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Hypernatraemic dehydration revisited

G R Stalder, F Wyler

University Children's Hospital, Basel, Switzerland

After discussing earlier concepts of hypernatraemic dehydration, experiments on infantile mini-pigs are reported. After giving osmolar NaCl and NH_4Cl solution, dehydration with chloride acidosis was produced and then rehydration was started for 24 h. From the findings the conclusion was drawn that in hypernatraemic dehydration cerebral lesions are not primarily due to an overall impairment of brain blood flow and that blood pressure is a misguiding criterion of fluid loss and circulatory assessment.

In industrial countries, severe hypernatraemic dehydration in infants has become a rare disease. Introduction of low-solute milks as well as early and appropriate treatment of gastroenteritis have contributed to this achievement. In developing countries however, a large number of patients with high lethality and morbidity are encountered due to the increasing use of dried cow's milk [4, 5, 13].

Recent publications on hypernatraemic dehydration have mainly been focussed on an appropriate fluid therapy, producing a small fall of hypernatraemia and thereby avoiding convulsions during rehydration [2, 10, 11, 18, 19].

On the other hand, hypernatraemic dehydration remains a puzzling complication of gastroenteritis with several unsolved problems. Acknowledged aetiologic factors are insensible and intestinal losses of water in excess of sodium combined with a poor water and/or high solute intake, but the role of skeletal sodium release has never been excluded. Whereas azotaemia, hyperuricaemia [1] and hyperglycaemia [18] are common features of normo- and hypernatraemic dehydration, hypocalcaemia of 9–7 mg/dl or less is a peculiar finding in the condition. Vitamin D deficiency and hyperphosphataemia with deposition of calcium are facultative aetiological factors, and calcium diuresis may also play a role [6, 8].

Beside lethargy other cerebral symptoms such as hyperirritability, a high pitched cry and a painful mimicry are often encountered in hypernatraemic dehydration. Therefore, lumbar puncture is more widely performed than in other forms of

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dehydration. It can show discrete pleocytosis as well as an increased CSF-protein concentration up to several hundred mg/dl [6, 14, 17, 18]. Moreover, contraction of brain volume, rupture of the bridging vessels and other unknown mechanisms may lead to subdural, subarachnoid and intracerebral haemorrhage, which results in a poor prognosis of hypernatraemic dehydration.

It has been shown in experimental animals that hypernatraemia following infusion of hypertonic saline leads to consistent losses of brain water and a concomitant increase in whole brain sodium, potassium and chloride concentrations, which account fully for the elevated brain osmolality. In sustained hypernatraemia of one week, brain water and electrolyte concentrations return to control levels, but brain osmolality is still in equilibrium with the hypertonic extracellular fluid. The de novo appearance of intracellular nonelectrolyte solutes has been termed generation of "idiogenic osmoles" [15]. These idiogenic osmoles have been the subject of a series of recent publications [16]. In mammalian species they have been identified as glucose, urea and to a great proportion as amino acids, notably glutamine, and possibly including neurotransmitter substances. The dissipation of idiogenic osmoles seems to take more than 24 h after correction of extracellular hypernatraemia. These experimental findings in sodium intoxication may explain a well-known clinical phenomenon in severe hypernatraemic dehydration in infants; seizures occurring in the first 12–24 h of rapid rehydration with hypotonic solutions. An inappropriate uptake of water by the still hyperosmolal brain cells from the already normonatraemic extracellular fluid may account for these seizures. In fact, brain oedema is a more common autopsy finding in hypernatraemic dehydration than brain shrinkage, probably due to fluid therapy before death [18]. Therefore, a fast restoration of blood volume with plasma or diluted saline followed by a slow infusion with sodium (and potassium) containing solutions is recommended by most authors.

Our own research on hypernatraemic dehydration reworks well established grounds [3, 12] with some more sophisticated methods.

Materials and Methods

Infant mini-pigs were fed with osmolar NaCl and NH_4Cl solutions for 48 h. By osmotic diuresis hypernatraemic dehydration with chloride acidosis was produced. Then, i.v. rehydration was started for 24 h. Haemodynamic parameters were measured before, during shock as well as 3 and 24 h after the beginning of rehydration. Arterial blood pressure was measured by indwelling arterial catheter, cardiac output by cardiogreen dilution and distribution of cardiac output by left atrial injection of radioactive microspheres [7, 9].

Results and Discussion

This animal model corresponds well a severe hypernatraemic dehydration in infants except for the type of metab-

olic acidosis: chloride acidosis rather than organic acid acidosis. Median total weight loss was 230 g/kg and median fluid loss, corrected for starvation, was 140 ml/kg or 14 % of body weight. Median plasma and blood values were significantly elevated over control values for sodium (166 mmol/L), chloride (145 mmol/L), glucose 12.8 mmol/L), urea (20.7 mmol/L), creatinine (90.1 μmol/L), osmolality (370 mosmil/L) and haematocrit (41 %). The latter value had increased by 1/4. Significantly decreased were the median values for pH (7.19), pCO_2 (24.5 mm Hg) and bicarbonate (8.0 mmol/L) Potassium and calcium concentration did not change during the whole experiment.

Median haemodynamic data showed a significant reduction of cardiac output from 551 to 272 ml/min and an increase of total peripheral arterial resistance from 0.164 to 0.336 units (both $P < 0.001$). Therefore, systolic and diastolic arterial pressure were maintained throughout. Cardiac output was redistributed and significantly increased fractions were allotted to brain and adrenals. Thus, their blood flow remained unchanged in contrast to all other organs including the heart (median value of myocardial blood flow, 19.1 ml/min before and 11.4 ml/min during shock; $P < < 0.01$).

After 24 h i. v. rehydration blood chemistry, osmolality and haematocrit had returned to normal with the exception of creatinine concentration. Cardiac output was still slightly decreased (492 ml/min; $P < 0.05$) and total peripheral arterial resistance increased (0.197; $P < 0.05$). But only GI-tract and renal blood flow had not returned to control values (both $P < 0.01$).

These data demonstrate that in infant mini-pigs with severe hypernatraemic dehydration and substantial reduction of cardiac output a normal brain blood flow was maintained by redistribution of cardiac output. In contrast to other forms of shock, however, myocardial blood flow decreased significantly and arterial pressure was maintained through the experiment. Both phenomena can possibly be explained by the rise in haematocrit, which satisfies the myocardial oxygen needs in spite of a reduced coronary flow and increases blood viscosity and contributes to a high peripheral resistance. Moreover, other mechanisms such as vasopressin release as a consequence of hypernatraemia may favour vasoconstriction.

The clinical implications of these animal data may be that in hypernatraemic dehydration cerebral lesions are not primarily due to an overall impairment of brain blood flow and that blood pressure is a misguiding criterion of fluid loss and circulatory assessment.

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Prof G R Stalder
University Children's Hospital
Römergasse 8
4000 Basel, Switzerland