Acute Dehydrating Gastro-enteritis in Undernourished Infants

THE DIAGNOSIS AND CORRECTION OF ELECTROLYTE AND METABOLIC ABNORMALITIES

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SUMMARY

In 80 undernourished infants with acute dehydrating gastro-enteritis a pattern of electrolyte and metabolic disturbances was found, including acidosis, hyponatraemia and hypokalaemia. Clinical assessment of acidosis and dehydration was reliable in most cases, but electrolyte disturbances, including hypernatraemia, could not be accurately diagnosed. In the majority of infants presenting with dehydrating gastro-enteritis, electrolyte and acid-base investigations are not obligatory. The use of half-strength Darrow's solution in 2,5% dextrose water, with supplementary intravenous sodium bicarbonate and oral potassium, rapidly corrected the electrolyte and acid-base disturbances. No significant difference resulted when this regimen was modified by variations in the rate, volume or type of intravenous fluid given.

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In areas where infant undernutrition is prevalent, acute gastro-enteritis is a common and often epidemic occurrence, with a tendency to severe complications, frequent recurrences and increased morbidity and mortality.[1-3]

Regimens for handling this problem in paediatric units which provide a service to predominantly lower socio-economic groups by the utilisation of outpatient rehydration wards, have been described.[2,4] At the Red Cross War Memorial Children's Hospital, where more than 10 000 infants suffering from acute gastro-enteritis and in need of intravenous fluid therapy are seen annually, one such method has been shown to work satisfactorily.[4] This large number of patients necessitates economical use of available medical, nursing and laboratory personnel; and a simple standardised plan of management, which also ensures optimum care for the majority of patients, is essential.

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The regimen currently used at our hospital for all patients, i.e. those belonging to all socio-economic groups, relies principally on the use of half-strength Darrow's solution in 2,5% dextrose water for the correction of fluid and electrolyte deficits and for maintenance requirements. Most of the children seen have clinical and laboratory evidence of metabolic acidosis, and the rapid correction of acidosis with intravenous sodium bicarbonate has been shown to be effective and safe.[5] In addition, many of the children demonstrate clinical and laboratory evidence of undernutrition and derangement of serum electrolyte levels. Supplementation with potassium chloride from the onset of therapy has been used successfully and without complications to correct serum potassium levels.[4,6]

This study was designed, firstly, to assess the nutritional, electrolyte and acid-base status of a representative group of our patients on admission, and to follow their response to intravenous fluids, supplementary sodium bicarbonate and oral potassium therapy. Attempts were made by frequent clinical examinations to detect those children who had electrolyte and acid-base abnormalities, and to compare these findings with electrolyte and Astrup determinations, done at the same time. The need and indications for serum electrolyte investigations in the management of these patients were also reviewed. Clinical assessment of dehydration was compared with the actual weight gained after rehydration.

Secondly, the patients were divided into 4 groups in which modifications of our standard intravenous fluid regimen were made to assess whether they had any beneficial value.

PATIENTS AND METHODS

Patients

Patients were selected in the following manner. All infants over 6 weeks old and children under 4 years old weighing less than 15 kg, who needed intravenous rehydration as a result of gastro-enteritis, were admitted to the study. Consecutive cases admitted between 0900 and 1530 on Monday to Thursday of each week in February and March 1972 were accepted, provided the clinical investigator was not still busy with the preceding case. All the 80 patients studied were Coloured or Black infants.

Nutritional assessment was based on percentage expected weight for age, using the 50th Boston percentile[7] as normal, and on serum albumin levels after rehydration. Dehydration was graded as 5% (moderate) if there were signs of a loss of tissue turgor, sunken eyes, sunken fontanelle, or dry mucous membranes. If more than one of these signs was present, or if there were signs of peripheral vascular collapse or shock, they were graded as 10% (severe) dehydration. These groups were compared with the actual weight gained after rehydration was complete.

An attempt was made to diagnose hypernatraemia clinically. Signs looked for and recorded included alterations in level of consciousness, increased muscle tone, convulsions and a doughy or rubbery consistency of the skin.[8-12]

Clinical signs of acidosis, such as deep rapid breathing and alteration in the level of consciousness, were recorded and arbitrarily graded as moderate or severe acidosis. The study was designed to ensure that the results of electrolyte and acid-base investigations were not known to the paediatrician responsible for the clinical assessment, but in the interests of the patients these were made available to the other investigators.

