Hyponatremic Seizures Secondary to Oral Water Intoxication in Infancy: Association With Commercial Bottled Drinking Water

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ABSTRACT. In recent years, hyponatremic seizures resulting from water intoxication have been reported in the United States with an increasing frequency that some have likened to an epidemic.[1] Infants of parents living in poverty and uninformed of the risks of feeding fluids other than infant formula to their babies are particularly at risk.[1–12] Young infants with vomiting and diarrhea are especially prone to developing hyponatremia if fed fluids lacking sufficient sodium, but even those who are otherwise well may develop symptomatic hyponatremia as a result of being fed excess solute-free water. Most often tap water, either in the form of supplemental feedings or overly dilute formula, has been given in excessive amounts over relatively short periods of time.[1–11,13–16] Less frequently, water in other forms such as juice, soda, or tea has been implicated.[12,16–19] This report includes the cases of two infants treated at our institution for hyponatremic seizures and water intoxication after being fed with the same bottled drinking water product marketed for use in infants. The medical records of all infants 1 year of age admitted to our institution over 10 years with the diagnosis of hyponatremic seizures were also reviewed.

ABBREVIATIONS. WIC, Women, Infants, and Children Supplemental Feeding Program; FDA, Food and Drug Administration.

CASE REPORTS

Case 1

On October 7, 1993, a 55-day-old African-American infant was brought to the emergency department at a local hospital for evaluation of new onset "eye twitching." En route to the hospital, she began to have generalized tonic–clonic seizure. Her rectal temperature was 35.6°C; heart rate, 180; and blood pressure, 90/50 mm Hg. Pupils were equal and reactive, and funduscopic examination was normal. Edema was noted in the periorbital and gluteal regions. All four extremities were moving rhythmically, and deep tendon reflexes were symmetrically hyperactive. Capillary refill time was <2 seconds, and the infant was acyanotic. Weight was 4.77 kg (50%); length, 52.0 cm (10%); and occipitofrontal circumference, 36.0 cm (10%).

Laboratory analysis revealed serum sodium of 116 mEq/L; chloride 85, mEq/L; potassium, 5.6 mEq/L; bicarbonate, 16 mEq/0; glucose, 151 mg/dL (8.4 mmol/L); total calcium, 8.2 mg/dL (2.1 mmol/L); phosphate, 6.2 mg/dL (2.0 mmol/L); creatinine, 0.4 mg/dL (35.4 mmol/L); and blood urea nitrogen, 7 mg/dL (2.5 mmol/L). Blood gas analysis showed metabolic acidosis with base excess −4.5 mEq/L. After >45 minutes of seizure activity, treatment with lorazepam (0.13 mg/kg), phenytoin (20 mg/kg), and phenobarbital (20 mg/kg) provided control of seizures but resulted in respiratory depression. Urine output exceeded 6 mL/kg/h over the next 8 hours and was accompanied by a weight loss of 180 g and resolution of edema. With intravenous administration of 0.9% saline at a rate of 100 mL/kg/day, the serum sodium concentration returned to 138 mEq/L within 20 hours (a rate of 1.0 mEq/h); the metabolic acidosis also resolved. Clinical improvement within 24 hours was accompanied by a weight loss of 350 g. The infant was discharged in good condition, on formula feedings, after a 5-day hospitalization.

Additional history revealed that the infant's 22-year-old mother had been buying cow-milk formula and supplementing feedings with bottled drinking water for several days. The mother and child had been living with the mother's aunt, who was taking an active role in child care and expressed concern over the lack of time the mother spent with her infant. Despite eligibility for financial assistance through the Aid for Families with Dependent Children program, none had been sought. Both care givers related that the particular bottled water product was inexpensive and labeled in such a way that it seemed to contain nutrients adequate for use as an infant feeding supplement.

Case 2

On December 8, 1993, a 56-day-old African-American infant was brought to the emergency department at Children's Hospital of Wisconsin for evaluation after a brief seizure. With the exception of symptoms of upper respiratory tract infection for several days, he had been in good health. His rectal temperature was 37.8°C; respirations, 52/min; heart rate, 152/min; and blood pressure, 94/58 mm Hg. The infant appeared alert, healthy, and in no distress. Funduscopic examination was normal, and pupils were equal and reactive. There were no focal neurologic findings, and capillary refill time was <2 seconds. Weight was 4.26 kg (25%); length, 57.5 cm (50%), and occipitofrontal circumference, 38.5 cm (50%).

