Case Reports in Nephrology and Urology

Case Rep Nephrol Urol 2013;3:147–152

DOI: 10.1159/000357667
Published online: December 21, 2013

1664–5510/13/0032–0147$38.00/0
www.karger.com/cru

A Case of Water Intoxication with Prolonged Hyponatremia Caused by Excessive Water Drinking and Secondary SIADH

Mari Yamashiro[a] Hajime Hasegawa[b] Akihiko Matsuda[b]
Masanobu Kinoshita[c] Osamu Matsumura[d] Kazuo Isoda[b]
Tetsuya Mitarai[b]

[a]Sekishinkai Sayama Renal Clinic, Sayama, [b]Department of Nephrology and Hypertension, Saitama Medical Center, Saitama Medical University, Kawagoe, [c]Faculty of Health Science, Tokyo Metropolitan University, Tokyo, and [d]Musashi-Ranzan Hospital, Ranzan, Japan

Key Words
Water intoxication · Hyponatremia · SIADH · Free water clearance

Abstract
Water intoxication is a life-threatening disorder accompanied by brain function impairment due to severe dilutional hyponatremia. We treated a 22-year-old man without psychotic illness who had been put in a detention facility. He drank 6 liters of water over a 3-hour period at the facility as a game's penalty, and he showed progressive psychiatric and neurological signs including restlessness, peculiar behavior and convulsions. On his admission, 15 h after the discontinuation of the water drinking, he was in a coma, showing intermittent convulsions and remarkable hyponatremia (120 mmol/l). Because his laboratory tests showed hypertonic urine and normal sodium excretion, the diagnosis of secondary development of syndrome of inappropriate secretion of antidiuretic hormone (SIADH) was strongly suggested and later confirmed by the suppression of the renin-aldosterone system and the inappropriately elevated secretion of ADH. Saline infusion and an initial administration of furosemide in addition to dexamethasone as treatments for the patient's brain edema successfully improved his laboratory data and clinical signs by the 3rd hospital day, and he was returned to the facility without physical or psychiatric abnormalities on the 6th day. The secondary SIADH might have been due to the prolonged emesis, recurrent convulsions and rapid elevation of intracranial pressure.

Assoc. Prof. Hajime Hasegawa, MD
Department of Nephrology and Hypertension
Saitama Medical Center, Saitama Medical University
1981 Kamoda, Kawagoe, Saitama 350-8550 (Japan)
E-Mail hase2126@saitama-med.ac.jp

Introduction

Water intoxication is a fatal disorder with brain function impairment, defined as hypo-osmolar syndrome resulting from an excess intake of water, with dilutional hyponatremia formed principally by (1) the retention of water exceeding renal free water excretion, or (2) impaired free water excretion from the kidneys. The former situation is occasionally observed in psychiatric patients with polydipsia, or it may develop as a result of iatrogenic water overloading. The latter situation results from an inappropriate secretion of antidiuretic hormone (ADH) to the plasma osmolality. In hypo-osmolar syndrome, the translocation of a massive amount of extracellular water into the cells generates an increase in the cellular volume, leading to the development of brain edema, demonstrating a variety of neurological signs from appetite loss or emesis to convulsion or consciousness disturbance, depending on the severity and rapidity.

Here, we report a case of water intoxication caused by excessive water drinking in a detention facility. In this case, the secondary development of syndrome of inappropriate secretion of ADH (SIADH) contributed to the patient's prolonged hyponatremia after discontinuation of the excessive water intake.

Case Report

A 22-year-old man who was an inmate in a detention facility joined a game of 'rock/paper/scissors' with his roommates at 8:00 p.m. They made a rule that the loser of each game must drink a cup of water as a penalty by using a plastic cup with a capacity of 300 ml. That night, he lost the game again and again, and had to drink 20–22 cups of water during 25–28 games in total for the 3-hour game, indicating that he must have drunk at least 6 liters of water in 3 h. At 11:30 p.m., 3.5 h after beginning the penalty drinking, he showed restlessness and peculiar behavior, including speaking meaningless words. Because he also started vomiting and having convulsions soon thereafter, he was seen by a doctor in a clinic at the facility at midnight, and he was administered 100 mg phenobarbital intramuscularly.

However, his condition was not improved by the treatment, and it progressively worsened, showing more serious signs such as incontinence of urine and feces, tonic convulsions, and consciousness disturbance. He was finally transferred to our hospital at 2:00 p.m., 18 h after the beginning of the penalty drinking. Clinical episodes which can cause SIADH, such as epilepsy, brain surgery history, head injury or a history of meningoencephalitis, were not seen in his past history.