The patients were allocated at random to 4 groups, who received different types of intravenous fluid therapy.

Management

Group 1: This group received the routine replacement therapy and maintenance fluid administration in use in our rehydration ward. In all patients the volume of replacement fluid was 50 ml/kg if 5% dehydrated, and 100 ml/kg if 10% or more dehydrated. The volume of maintenance fluid given was 150 ml/kg/day and half-strength Darrow's solution in 2,5% dextrose solution was used for both this and the replacement volume. The whole replacement volume was given during the first 4 hours and the maintenance fluid at a constant rate over the next 20 hours. Apart from the differences listed below, groups 2, 3 and 4 received the same intravenous fluid regimen as group 1.

Group 2: The time of infusion of the replacement volume was extended to 8 hours.

Group 3: Full-strength Darrow's solution with 2,5% dextrose was given for the replacement volume over a 4-hour period.

Group 4: The volume of maintenance fluid given to this group was calculated on the basis of calories metabolised. The expected calories metabolised in 24 hours by each infant were derived from tables, and 100 ml fluid given per 100 calories metabolised.[13]

The following supplements were given to all patients:

(a) Intravenous sodium bicarbonate (calculated from the formula mEq sodium bicarbonate = BE × wt in kg × 0,3[14]) for an assumed BE measurement of −8 mEq/litre. This was added to the first 300 ml of intravenous fluid given.

(b) Potassium supplement of 9 mEq/kg/day. The required amount of potassium in excess of that contained in the intravenous fluid was given orally as potassium chloride.

(c) An intravenous preparation of vitamins A, C and D on the first 2 days of treatment.

No oral fluids were given during the first 24 hours, but thereafter the volume of intravenous fluid was reduced and oral feeding with half-cream milk commenced if the patient's condition warranted it. Patients were admitted to the inpatient service if intravenous therapy was still required after 48 hours. The remaining children were followed in the outpatient department. Antibiotics were given when clinically indicated for parenteral infections, but not for gastro-enteritis unless a pathogen was isolated from the stool.

Investigations

Venous blood samples for serum sodium, potassium, chloride and albumin estimations, and arterialised capillary blood samples from a warmed heel stab, for pH, pCO^2, base excess and standard bicarbonate estimations were taken on admission and at 6, 24 and 48 hours thereafter. Sodium and potassium were assayed on a flame photometer, chloride on a Cotlone chloridometer, albumin based on quantitative densitometry of cellulose acetate electrophoresis, and acid-base measurements by the Astrup technique.

Statistical analysis for differences in the results of the 4 treatment groups was made, using the Kruskal-Wallis test.[15]

RESULTS

In all, 80 children were admitted to the study; 44 were male, and the mean age was 9,4 months (range 15 - 48 months). There were no statistical differences in age or sex between groups. There were no deaths and 55 cases (69%) were discharged after 48 hours and followed as outpatients. The remainder required further therapy for continuing diarrhoea and were admitted to the inpatient service for varying periods.

Nutritional Status

The distribution of serum albumin levels and the percentage expected weight for age for all the patients is shown in Fig. 1. No statistical differences in albumin levels between the 4 groups were present.

Serum Sodium Levels

The distribution of serum sodium levels for all patients on admission, at 24 and at 48 hours is shown in Fig. 2. There were no statistical differences in serum sodium levels between the groups on admission. At 6 hours and at 24 hours, group 3, who received full-strength Darrow's solution as rehydration fluid, had a higher serum sodium concentration than the other groups ($P<0,05$). By 48 hours this difference was no longer statistically significant ($P>0,1$). Only 5 patients had hypernatraemic serum sodium levels (greater than 150 mEq/litre). Three had hypernatraemia on admission and 2 developed levels above 150 mEq/litre within 48 hours (Fig. 2).