At the time of admission, the serum sodium concentration was 121 mEq/L; chloride, 87 mEq/L; potassium, 4.8 mEq/L; bicarbonate, 21.3 mEq/L; creatinine, 0.3 mg/dL (26.5 mmol/L); and blood urea nitrogen, <2 mg/dL (0.7 mmol/L). Urine specific gravity was <1.005. Computed tomographic imaging of the head performed within 2 hours of the initial sodium measurement was normal.

The infant and his 16-year-old mother had been living with the mother's parents. His mother related supplementing feedings of soy formula (obtained through participation in the Women, Infants, and Children Supplemental Feeding Program [WIC]) with bottled drinking water since the onset of cold symptoms. Daily feedings consisted of three bottles of formula and three bottles of drinking water. The drinking water was viewed in this case as a safe and economical form of clear liquid to assist in the relief of cold symptoms. His mother stated the label on the bottle depicted a product specially made for infants (Fig 1).

Intravenous fluid therapy consisted initially of 0.9% saline, then 5% dextrose in 0.45% saline, at a rate of 200 mL/kg/day. Diuresis at a rate >5 mL/kg/h was accompanied by a weight loss of 140 g. Within 9 hours, the serum sodium concentration had returned to 136 mEq/L (rate of return 1.4 mEq/h). The patient was discharged home in good condition, after dietary counseling, <24 hours after admission.

Before we began the records review, the two cases associated with bottled drinking water were reported to the Food and Drug Administration (FDA) and the local health department.

Using the Children's Hospital of Wisconsin IDX computer system, our medical records department conducted a search for all

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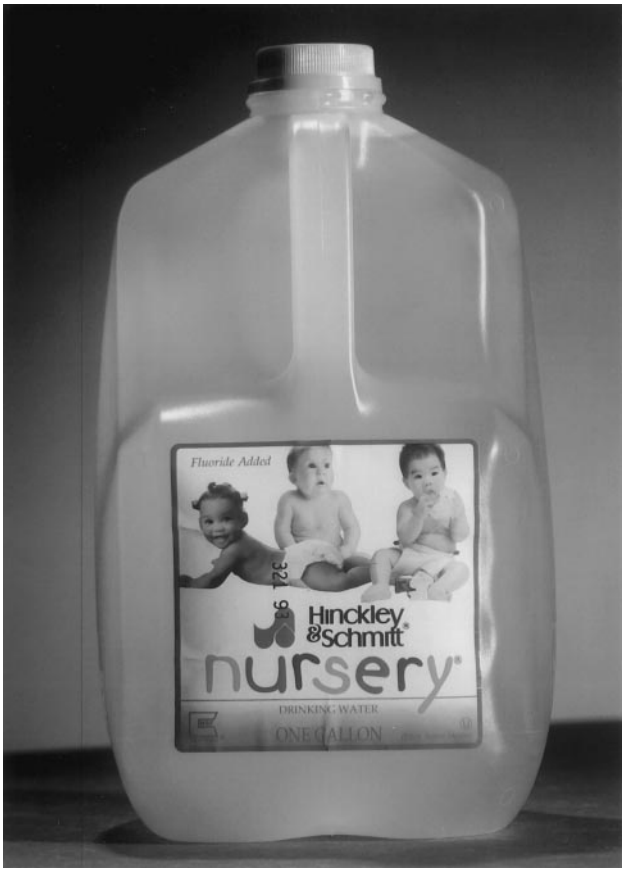

Fig 1. The bottled water product fed to the two infants discussed in the case reports.

patients ≤1 year of age admitted with the diagnosis of hyponatremia and seizure over the 10-year period from January 1984 through March 1994. Cases were included if the initial serum sodium concentration was ≤130 mEq/L and if there was no history of chronic illness. Two patients were excluded, one with panhypopituitarism and the other with cystic fibrosis. We retrospectively reviewed the remaining records and recorded all pertinent clinical, laboratory, and demographic information. Excess total body water was calculated using body weight, serum sodium concentration, and age-specific estimations of normal total body water[20] to approximate the volume of solute-free water necessary to cause water intoxication and hyponatremic seizures.[21] Significant trends in age distribution and correlations between age and various clinical observations were measured (t test and χ^2 analyses).

