response to simultaneous feedback of biological information. For example, in cases of intractable epilepsy it has been found that training patients to alter the pattern of their electroencephalogram reduced seizure rates over a six month period.²² With real time functional MRI, it might become possible to show patients images of their own brain function while they are in the scanner in order to facilitate biofeedback.

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Lesson of the week

Hyponatraemic seizures and excessive intake of hypotonic fluids in young children

P Bhalla, F E Eaton, J B S Coulter, F L Amegavie, J A Sills, L J Abernethy

Afebrile seizures in young children may be caused by hyponatraemia—take a dietary history and measure serum electrolytes

Royal Liverpool Children's NHS Trust, Liverpool L12 2AP

P Bhalla

specialist registrar

J B S Coulter

senior lecturer

L J Abernethy
consultant radiologist

continued over

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The differential diagnosis of afebrile seizures in children with normal development includes epilepsy and metabolic disorders. Children admitted to hospital with seizures (febrile or afebrile) of unknown cause are often treated with antibiotics and antiviral agents for suspected infection of the central nervous system while investigations are undertaken. Afebrile seizures caused by hyponatraemia associated with excessive intake of hypotonic fluids was first reported in 1967.¹ This is a common problem in the United States,²⁻⁸ but it has rarely been reported in the United Kingdom.⁹⁻¹⁰ We describe four cases (table).

Case reports

Case 1

A 20 month old girl presented with a short history of vomiting, cough, and anorexia. She had attended the accident and emergency department on four occasions—with a viral illness, urinary tract infection, pertussis, and breath holding. She was admitted for observation, and a provisional diagnosis of viral illness was made. The girl refused solid food but took fluids well over the next 48 hours. At this time she had a tonic

seizure associated with apnoea but responded to treatment with rectal diazepam. Biochemical investigations showed serum sodium concentration 116 mmol/l, chloride 84 mmol/l, potassium 2.8 mmol/l, urea 2.8 mmol/l, and creatinine 35 mmol/l.

The patient's fluid intake was restricted to 60% of the maintenance requirement, but four hours later she had a further tonic seizure associated with decerebrate posturing. She was intubated and ventilated and given intravenous mannitol and phenytoin. Computed tomograms of the brain showed diffuse cerebral oedema (figure). Her urine output over the next 12 hours was approximately 12 ml/kg per hour, and with fluid restriction her serum electrolyte values returned to normal. Repeat computed tomography 24 hours later showed appreciable improvement, with normal basal cisterns and ventricles (figure).

The girl was considered to have encephalitis and was ventilated for six days, during which time her electrolyte values remained normal. However, analysis of cerebrospinal fluid removed by lumbar puncture was normal, blood cultures were sterile, and viral serology failed to show infection. Dietary inquiry showed that

the child had been drinking a great deal, particularly over the previous eight weeks, and that this had been more pronounced in the week before admission to hospital, when she had eaten almost no solid food. Her average daily fluid intake was approximately 2500 ml of half strength milk (225 ml/kg per day) and 1500 ml of diluted juice, cola drink, or lemonade. Her mother reported that the child continuously demanded drinks and would take bottles from other children if she was not given fluids.

During convalescence on the ward, the girl constantly asked for drinks. Nevertheless, she was successfully restricted to 800-1000 ml/day and her serum sodium concentration remained normal. Dietary advice was given to the parents, and on follow up the mother reported that she was managing to restrict the child to a reasonable fluid intake and was giving her more solid food.

Case 2

A 12 month old girl presented with an afebrile generalised seizure. She had attended the accident and emergency department frequently in the past because of vomiting and non-specific diarrhoea. Her parents had stopped giving her milk as they believed she had cows' milk intolerance, but the girl was consuming milk protein in cheese and chocolate and with tea, with no adverse effects. There was a strong family history of cows' milk allergy. No cows' milk substitute was being given. The girl's serum sodium concentration was 128 mmol/l. Her seizure responded to rectal diazepam and she had no further problems during her stay in hospital. The girl's parents refused to allow her to have a milk challenge and so, after dietary advice about excluding milk products, she was discharged home and prescribed a cows' milk substitute (Nutramigen; Bristol-Myers).