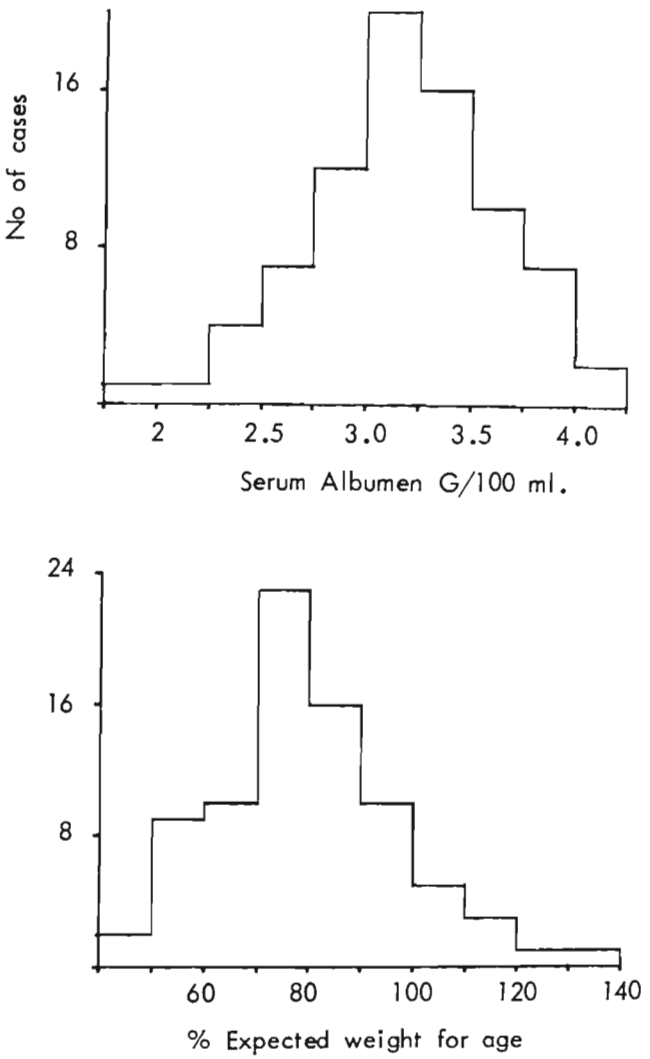

Fig. 1. Nutritional status of patients.

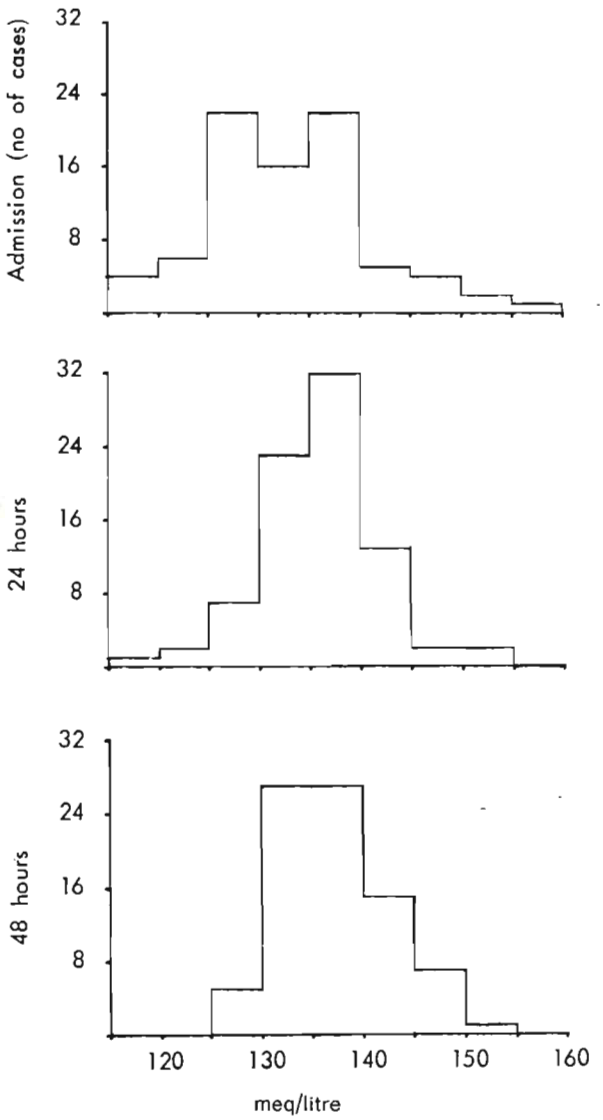

Fig. 2. Serum sodium levels of patients on admission, and at 24 and 48 hours.