Demographic and Historical Data

Twenty-five consecutive additional cases of hyponatremic seizures treated previously at our institution were identified (N = 27). The mean age of all cases was 4.8 ± 2.9 months, with a male-to-female ratio of 1:1. Twenty-one infants were <6 months of age and 6 were older (P = .002). In 22 cases (82%), infants were being cared for by single parents. Nine of the 27 (33%) infants had no siblings, 18 (67%) had at least one other sibling, and 12 (44%) had two or more siblings. Twenty-six families (96%) qualified for financial compensation through government programs; however, 35% of these families were not making full use of these resources. The rate of immunization for all infants was 48% (13 of 27).

There was documentation of feedings of at least one form of solute-free water (alone or in addition to formula feedings) in all cases. Seventeen infants (63%) were fed straight tap water, and four (15%) were given sugar water (apparently mixed at home). Four infants (15%) were fed tea, soda, or Kool-Aid. Seven infants (26%) were being fed with overly dilute formula by parents who admitted doing so either because they ran out of formula or wished to save money. The parents of two infants claimed they had been given feeding instructions, each from a different health care provider by telephone, which included feeding solute-free water. Three infants were fed water in an attempt to provide relief of upper respiratory symptoms. Eleven patients (41%) were reportedly being fed some form of excess water on a regular basis; 4 (15%) were fed excess water acutely in addition to daily excess water; and 12 (44%) reportedly became water-intoxicated acutely (within a 24-hour period) without a history of regular feedings of excess solute-free water. There were no other cases of hyponatremic seizures and water intoxication associated with feedings of commercial bottled drinking water.

Clinical Data

The mean serum sodium concentration was 121 ± 4 mEq/L (113 to 127 mEq/L). Prolonged seizures (≥15 minutes) occurred in 48% of cases (13 of 27), and 9 infants (33%) required mechanical ventilation. Eight of the infants (30%) had seizures with focal characteristics. None of the infants >6 months of age required ventilatory support, and only 1 had a prolonged seizure. The mean body temperature on admission (including 4 infants with fever) was 36.4 ± 1.4°C. Serum sodium levels returned to normal within a mean time interval of 11.3 ± 5.7 hours (mean rate of return 1.6 ± 0.7 mEq/h). Mean total body water excess was 592 ± 209 mL (556 ± 212 mL for infants <6 months, 720 ± 147 mL for those older; P, not significant). The mean length of hospitalization was 4.4 ± 2.9 days, and no neurologic deficits were evident at the time of hospital discharge.

DISCUSSION

These examples illustrate a well-described spectrum of symptoms that characterize water intoxication, consisting of altered mental status (typically irritability or somnolence), hypothermia, edema, and seizure.[1–7,12–17] Symptoms are preceded by a rapid fall in serum sodium concentration to ≤125 mEq/L and result from an acute overload of solute-free water substantial enough to increase total body water by 7% to 8% or more.[22] Reported time intervals over which infants have been fed water in excess sufficient to precipitate hyponatremic seizures have varied from 90 minutes to 48 hours.[1,14] The subsequent rapid fall in serum sodium concentration is thought to result in physiologic dysfunction at the neuron level, which in turn leads to varying degrees of clinical neurologic dysfunction.[23] Twelve of the infants in our series underwent cranial computed tomographic imaging, 8 of whom had acute hyponatremia. The absence of radiographic evidence of cerebral edema in all cases studied lends support to the theory that ion gradient disturbances are at least as important as cellular swelling in causing neurologic dysfunction during water intoxication.