Two weeks later she was readmitted to hospital after two consecutive afebrile tonic-clonic seizures. Again these responded to treatment with diazepam. The girl was no longer taking Nutramigen and was drinking approximately 2 litres of dilute juice each day (206 ml/kg per day), including during the night. Results of biochemical investigations showed serum sodium concentration 126 mmol/l, chloride 97 mmol/l, potassium 4.3 mmol/l, urea 1.5 mmol/l, creatinine 41 mmol/l, plasma osmolality 269 mmol/l, and urine osmolality 127 mmol/l.

The hyponatraemia was corrected by fluid restriction and the girl's parents allowed her to try

Case 1: computed tomograms of the basal cisterns and cerebellum (left) and the third ventricle and foramina of Munro (right) at the time of admission (top) and 24 hours later (bottom)

artificial milk, with no adverse effects. Her diurnal cortisol values were normal. A milk isotope scan showed appreciable gastro-oesophageal reflux. She was discharged home after three days and her parents were advised to reduce the amount of juice she drank and to give gradually increasing amounts of artificial milk in addition to a balanced mixed diet. Over the next six months the girl continued to tolerate milk products and her vomiting settled. She regained the weight she had lost, had no further seizures, and her serum electrolyte concentrations remained normal.

Whiston Hospital,
Prescot, Merseyside
L35 5DR
F E Eaton
specialist registrar
F L Amegavie
consultant
J A Sills
consultant

Correspondence to:
J B S Coulter
tch@liv.ac.uk

Dietary and clinical details of four children with hyponatraemic seizures

Case	Age (months)	Growth and development	Duration of excess fluid intake	Type of fluid usually taken	Temperature (°C)	Serum sodium (mmol/l)	Blood glucose (mmol/l)	Comment
1	20	Normal	8 weeks	Half strength milk, dilute juice	35.4	116	9.0	Computed tomograms showed cerebral oedema
2	12	Weight faltering*	6 weeks	Dilute juice	36.3	128 (126)†	4.0	Two admissions for afebrile seizures; no milk substitute was being given
3	9	Normal	24 hours	Dilute juice	34.9	119	5.7	Computed tomograms normal
4	34	Normal	12 weeks	Dilute juice	34.0	118	5.3	

*Weight had fallen from 50th to 9th centile over previous three months.

†First (second) admission.

Case 3

A 9 month old boy presented at the accident and emergency department with a four hour history of irritability, unexplained crying, and refusal of solid food. While waiting to be examined he had an afebrile seizure which consisted of eye rolling followed by clonic movements of the left arm and leg. He required both rectal diazepam and paraldehyde to control the seizure. His eyelids were slightly puffy and his bladder was distended. Laboratory investigations showed serum sodium concentration 119 mmol/l, potassium 3.0 mmol/l, urea 1.1 mmol/l, creatinine 18 mmol/l, plasma osmolality 258 mmol/l, and urine osmolality 50 mmol/l. Because of the focal nature of the convulsion, computed tomography of the brain was performed, but scans were normal. A provisional diagnosis of water intoxication was made and fluid intake was restricted to 70 ml/kg per 24 hours.

The boy usually took a mixed diet appropriate to his age and drank two bottles (225 ml each) of juice or milk per day. However, on the day before admission to hospital he had drunk 10 bottles of dilute orange juice, and he had consumed two more bottles on the morning of admission, giving a total intake of approximately 280 ml/kg per 24 hours.

Three hours after admission, the boy's serum sodium concentration had risen from 119 mmol/l to 126 mmol/l, and after seven hours of fluid restriction it was 133 mmol/l. His urine output over the 15 hours after admission was 20 ml/kg per hour and his urine osmolality remained around 100 mmol/l for up to 48 hours after admission. The boy remained well and his level of consciousness did not deteriorate. At the time of discharge home his parents were advised to reduce his intake of juice, and at the time of follow up one month later he was taking two to three bottles (225 ml each) of milk or juice per day, with no drinks overnight. His electrolyte concentrations and serum and urine osmolality values were normal.