Serum Potassium

The distribution of serum potassium levels for all patients on admission, at 24 and at 48 hours is shown in Fig. 3. No statistical differences in serum potassium levels between the 4 groups were present at any stage.

Serum Chloride

Serum chloride levels paralleled those for serum sodium in all determinations, and differences present were identical with those found with the serum sodium results.

Acid-Base Determinations

The distribution of the pH, pCO^2 and base excess values for all patients on admission and at 6 hours is shown in Fig. 4. There were no statistical differences of these measurements on admission and at 6 hours between the 4 groups. In group 4 at 24 hours pH, base excess and standard bicarbonate levels were lower than in the other groups ($P<0,05$), but by 48 hours no differences were present ($P>0,1$).

Clinical Assessment

At the time of admission 19 patients (23,5%) were assessed as being 5% dehydrated, and 61 (76,5%) as being 10% or more dehydrated. The percentage weight gained on full rehydration — usually at 48 hours — was calculated, and these values were compared with the assessment of dehydration in the 2 groups above.

In the 5% dehydration group the mean percentage weight gained was 5,8% (SD 2,6) and in the 10% group the mean value was 8% (SD 2,7). In 7 patients a clinical diagnosis of hypernatraemia was made because of abnormal neurological findings but no patient had an abnormal skin texture. None of these infants had symptoms suggesting hypernatraemia nor were any differences from the other cases detected in this respect. All recovered normally and the neurological findings were all normal by the time of discharge. Only 2 of these patients had serum sodium levels above 150 mEq/litre. It was not possible to define clinical signs indicative of hyponatraemia.

Patients were clinically assessed as having mild or marked acidosis. There were 54 (67,5%) in the former and 25 (31%) in the latter group, and 1 patient was thought not to show signs of acidosis. The mean pH value of the markedly acidotic patients was 7,15, while that of those mildly acidotic was 7,26.

DISCUSSION

The majority of patients in this series showed some evidence of undernutrition. When rehydrated, more than 75% had a serum albumin concentration less than 3,5 g/100 ml, and more than half of them were less than 80% of their expected weight for age (Fig. 1).

Similar studies in groups of undernourished infants with gastro-enteritis have shown that hyponatraemia and hypokalaemia are commonly present, but that hypernatraemia is rare.[1,4,18,19] The results in this group of infants agree with these findings. If hyponatraemia and hypernatraemia are defined as serum sodium levels of less than 130 mEq/litre, and 150 mEq/litre or greater, then 40% of the patients were hyponatraemic and only 4% hypernatraemic before treatment (Fig. 2). Serum potassium levels before treatment show that 38% had levels of less than 3,5 mEq/litre and 3% had levels greater than 5,5 mEq/litre (Fig. 3). Nearly all the children showed some degree of metabolic acidosis (Fig. 4).

Clinical assessment of dehydration showed a rough correlation with actual weight gained when the patients were fully rehydrated, although in a few cases estimation was incorrect. The limited number of cases of hypernatraemia does not allow for any conclusions to be drawn regarding the validity of clinical signs as an aid to diagnosis. Five of the 7 cases clinically diagnosed as hypernatraemic had normal serum sodium levels, and in only 2 of the 5 cases with hypernatraemia at some stage was the clinical diagnosis correct. No patients had a doughy or rubbery texture of the skin.

The few cases of hypernatraemia seen in this study, and the low incidence in dehydrated infants of parents in the higher socio-economic groups treated at this hospital, differ markedly from the higher incidence of hypernatraemia reported from Western Europe and North America. In one recent survey from Manchester more than 60% of dehydrated babies had hypernatraemia on admission.[20] This probably accounts for the difficulty experienced by us in making a clinical diagnosis. Others have also had difficulties in diagnosing hypernatraemia.[16,17]

