Cereal based oral rehydration solutions

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SUMMARY A total of 257 boys (age range 4–55 months), who had acute diarrhoea with moderate to severe dehydration, were randomly assigned to treatment with either the World Health Organisation/United Nations Childrens Fund (WHO/Unicef) recommended oral rehydration solution or cereal based oral rehydration solution made either of maize, millet, sorghum, or rice. After the initial rehydration was achieved patients were offered traditional weaning foods. Treatment with oral rehydration solution continued until diarrhoea stopped. Accurate intake and output was maintained throughout the study period. Efficacy of the treatment was compared between the different treatment groups in terms of intake of the solution, stool output, duration of diarrhoea after admission, and weight gain after 24, 48, and 72 hours, and after resolution of diarrhoea. Results suggest that all the cereal based solutions were as effective as glucose based standard oral rehydration solution in the treatment of diarrhoea.

Diarrhoea and its interaction with malnutrition is an important health problem and a major cause of death in infants and young children throughout the non-industrialised world. In these countries children under 5 years may suffer two to five diarrhoeal episodes resulting in considerable illness for 20–30 days each year (R E Black, *et al*, unpublished observations).^{1–5} About one in every 10 children born in these countries dies from diarrhoea before reaching the age of 5 years.⁶ It is reported that in Africa, Asia, and Latin America alone 750–1000 million cases occur in children under 5 years annually.⁷

Effective and timely use of oral rehydration therapy has been shown to reduce the diarrhoea related mortality. One way of increasing the coverage of oral rehydration therapy is to ensure its availability and accessibility to every household in areas where diarrhoea is endemic. Knowledge of how to administer oral rehydration therapy at the earliest onset of diarrhoea is also vital. World Health Organisation/United Nations Children's Fund (WHO/Unicef) recommended oral rehydration solution has not been readily available in many countries because of cost and logistic problems in procurement and distribution. This is especially the case in many African countries. The use of packets of WHO/Unicef oral rehydration solution should

not be the only strategy for reducing diarrhoea related mortality. Therefore we compared the efficacy of oral rehydration solutions made from various low cost cereals readily available and accessible in most parts of Africa.

Patients and methods

The study was conducted in the paediatric ward of Kakamega Provincial General Hospital by staff experienced in conducting balance studies in children with diarrhoea. The research proposal was approved by the Scientific and Ethical Review Committees of the Kenya Medical Research Institute and the International Centre for Diarrhoeal Disease Research in Bangladesh (ICDDR, B). Boys aged 4–59 months with a history of three days or less of diarrhoea, judged to have moderate to severe degree of dehydration according to WHO criteria,⁸ and without a history of prior medication were selected for the study.

Patients with a history of bloody diarrhoea, severe malnutrition, or signs of any systemic illness (except malaria) were excluded from the study. Informed consent was obtained from the parents or legal guardians of the patients before being included in the study.

No antibiotics were prescribed. Those needing

antibiotics on clinical indications were taken out of the study. Once included in the study the patients were assigned to the different treatment groups after block randomisation.⁹

Packets of maize, millet, sorghum, and rice oral rehydration solutions were made up with 60 g of the respective cereals replacing the 20 g of glucose contained in the WHO/Unicef solution. The 60 g of cereal flour was boiled in 1100 ml of water for approximately 6–7 minutes and stirred continuously. The solution was brought to room temperature and electrolytes (sodium chloride 3.5 g, sodium bicarbonate 2.5 g, and potassium chloride 1.5 g) were added before administration.

TREATMENT

Children in the control group received standard WHO/Unicef oral rehydration solution (sodium chloride 3.5 g, trisodium citrate dihydrate 2.9 g, potassium chloride 1.5 g, glucose 20 g, and water 1.0 l) and those in the study groups received cereal based solutions. Patients with severe dehydration received initial rehydration standardised for duration and volume by kg body weight through the intravenous route by half strength Darrow's solution.¹⁰ After the initial rehydration of the severely dehydrated patients they were started on oral rehydration. Mothers were trained to feed oral rehydration solution to their children under supervision of research nurses and physicians. Accurate records (± 1 g and ± 1 ml) of intake of the solution,

water, or any other food or fluid during the study period were maintained. Stool, urine, and vomit were collected separately and measured at intervals of eight hours. Patients were allowed plain water on demand. After the initial rehydration (six to eight hours) breast feeding and the foods usually fed to the child were continued and offered freely.