When he was hospitalized, he was in a coma (Japan Coma Scale; III-100). His height, body weight, blood pressure, pulse rate and body temperature were 167 cm, 49 kg, 140/90 mm Hg, 60 beats/min and 36.8°C, respectively. Edema was not present in his face or legs. The neurological examination showed no abnormality including enhanced or pathological tendon reflex. Muscle rigidity was slightly enhanced in the proximal portion of his extremities. The results of the laboratory tests on admission are summarized in table 1, and significant hyponatremia (120 mmol/l) was assumed to be the principle cause of the coma and/or other neurological abnormalities. A brain magnetic resonance imaging (MRI) study showed high-intensity signals in the perilateral ventricular region and brain white matter consistent with the development of brain edema, as shown in fig. 1. A chest X-ray showed no abnormalities, including alveolar shadow, pleural effusion, cardiomegaly and congestion (X-ray not shown).

Although excess water drinking in the detention facility would have triggered the dilution of the patient's body fluid, it was not concluded that the temporal massive water drinking caused the prolonged dilution of body fluid until 15 h after the discontinuation of the water drinking. Indeed, his laboratory tests showed hypertonic urine (305 mosm/kg H_2O), indicating the disturbance of free water excretion in response to the remarkable hyponatremia. This finding, taken together with the patient's decreased free water clearance, inhibition of the renin-aldosterone system and hypouricemia with elevated uric acid clearance led us to make a tentative diagnosis as secondary SIADH, and the diagnosis was confirmed later by the detection of an inappropriate elevation of the plasma ADH concentration.

The patient's clinical course and the changes in the laboratory findings are summarized in fig. 1. As an initial therapy for the severe hyponatremia, physiological saline was infused in combination with 40 mg furosemide twice a day. In addition, 6.6 mg dexamethasone was also administered for the reduction of the patient's brain edema. Because he showed systemic convulsions again on the 2nd day, an electroencephalogram was performed and showed a spike and wave pattern, suggesting the diagnosis of epilepsy. The convulsions disappeared after an administration of phenytoin.

On the 3rd day, his consciousness disturbance had almost disappeared, with an elevation of the serum sodium concentration (138 mmol/l). On admission, he showed elevated serum creatine phosphokinase (2,386 IU/l) and urine myoglobin (372.1 ng/ml) as well as muscle pain, which were consistent with rhabdomyolysis resulting from the recurrent convulsions and hyponatremia. Following the improvement of the hyponatremia, those abnormalities also disappeared by the 5th day. After confirmation of the disappearance of the brain high-intensity signals by MRI and the normalization of the disturbed free water clearance on the 5th day, the patient was discharged and he returned to the detention facility with no significant clinical signs on the 6th day.

Discussion

Many patients with psychotic illness have shown excessive drinking behavior, and 6–10% of hospitalized psychotic patients show polydipsia, which occasionally causes water retention and resultant hyponatremia [1, 2]. The majority of these patients are administered anticholinergic agents or carbamazepine, which are known to cause drug-induced SIADH [2]. Some of the patients are known to show an abnormal threshold of thirst, leading to the loss of suppression of their drinking desire even if their body fluid osmolality is sufficiently low [3, 4]. However, our patient had no history of psychotic abnormalities or of taking psychosomatic medications or any medications known to cause drug-induced SIADH, suggesting that the water intoxication in this case was triggered purely by the excessive water intake.

Urine osmolality can reach 40–100 mosm/kg H_2O in the maximum water-diuretic condition [5], and the maximum excretion of free water by an adult human is approximately 18 liters/day [6]. Hence, a maximal water intake of 2.6 liters over a 3.5-hour span is theoretically considered to be excreted without changing the plasma osmolality. However, our patient reportedly drank 6 liters of water over a 3.5-hour period, which was a far greater volume than the safety range, indicating that at least 3.4 liters of water would have accumulated in his body even if the free water was excreted normally. Assuming that approximately 2.3 liters of water would move to the intracellular space, the remaining 1.1 liters of water in the extracellular space would be sufficient to lower the sodium concentration to 125 mmol/l, and the translocation of water into the intracellular space would be sufficient to cause

cellular edema by an approximately 12% increment in intracellular volume. If our patient's free water had been excreted adequately, his plasma osmolality and sodium concentration would have been restored to the normal range within 6–9 h. However, his hyponatremia was prolonged until 15 h after the discontinuation of the drinking, suggesting that his hyponatremia was conserved by an additional disease causing impaired free water excretion, such as SIADH. The patient's recurrent emesis might have been involved in the development of the secondary SIADH, although emetic stress is generally believed to have a limited effect on ADH secretion [7].