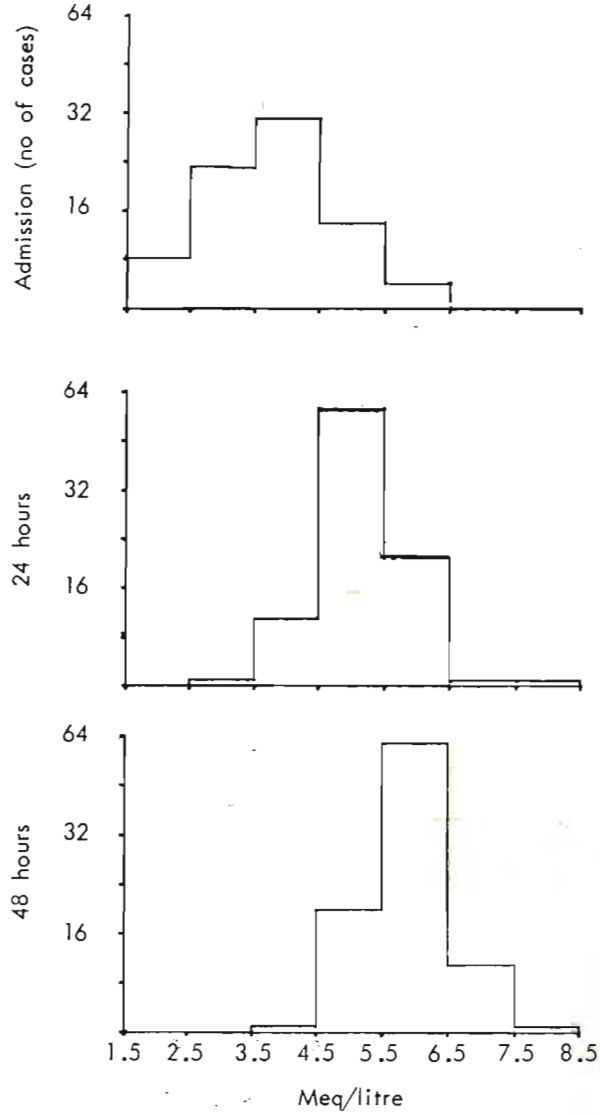

Fig. 3. Serum potassium levels of patients on admission, and at 24 and 48 hours.

Clinical assessment of acidosis showed some correlation with Astrup results, although in a few patients normal acid-base values were obtained when the diagnosis of acidosis was clinically recorded.

Many different rehydration schemes have been proposed for infants with gastro-enteritis. Oral fluid therapy is the safest and easiest method of treatment for those children with mild gastro-enteritis who are not dehydrated. In more severe cases, when dehydration is present, intravenous fluids are necessary, the composition of the fluid used varying in different centres. Half-strength Darrow's solution in 2,5% dextrose water which contains sodium 61 mEq/litre, potassium 17 mEq/litre, lactate 27 mEq/litre and 2,5% dextrose water, has been shown to be effective in our hospital and other centres in South Africa.[2,4,18,19] Because as many as 100 children with gastro-enteritis may be admitted in one day, simplicity of management is necessary,