Case 4

A 34 month old boy presented with a prolonged afebrile seizure which was controlled only after two doses of rectal diazepam and one dose of rectal paraldehyde. He had vomited frequently for 48 hours and been drowsy for 24 hours before admission to hospital. The boy had continued to drink bottles of dilute juice during the illness. Over the preceding few months he had been regularly taking up to eight bottles of dilute juice each day, and some days he had drunk up to 2.5 litres of fluid.

Laboratory investigations showed serum sodium concentration 118 mmol/l, chloride 86 mmol/l, potassium 4.3 mmol/l, urea 4.0 mmol/l, creatinine 41 mmol/l, plasma osmolality 261 mmol/l, and urine osmolality 624 mmol/l. Treatment with fluid restriction was started. His serum sodium concentration returned to normal values by 12 hours; his urine osmolality fell to 368 mmol/l by 12 hours and was 188 mmol/l at 24 hours. The vomiting settled and the boy made an uneventful recovery. At the time of discharge home, his parents were given advice about appropriate fluid intake, and at follow up the boy was well.

Discussion

This report describes four children who developed seizures associated with taking inappropriate amounts of dilute fluids. One showed cerebral oedema on computed tomography and required mechanical ventilation. Three children had regularly taken excessive amounts of commercial drinks. In the other case excess fluid intake only occurred during the presenting illness.

Drinking too much high energy fluid—the “squash drinking syndrome”—has been reported in the United Kingdom as a cause of failure to thrive, poor appetite, and non-specific or “toddler's” diarrhoea, and as a cause of seizures in two children.⁹⁻¹¹ In Britain, over 70% of preschool children never drink plain water, preferring fruit juices and carbonated soft drinks.¹² Side effects of excess consumption of these fluids include poor appetite, tooth decay, behavioural disturbance at meal times, poor weight gain, and loose stools. This fashion may have serious consequences in a small group of young children whose homeostatic mechanisms are unable to adapt to an excess volume of hypotonic fluids, such as may be taken during periods of infection such as mild gastroenteritis. In the United States, hyponatraemia associated with intake of dilute formula or beverages is reported to be the most common cause of non-febrile seizures in children under 2 years.^{13 14}

Children who develop hyponatraemic seizures fall into several categories, and in some cases more than one category may apply. The first group, and the most common, comprises young infants (usually aged under 6 months) fed dilute formula or excessive amounts of water.¹⁻⁸ In the United States, most cases of hyponatraemic seizures occur in summer, when additional fluids are offered. The patient is typically 3-6 months of age, comes from a poor family, and presents with apnoea or seizures. Respiratory failure is common. Patients' body temperature is low, even in hot weather, and they may have oedema.¹⁻³ The blood glucose concentration is often raised. Although an infant's capacity to handle a water load is the same as that of an adult, this ability may be compromised by malnutrition,¹⁵ and the system may be overwhelmed when excess hypotonic fluids are given during mild infections or in hot weather.¹⁴

The second group comprises very young children who demand—and may have an insatiable desire for—dilute squash (cases 1, 2, and 4 in this report). However, there are few reports of “dilutional” hyponatraemia in children over 12 months of age.²⁻¹⁰

The third group comprises children who seem to have a reasonably normal diet and fluid intake but who drink too much water or dilute squash when they develop an illness with associated salt loss or dehydration, or both (case 3).^{8 9} Inappropriate antidiuretic hormone secretion triggered by infection or vomiting may be an additional factor in a few cases (possibly case 4).¹⁶⁻¹⁸