The elevation of intracranial pressure is reported to be a sufficient stimulus to cause secondary SIADH in patients with meningoencephalitis or hydrocephalus [8]. Therefore, an elevation of intracranial pressure by the rapid development of brain edema might contribute to the development of secondary SIADH. Although we did not observe apparent physical signs being consistent with the elevation of intracranial pressure, it was presumed that his convulsion in the early phase resulted from brain edema. Therefore, in addition to the brain MRI findings, we suspected the possible involvement of brain edema as a partial cause of the secondary SIADH. Additionally, elevated ADH concentrations have been reported in epileptic patients showing frequent convulsions [9], and the expression of vasopressin mRNA is up-regulated by convulsions in rats [10]. Our patient's repeated convulsions might also have been involved in his secondary SIADH.

Cases of water intoxication without psychotic illness have been reported, including a case of massive water intake in the context of serious diarrhea [11], excess water supplementation for thirst during military training [12], compulsory water drinking as a form of child abuse [13] and massive water drinking during military urine drug screening [14]. Some of these cases demonstrated prolonged hyponatremia even at 20 h or more after the discontinuation of water intake, but the involvement of secondary SIADH was not discussed in the case reports. Hyponatremia resulting from water intoxication should be limited to the short term if the free water excretion is not disturbed. Therefore, the majority of the cases cited above may have been associated with secondary SIADH, as in the present case.

References

1 Jose C, Perez-Cruet J: Incidence and morbidity of self-induced water intoxication in state mental hospital patients. Am J Psychiatry 1979;136:221.
2 Mercier-Guidez E, Loas G: Polydipsia and water intoxication in 353 psychiatric inpatients: an epidemiological and psychopathological study. Eur Psychiatry. 2000;15:306–311.
3 Illowsky BP, Kirch DG: Polydipsia and hyponatremia in psychiatric patients. Am J Psychiatry 1988;145:675–683.
4 Thompson CJ, Edwards CR, Baylis PH: Osmotic and non-osmotic regulation of thirst and vasopressin secretion in patients with compulsive water drinking. Clin Endocrinol (Oxf) 1991;35:221–228.
5 Gillum DM, Linas SL: Water intoxication in a psychotic patient with normal renal water excretion. Am J Med 1984;77:773–774.
6 Bricker NS, Dewey RR, Lubowitz H, Stokes J, Kirkensgaard T: Observations on the concentrating and diluting mechanisms of the diseased kidney. J Clin Invest 1959;38:516–523.
7 Berl T, Verbalis J: Arginine vasopressin synthesis and secretion; in Brenner BM, (ed): Brenner & Rector's The Kidney, ed 7. Philadelphia, WB Saunders, 2004, pp 860–868.
8 Cotton MF, Donald PR, Schoeman JF, Van Zyl LE, Aalbers C, Lombard CJ: Raised intracranial pressure, the syndrome of inappropriate antidiuretic hormone secretion, and arginine vasopressin in tuberculous meningitis. Childs Nerv Syst 1993;9:10–15, discussion 15–16.
9 Meierkord H, Shorvon S, Lightman SL: Plasma concentrations of prolactin, noradrenaline, vasopressin and oxytocin during and after a prolonged epileptic seizure. Acta Neurol Scand 1994;90:73–77.
10 Greenwood RS, Fan Z, Meeker R: Persistent elevation of corticotrophin releasing factor and vasopressin but not oxytocin mRNA in the rat after kindled seizures. Neurosci Lett 1997;224:66–70.
11 Sjoblom E, Hojer J, Ludwigs U, Pirskanen R: Fatal hyponatraemic brain oedema due to common gastroenteritis with accidental water intoxication. Intensive Care Med 1997;23:348–350.

12 O'Brien KK, Montain SJ, Corr WP, Sawka MN, Knapik JJ, Craig SC: Hyponatremia associated with overhydration in U.S. Army trainees. Mil Med 2001;166:405–410.
13 Arieff AI, Kronlund BA: Fatal child abuse by forced water intoxication. Pediatrics. 1999;103(6 Pt 1):1292–1295.
14 Tilley MA, Cotant CL: Acute water intoxication during military urine drug screening. Mil Med 2011;176:451–453.