Various physiologic mechanisms have been proposed to explain why young infants, particularly those <6 months of age, are at risk for developing water intoxication. Immature renal function in infancy is thought to be a significant factor. Children <1 year of age have a relatively low glomerular filtration rate, and although urine output may exceed baseline rates in water-intoxicated infants, they are less able to excrete free water per unit time than are older children and adults.[22] The hunger drive of infancy has also been described as a powerful mechanism predisposing young infants to overfeeding with water, overriding any innate tendency to select a diet with higher solute content, which might otherwise serve as a protective homeostatic mechanism.[2,13] Others have hypothesized that excess secretion of antidiuretic hormone is an important factor, but the brisk

diuresis of dilute urine that invariably accompanies recovery of normal serum sodium levels has been cited as evidence against this theory.[2,18] Fortunately, despite the use of many different therapeutic interventions, prompt return of sodium levels and full restoration of neurologic function have been the rule in cases reported previously of hyponatremic seizures associated with oral water intoxication in infancy.[1–8,13–18]

A wide range of ingested volumes of water and times over which the ingestion occurred has been reported.[1–8,13–17] The accuracy of dietary histories, often a nebulous combination of chronic as well as acute ingestions in the same patient, is confounded additionally by retrospective analysis. Although adequate neurologic homeostasis can be maintained in chronically hyponatremic patients, such infants may be especially prone to developing symptomatic hyponatremia after a relatively small increment in total body water.[23] In calculating excess total body water in our patients,[24] we found that an infant who ingests from 260 to 540 mL of solute-free water may become symptomatic over a relatively short period.

Once considered a rare clinical entity, oral water intoxication is being reported with increasing frequency in the United States, especially in urban settings. Poverty, care giver inexperience, lack of proper instruction by health care providers, or a combination of these factors has been implicated in virtually all reported cases.[1–18] These associations characterize the patients in our series as well. Some have identified an association of infantile water intoxication with families receiving infant formula through the WIC.[1,11,12] Cases of corruption of the WIC reimbursement procedures by grocery store operators, whereby other products have been substituted for infant formula, have been described.[11] In other cases, it has been stated that the standard allotments of formula provided through WIC may be inadequate for some infants by the time they reach 4 to 6 months of age.[1] Previous reports of cases clustered during the summer months have led to speculation that elevated ambient temperatures (resulting in diaphoresis and increase thirst)[8] and the absence of school lunch programs (representing additional financial stress caused by an increase in money spent on food for families with school-age children)[1] are contributing factors. Elsewhere, researchers in the area of child development have described excess water drinking as a marker of care taker interaction disturbance,[25] and cases of water intoxication in infants have been associated with abusive as well as psychologically unstable care givers.[1,2,4] In offering explanations for why water intoxication in infants is being reported with increasing frequency, some have addressed the issue of infant formulas and their sodium content. Changes in most infant formulas in recent years have resulted in a lower sodium content, which theoretically may make diluted formula a more potent inducer of water intoxication.[18]

Since our initial report of the two infants who became ill after bottled water feedings, the FDA has recommended that the labels on infant drinking water products display a reminder that the product is not to be used as an electrolyte solution.[26] Although the products are so labeled, the warning print is generally extremely small, and some stores continue to stock bottled water products for infants next to oral electrolyte solutions. An added concern, which is beyond the scope of this report, is that these products tend to have fluoride added without FDA regulation.

Although specific recommendations exist with regard to proper mixing of infant formula, health care providers must continue to reiterate these guidelines and the hazards of deviations from them, especially for infants of families living under financial stress. To date, no specific guidelines exist to assist parents in knowing how much water to feed their infants. The calculation of excess total body water provides only an approximation. Moreover, there was no statistical correlation between excess total body water and patient age. Therefore, the available data provide only a crude estimate of the volume necessary to cause symptomatic hyponatremia in any given infant.

We conclude that commercially available bottled water products marketed specifically for use in infants represent a potential threat to the health of the children most likely to suffer from water intoxication. With their packaging and relatively affordable price, these products might be misused as feeding supplements by some parents with limited financial resources. An awareness of these facts is essential to the proper labeling of bottled water products and to educating the care givers of young infants at risk. We must continue to inform the care givers of infants in our clinics of the hazards of feeding excessive amounts of this or any other form of solute-free water to young infants.

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