Efficacy was measured by assessing the volume of intake of the solution, stool volume, weight gain, and duration of diarrhoea after admission.

LABORATORY TESTS

The stool and urine were examined microscopically on admission. Stool and rectal swabs were cultured for *Vibrio cholerae*, rotavirus, salmonella, shigella, and *Escherichia coli* groups. Routine investigations were carried out for clinical care of the patients and included total white blood count, haemoglobin concentration, haematocrit, malaria parasites, and concentrations of serum electrolytes. Body weight was measured on admission and after 24, 48, and 72 hours, and at discharge.

STATISTICAL ANALYSIS

Statistical analyses were based on analysis of variance. Basically comparisons were made between individual cereal based and the WHO/Unicef glucose oral rehydration solutions on the rate of purging, change in body weight, urine output, vomit, solution intake, and duration of diarrhoea after admission.

Table 1 Clinical features of children on different oral rehydration solutions on admission

Admission variables	Treatment groups				
	Maize (n=51)*	Sorghum (n=48)*	Rice (n=51)*	Millet (n=50)*	Glucose† (n=50)*
Mean (SD) age (months)	12 (6)	13 (9)	10 (5)	11 (6)	11 (8)
No (%) vomiting before admission	50 (98)	47 (98)	48 (94)	50 (100)	46 (92)
Mean (SD) diarrhoea duration before admission (hours)	64 (5.6)	63 (6.5)	70 (5.7)	67 (5.7)	69 (4.4)
Mean (SD) body weight at admission (kg)	8 (1)	8 (2)	8 (2)	8 (2)	8 (2)
No (%) with moderate dehydration	48 (94)	43 (90)	46 (90)	39 (78)	41 (82)
No (%) with severe dehydration	3 (6)	5 (10)	5 (10)	11 (22)	9 (18)
Mean (SD) diarrhoea duration after admission (hours)	45 (21)	50 (20)	42 (10)	51 (11)	46 (9)
No (%) treatment failures	1 (2)	3 (6)	1 (2)	1 (2)	1 (2)

*Denotes successfully rehydrated cases only.

†WHO/Unicef recommended solution.

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Table 2 Fluid balance at the end of 24 hours treatment. Results are mean (SD)

Type of oral rehydration solution	Intake in ml/kg body weight			Output in ml/kg body weight			
	Oral rehydration solution	Plain water	Total intake	Stool	Urine	Vomit	Total output
Maize	201 (29)	37 (11)	241 (33)	83 (22)	66 (15)	28 (8)‡	178 (21)
Sorghum	177 (24)†	48 (16)	229 (29)	87 (27)	58 (14)	25 (6)§	169 (17)
Rice	196 (23)	38 (8)	243 (33)	100 (28)	60 (16)	19 (4)	172 (21)
Millet	200 (26)	40 (10)	240 (41)	102 (30)	68 (18)	18 (5)	179 (27)
Glucose*	214 (31)	39 (8)	258 (57)	103 (31)	62 (12)	16 (3)	173 (23)

*WHO/Unicef recommended solution.

†0.02<p<0.05; ‡0.02<p<0.05; §0.04<p<0.05.

Figure Fluid balance at the end of 24 hours.

