CASE REPORT

Hyponatremia in an 85-Year-Old Hiker: When Depletion Plus Dilution Produces Delirium

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We report a case of critical exercise-associated hyponatremia in an 85-year-old man, an experienced hiker, during an overnight trek through Yosemite National Park. His medical history was significant for mild renal insufficiency, diastolic dysfunction, and pulmonary hypertension. He was taking a thiazide diuretic (hydrochlorothiazide), without a prior history of an electrolyte imbalance. The hiker drank a modest amount of fluid (3 liters) and urinated only once during the 9-hour descent, from a starting elevation of approximately 3000 meters, before the sudden onset of delirium occurred. He was subsequently airlifted to the nearest hospital. Initial blood sodium concentration ($[Na^+]$) was 120 mEq/L, urine $[Na^+]$ was 21 mEq/L, plasma osmolality was 266 mOsm/kgH₂O, and urine osmolality 364 mOsm/kgH₂O. The patient did not respond to infusions of normal saline, but after an intravenous 20 mg bolus of furosemide, a copious diuresis ensued, after which he recovered fully. This case highlights the complexities of fluid and sodium homeostasis during prolonged hiking, as the combination of both environmental factors (extreme temperatures, altitude, and water and sodium availability) and individual factors (hypertension, age) may have all contributed to the development of life-threatening exercise-associated hyponatremia. This case is unique in that neither the water intoxication model nor the sodium depletion model can fully explain the pathophysiologic findings documented in this report.

Key words: SIADH, arginine vasopressin, exercise-associated hyponatremia

Introduction

Clinically significant exercise-associated hyponatremia (EAH) in hikers was first reported in 1993 in 4 female hikers trekking through the Grand Canyon.¹ The authors of that case series hypothesized that EAH was likely associated with an exercise-induced nonosmotic stimulus to arginine vasopressin (AVP) secretion. Accordingly, all 4 of those Grand Canyon hikers exhibited signs of fluid overload, with 2 hikers fulfilling the diagnostic criteria of the syndrome of antidiuretic hormone secretion (SIADH) variant of hyponatremia.^{2,3} Since that initial case series, 3 separate case reports of symptomatic hyponatremia have been reported in wilderness settings: the first being a man trapped in a cold Alaska environ-

ment,⁴ the second an athletic woman hiking at a low altitude in Nepal,⁵ and the third describing a physically fit man participating in an 8-day guided trek in New Guinea.⁶ In 2 of the 3 cases, fluid overload (with or without SIADH) appeared to be the predominant pathophysiological mechanism,^{4,5} with sodium losses playing only a minor pathological role. Aside from these singular cases in wilderness settings, a majority of the documented cases of EAH have been reported for endurance athletes. Accordingly, the incidence of EAH in 2,135 endurance athletes was found to be 7%, with clinically significant cases (1% with a blood sodium concentration <128.9 mEq/L) further classified as hypervolemic (overhydration 81%) or euvoletic (euhydration 19%) as determined by pre-race to post-race body weight changes.⁷

Herein we describe an unusual case of EAH with delirium in an 85-year-old man, a retired internal medi-

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cine physician, approximately 36 hours into an overnight hike through Yosemite National Park. He was accompanied by his son, also an internal medicine physician. The collective history, physical examination, and biochemistry findings do not delineate a hypovolemic, euvoletic, or hypervolemic classification of hyponatremia that would be generally used to determine etiology and guide treatment.² Thus, while hyponatremia is generally thought to occur from water overload or sodium depletion, this case report supports the existence of a “gray area,” with both water retention and sodium deficits contributing synergistically to the development of life-threatening EAH.

Case Presentation

This patient was an 85-year-old, 75-kg man with a medical history significant for well-controlled hypertension with mild renal insufficiency and diastolic dysfunction. His medications included losartan (50 mg), hydrochlorothiazide (12.5 mg), and nadolol (40 mg). Previous surgical history was significant for an aortic valve replacement and pacemaker implantation.