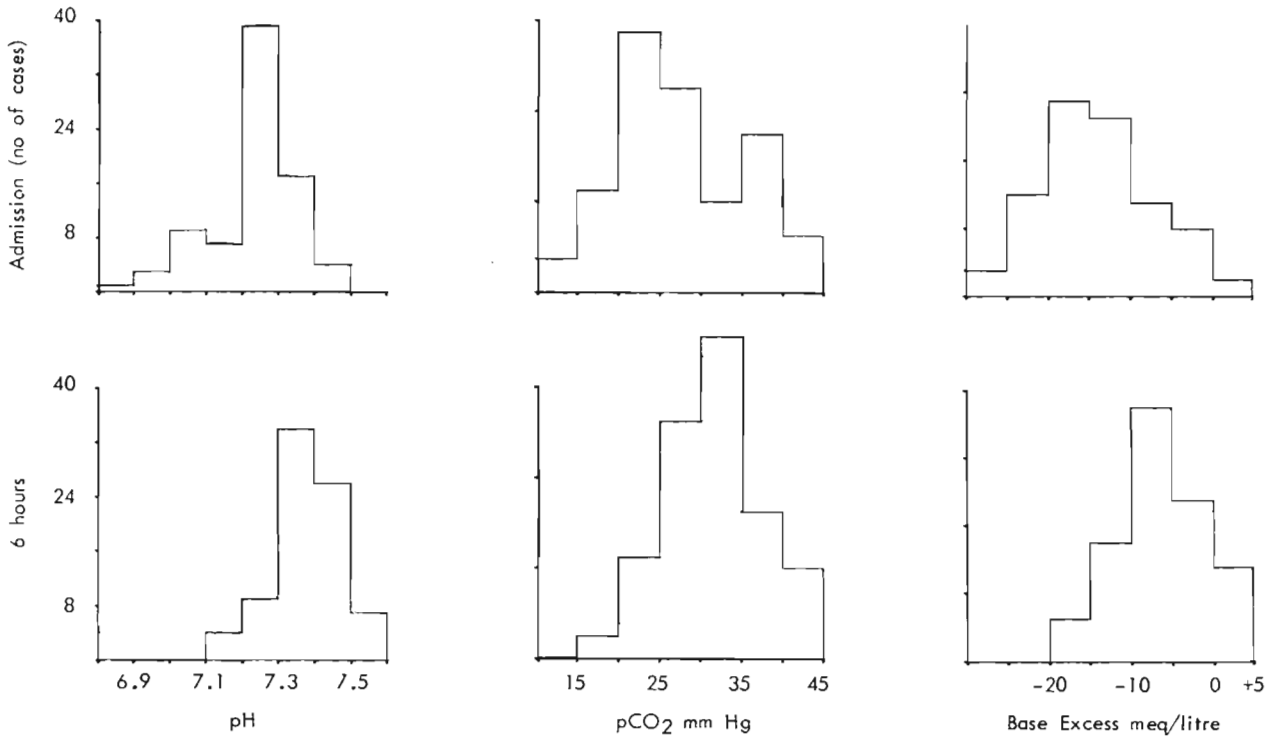

Fig. 4. pH, pCO_2 and base excess levels on admission and at 6 hours.

and this solution is used as standard intravenous fluid both for rehydration and maintenance. For ease of management, rehydration and maintenance volumes are calculated from simple formulae based on weight. Thus a clinical assessment of either 5% or 10% dehydration will require 50 or 100 ml/kg intravenous fluid for replacement, and 150 ml/kg as maintenance fluid. The rehydration volume is usually given over a period of approximately 4 hours, and in severely shocked cases more rapidly, while the maintenance fluid is administered during the balance of 24 hours.

In this study the effects on electrolyte and acid-base levels of three modifications of the standard regimen, as outlined above, have been investigated. In the one group (group 3) full-strength Darrow's solution was used for rehydrating the infants. The increased electrolyte content of this fluid has the theoretical advantages of: (*a*) being a more efficient volume expander; (*b*) replacing electrolyte deficits more rapidly; and (*c*) if hypernatraemia is present, it prevents the development of cerebral oedema due to rapid shifts of hypotonic fluid into cerebral cells.[9]

The results in this group show statistically higher serum sodium levels at 6 and at 24 hours than in the other groups, without reaching hypernatraemic levels.

The importance to the patient of these effects can only be a matter of speculation. The advantages of rapidly restoring serum electrolyte levels to normal, such as improved circulation and increased availability of electrolytes to replenish intracellular deficits which may be present, must be weighed against the possible dangers of increasing hypernatraemia. There were too few cases of hypernatraemia in this study for any conclusion to be reached in this regard. By 48 hours serum sodium levels were similar in all groups. Thus from our limited material in this series no particular advantage can be ascribed to the use of full-strength Darrow's solution as a rehydrating fluid, and a large series would be necessary to decide if the early rise of serum sodium to normal levels is advantageous. By 48 hours there were no differences in serum sodium levels between the different groups, so that patients receiving a lesser amount of sodium were able to adjust their levels to normal by 48 hours.

The use of a slower rehydration period (group 2) is theoretically also important in hypernatraemia, when slow equilibration between intra- and extracellular sodium results in less risk of cerebral oedema due to rapid fluid shifts.[9] Insufficient cases of hypernatraemia do not allow us to draw any conclusion in this group. Establishment of normal circulation and correction of shock are probably more important than slow equilibration between intra- and extracellular sodium in the average case.

No electrolyte differences were detected in group 4 in which the maintenance volume was calculated by using the number of calories metabolised as a basis for maintenance fluid requirements. In this group the volume of maintenance fluid was less than the other groups, and the lower pH, base excess and standard bicarbonate values found at 24 hours may be significant in that insufficient fluid administered resulted in delayed return of metabolic functions to normal. After oral fluids were administered in the second 24 hours, the results of acid-base levels were comparable in all groups.