Three of the children described here (cases 1, 2, and 4) fit into the second group, in which an excessive amount of dilute squash is demanded and given at the expense of a normal diet. Suggested reasons for such behaviour include hunger (if feeds are overdiluted), salt craving, or a form of self stimulation secondary to maternal deprivation or stress whereby the infant takes excess fluid to pacify himself.^{1 2} Habit plays an

important part. Parental poverty, misjudgment, and inexperience are common factors.^{2 4 6} In some cases neglect is an important element, and water intoxication may be a form of child abuse.^{7 19}

It is difficult to understand how children, especially older children, can continue to drink excess fluid without homeostatic mechanisms abolishing thirst. The diet is usually low in solute and it may be that hunger overrides the thirst mechanism.³ In addition, there may be salt craving.²

Investigation and treatment

Hyponatraemic seizures may be more difficult to treat than simple febrile seizures. There is controversy about management.^{7 8 13 14} A short seizure in a child who is otherwise neurologically normal may be treated simply by restricting fluid to 60-70 ml/kg per 24 hours. For more difficult cases, opinions differ on whether to give physiological (sodium 150 mmol/l)^{13 14} or 3% hypertonic (sodium 513 mmol/l) saline.^{7 8} The aim is to raise the serum sodium concentration to approximately 125 mmol/l at a rate of no more than 2-3 mmol/l per hour. If there is impaired consciousness, recurrent or prolonged seizures, or neurological deterioration, rapid correction of the sodium concentration is warranted. The dose of hypertonic (3%) saline may be calculated as follows: $0.6 \times \text{body weight (kg)} \times \text{desired sodium concentration (125 mmol/l)} - \text{the actual sodium concentration}$. It should be given over 30-90 minutes, depending on the patient's sodium concentration. A dose of 12 ml/kg of 3% saline usually raises the serum sodium by about 10 mmol/l.

In Britain, it is common for children to drink excessive quantities of dilute commercial drinks (and also tea) from a bottle, and oral water intoxication may therefore be a more frequent cause of afebrile seizures than is currently appreciated. It is essential to take a detailed dietary history in this group—something that is often overlooked. Serum electrolyte concentrations should always be measured in children with afebrile seizures and urine should be obtained for additional biochemical analysis (if indicated). Recognition of the condition will prevent inappropriate investigations and treatment.

Parents should be informed about the potential dangers of drinking too much dilute fluid and the importance of a balanced diet. Doctors should also be

aware of the problem—particularly the importance of young children going back to drinking milk after dehydration has been treated with oral rehydration fluids, and of not continuing to give them dilute fluids for too long.²⁰

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One hundred years ago

A case of rupture of the heart

[Communicated by the Principal Civil Medical Officer, Colombo.]

M., an estate labourer, aged about 45 years and married, was, on May 2nd, 1899, one of a gang of coolies paid off from one estate and going on to another, deceased carrying a box on her head weighing thirty pounds. The road was uphill. She was observed to strike her foot against a projecting stone, to try to regain her lost balance, but failing, to fall forward and to the right side. Her breathing was embarrassed, and she was restless and speechless for a few minutes, and died almost immediately.

Very little of her past history could be ascertained; she had been in good health, and worked regularly as a tea plucker.

Post-mortem Examination 24 hours after death.—She was well nourished—rigor mortis was present; the pericardium was found distended and contained about six ounces of dark fluid blood and a large clot. There was a rupture of the left ventricle half an inch

from the auriculo-ventricular septum and along the left border, longitudinal in direction and one inch in length, the corresponding tear on the inner surface slightly less. The heart was fatty, and the muscular wall pale and friable; the cavities were contracted and empty, and the valves and orifices normal; there was no marked atheroma of the large blood vessels.

In this case it seems probable that as exciting causes there were the exertion of walking uphill with a box on the head, the stumbling and effort to regain her balance, with perhaps the fear of injury to herself and damage to the contents of the box, which caused violent action and consequent rupture, in a heart already predisposed to it by fatty degeneration.

Allan Kalenberg, L.R.C.S. & PEdin.
Bogawantalawa, Colombo.

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