrolyte solutions (Islam et al., 1988; Datta et al., 1988). Food-based solutions have the advantage that all the ingredients are available in the average village home, and mothers are familiar with the general method of their preparation. Solutions may also provide much needed nutrition. Since boiling is necessary, coconut-water except that sterility is guaranteed at least for the first few days. The major constraints in their use include: the need for cooking, incurring expenses in fuel, and the need to prepare these solutions frequently since they have a short stability of 8-12 h at high ambient temperatures and humidity (Ahmed & Molla, 1987).

Similar surveys need to be carried out in different regions of developing countries to identify local foods commonly used during episodes of diarrhoea. For an effective strategy, these local foods should be followed by intestinal perfusion studies to evaluate the effect of the liquid foods on intestinal water transport, so that only those food-based solutions are evaluated in clinical trials.
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References


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