The modifications of intravenous fluid therapy investigated in this study demonstrate no clear-cut advantages over the standard regimen in correcting electrolyte abnormalities. The low incidence of hypernatraemia does not allow any conclusion to be drawn in this condition. The use of full-strength Darrow's as a rehydration fluid warrants further investigation in a larger series of cases, and this study indicates that with a high proportion of hyponatraemic cases this may be beneficial to the patients.

The rapid correction of metabolic acidosis in infants with dehydrating gastro-enteritis using intravenous sodium bicarbonate has been shown to be effective and safe.[5] In this study and in other series metabolic acidosis in infants with gastro-enteritis is almost always present[4] (Fig. 4). Intravenous sodium bicarbonate therapy was calculated by assuming a base excess value of −8 for all the children. Fig. 4 shows that in many cases base deficits were greater than this, although a few were normal. At 6 hours pH values had risen to near normal levels but there was persistence of mildly compensated metabolic acidosis. By 48 hours acid-base values were near normal. This general improvement over 48 hours may have been partially due to improvement in fluid balance and metabolism, but the absence of a control group which did not receive bicarbonate therapy does not allow us to assess these factors. The use of sodium bicarbonate in the amounts given was not harmful, and alkalosis did not result from this treatment, nor did the infusion of the extra sodium give rise to raised serum sodium levels.

Potassium supplementation in children with gastro-enteritis is an essential part of their management,[3,4] but caution is advised in using potassium in intravenous fluid therapy until it is apparent that urine flow is established and there is no renal damage present, thus obviating the likelihood of hyperkalaemia.[9,10] Potassium losses in the stool may aggravate low serum, and total body potassium levels in undernourished children and serum potassium levels are not an accurate reflection of intracellular potassium.[21] The therapeutic maximum dose of 3 mEq/kg/day,[3] often recommended, has been shown to be inadequate in malnourished patients.[21] Supplementation of 6 - 9 mEq/kg/day of potassium has been shown to be safe, and to maintain the total body potassium levels within the normal range.[21,22] Serum potassium levels in patients with gastro-enteritis have been monitored in other series[4,5] using half-strength Darrow's solution (potassium content 17 mEq/litre) intravenously from the onset of therapy. In these studies serum potassium levels were not fully corrected and no complications were encountered with this form of therapy.

Based on these observations, we administered 9 mEq/kg/day of potassium to the children in this study. Fig. 3 shows that initial serum potassium levels were low in most cases, but that by 24 and 48 hours many of the children had levels that were higher than the normal expected range. No clinical signs of potassium intoxication were detected, but electrocardiographic monitoring was not performed, nor were total body potassium levels measured. The results suggest that if serum potassium levels cannot be monitored, this dosage of potassium is probably too high. Until further investigated, it is recommended that in undernourished infants suffering from dehydrating gastro-enteritis, not more than 6 mEq/kg/day of potassium be administered.

CONCLUSION

When planning the intravenous therapy of infants with gastro-enteritis, the most important aspect is to endeavour to detect when the illness is not uncomplicated, or when a complication is likely to develop.

An accurate history where possible, and careful and repeated clinical assessment of each case, will in most cases allow for this. In the relatively small number of cases clinically selected as being at risk, treatment can be planned with the aid of biochemical investigation and assessment of acid-base status.

For uncomplicated cases this study indicates that the use of half-strength Darrow's solution in 2,5% dextrose water for both rehydration and maintenance requirements, is effective and safe in correcting electrolyte abnormalities. Estimation of serum electrolyte values is not imperative for the management of the majority of infants suffering from gastro-enteritis treated at the Red Cross War Memorial Children's Hospital. The minor modifications of this regimen examined in this study, including the use of full-strength Darrow's solution, have no demonstrable advantages. However, these statements may require review should the incidence of hypernatraemia rise or if evidence is produced to show that the regimen employing half-strength Darrow's solution in 2,5% dextrose is harmful to patients with hypertonic dehydration. The use of intravenous sodium bicarbonate in the dosage described had no harmful effects and may be used without monitoring the acid-base status. The severely acidotic child, however, requires investigation and therapy must be designed according to his needs.

For routine purposes potassium supplementation should not exceed 3 mEq/kg/day, and in undernourished children with gastro-enteritis and dehydration 6 mEq/kg/day.

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