Results

Clinical information relating to the study patients is presented in table 1. There were no significant differences between the individual treatment groups of cereal based and WHO/Unicef glucose solutions with regard to any of the clinical features. The mean (SD) ages of patients in each treatment group were similar 10 (0.8) to 13 (1.3) months. The five groups were also comparable with respect to mean duration of diarrhoea before admission, degree of dehydration, admission body weight, and mean duration of diarrhoea. After admission of the 257 patients recruited into the study, 250 (97%) were successfully rehydrated. No adverse reactions or complications were noticed in any of the treatment groups. The main cause of failure and subsequent removal from the study of these seven patients was due to persistent refusal to take the oral rehydration solution and subsequent negative fluid balance as indicated by continued loss of weight and concomitant worsening of dehydration. Preadmission vomiting was reported in 92–100% of the patients. There were no significant differences in the amount of oral rehydration solution, plain water, and total intake among any of the groups at the end of the first 24 hours of therapy (table 2 and figure). Full rehydration was achieved during the first 24 hours of treatment. Stool output or purging rates and urine output were also comparable in all the five groups.

Table 3 Percent body weight gain by 24 hour periods in different oral rehydration solutions. Results are mean (SD)

Type of oral rehydration solution	No 24 Hours		No 48 Hours		No 72 Hours		No Discharge	
Maize	51	6.5 (3.2)	42	7.2 (4.3)	29	7.1 (4.8)	51	7.3 (4.1)
Sorghum	48	4.7 (1.8)	36	5.6 (2.0)	21	6.8 (2.7)	48	5.1 (1.5)
Rice	51	6.0 (2.3)	48	6.4 (1.2)	34	6.2 (1.6)	51	6.0 (3.1)
Millet	50	5.8 (3.1)	43	6.3 (2.9)	26	5.3 (1.1)	50	6.1 (2.4)
Glucose*	50	6.9 (1.7)	48	7.8 (2.1)	28	7.3 (2.0)	50	7.4 (3.2)

*WHO/Unicef recommended solution.

The group receiving the maize based solution had a lower stool output than the control group receiving WHO/Unicef glucose based solution, but this difference was not significant. Vomit of 28 (8) ml and 25 (6) ml in the groups receiving the maize and sorghum based solutions respectively were each significantly higher than that found in the control group (16 (3) ml, $p < 0.05$). There were no differences in absorption of the oral rehydration solution per kg body weight between the treatment groups (figure).

All treatment groups and the control group showed similar weight gain compared with admission weight after 24, 48, and 72 hours of hospitalisation and at the resolution of diarrhoea (table 3).

Discussion

After reports of successful trials of rice based oral rehydration solutions in Asia,¹¹⁻¹⁴ the Kenya Medical Research Institute decided to test some of the cereals that are widely available in Africa. Apart from a pilot study by Kinoti *et al* on a maize based solution,¹⁵ we believe that this is the first study to assess the efficacy of different cereal based solutions in the management of acute childhood diarrhoea.

We attempted to follow recommended clinical practice by offering food with the solutions after the initial rehydration as oral rehydration solutions have little nutrient value. Molla *et al* (A M Molla, unpublished observations) found that cereal based solutions were superior to the standard glucose based solution in children who were not fed, but their efficacy became similar after introduction of food in the first 24 hours of treatment.

When food based solutions are used proper feeding practices must be emphasised to mothers as they are likely to assume that adequate feeding is being provided to the child during administration of the food based solution. This assumption could be a serious disadvantage of these food based solutions, but we believe that underfeeding is unlikely to occur on a large scale when proper training is given.

While prospective and intensive clinical research is awaited, the next stage of this investigation would be to study the efficacy of a cereal-salt solution with locally available ingredients. The ultimate objective of any programme of oral rehydration is to expand the availability of solutions to every home in developing countries where diarrhoea is a major health problem among children. Mothers should be able to use ingredients available within their kitchens to prepare a solution and to initiate treatment at the very beginning of the onset of a diarrhoeal episode. This will make the programme self sufficient and will minimise the immediate and long term problems seen in children with diarrhoea.

The provision of packets of glucose based solutions to cover every episode of diarrhoea is neither feasible nor affordable at present in Kenya and in Africa at large. Therefore, a simple, effective and traditional home remedy will be the ideal solution for the treatment of diarrhoea.

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