Table 1. Laboratory findings on admission

Peripheral blood cell count	
White blood cell count /μl	13,700
Red blood cell count, ×10⁴/μl	450
Hemoglobin, g/dl	14.1
Hematocrit, %	41.6
Platelets, ×10⁴/μl	19.0
Blood biochemistry	
Total protein, g/dl	7.8
Albumin, g/dl	5.1
Blood urea nitrogen, mg/dl	11
Creatinine, mg/dl	0.65
Uric acid, mg/dl	2.2
Sodium, mmol/l	120
Potassium, mmol/l	4.2
Chloride, mmol/l	83
Calcium, mg/dl	9.9
Triglyceride, mg/dl	36
Total cholesterol, mg/dl	207
Fasting blood sugar, mg/dl	121
C-reactive protein, mg/dl	0.6
Urinalysis	
Specific gravity	1.007
pH	6.2
Protein	–
Sugar	–
Red blood cell count /HPF	0–1
White blood cell count /HPF	0–1
Blood gas analysis (room air)	
pH	7.502
pCO_2, mm Hg	25.6
pO_2, mm Hg	100.8
HCO_3, mmol/l	20.2
Endocrinology	
ADH, pg/ml	6.4
Plasma renin activity, ng/ml/h	<0.1 (0.3–5.4)
Plasma aldosterone, pg/ml	59 (30–159)
Plasma cortisol, μg/dl	32.6
TSH, μIU/ml	0.59
Free T4, ng/dl	1.07
Urine biochemistry and renal function	
Creatinine, mg/dl	26.7
Urea nitrogen, mg/dl	260
Uric acid, mg/dl	18
Sodium, mmol/l	65
Potassium, mmol/l	15.7
Chloride, mmol/l	52
Creatinine clearance, ml/min	88.4
Urine osmolality, mosm/kg H_2O	305
Plasma osmolality, mosm/kg H_2O	247
T^cH_2O, ml/min	1.73
(Free water clearance, ml/min	–1.73)
FENa, %	1.32
FEUA, %	20.0

FENa: Fractional excretion of sodium, FEUA: fractional excretion of uric acid; HPF = high-power field.

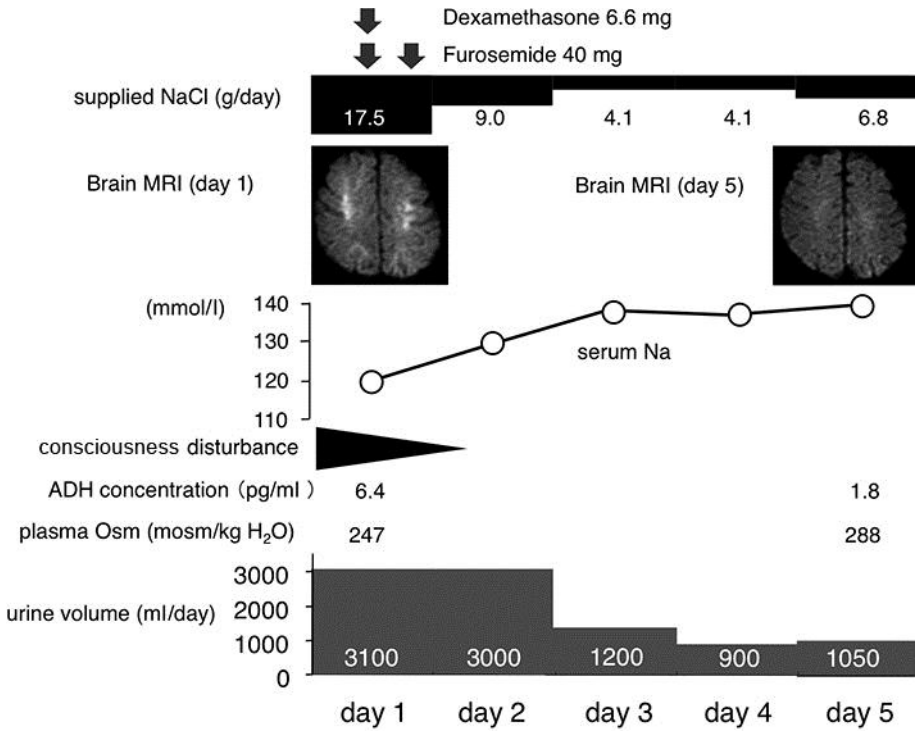

Fig. 1. Changes in the laboratory data and clinical signs of a 22-year-old male who drank approximately 6 liters of water over a 3-hour period.