This active and experienced hiker began a 3-day overnight summer hike with his family at Tuolumne Meadows (elevation 2600 m) in “hot weather” (maximum temperature 26°C). The group camped that evening at Camp Vogelsang (3078 m), where an unexpected afternoon rainstorm at the end of the day’s hike left the subject feeling cold, wet, and shivering as he fell asleep in his sleeping bag (minimum temperature 10°C). The group began hiking down the mountain in full backpacking gear through Vogelsang Pass at approximately 9:00 AM the next day, under clear and sunny skies. The son related that his father felt relatively well during this stretch and kept a slow but steady pace throughout (approximately 1 km per hour). The son also related that his father drank approximately 3 L tap and filtered creek water over the course of 9 hours of hiking and urinated only once. The son was worried about his father’s oliguria and encouraged him to “push fluids” beyond the absent sensation of thirst, thinking his father was dehydrated. They snacked on small bits of chocolate and beef jerky (1 to 2 bites). Also according to the son, they were moving too slowly to sweat noticeably, leisurely identifying as many wildflowers as they could along the trail. Around 6:00 PM (approximately 3 km from the next camp), the patient felt unusually sleepy, and his son recommended that they rest before continuing on. The son related that, within 5 minutes, his father went from normal mentation to profound mental impairment: confused, mumbling incoherently, and unable to follow any directions or respond purposely. The son then tucked his

father into a sleeping bag, thinking he was either hypoglycemic or simply exhausted, and built a fire. When the patient’s condition did not improve over the next several hours, help was summoned, and the patient was airlifted to a local hospital.

Upon arrival to the hospital, the patient’s initial blood sodium concentration ($[Na^+]$) was 120 mEq/L (Table 1). The patient received 0.9% saline at a rate of 150 mL·h⁻¹ over the next 15 hours approximately, making less than 1 L of urine during this time. His blood sodium improved marginally over the next 12 hours (to 122 mEq/L; Table 1) during which his systolic blood pressure remained in excess of 150 mm Hg, and his heart rate averaged less than 100 beats/min on the beta blocker. The physical examination was significant for rales and crackles in the left lung base, an oxygen saturation of 99.9%, and a temperature of 36.5°C. Other admission and sequential chemistry analyses are documented in Table 1. Chest radiograph was significant for left basilar infiltrate. Head computed tomography scan showed no evidence of hemorrhage, mass, or stroke. An echocardiogram revealed borderline low left ventricular function with an ejection fraction of 50% and mild pulmonary artery hypertension.

The son related that upon his own delayed arrival to the hospital approximately 18 hours after his father was admitted, his father had grown more agitated, becoming short of breath and struggling to sit upright, and had dilated external jugular veins. The oxygen saturation obtained 15 hours after admission was 93.5%. The son then contacted the treating physician and the 0.9% saline was discontinued within a few minutes. A 20 mg intravenous bolus of furosemide was then administered, and resulted in a spontaneous diuresis in excess of 500 mL and marked improvement in breathing. The patient slept for a few hours after the brisk diuresis, and when he awoke, his sensorium was largely restored to baseline with only a minor increase in blood sodium concentration (123 mEq/L). The patient was discharged approximately 48 hours later and went on to recover uneventfully without recurrence or permanent neurologic sequelae.

Discussion

Both exercise and extreme environments provide additional stressors to fluid and sodium homeostasis. Exercise stresses the cardiovascular and thermoregulatory systems as blood is redistributed away from organs (like the gut and kidney) toward working muscles and the skin. Sweating accompanies skin vasodilation to further assist with evaporative cooling, augmenting water and sodium losses during exercise. Moderate exercise can also act as a nonosmotic stimulus to AVP stimulation as a proposed adaptive response to conserve body water lost

Table 1. Sequential laboratory values of the patient throughout his hospital stay compared with baseline values from the patient's last documented laboratory report (August 2009)

Chemistry (normal range)	Baseline (last routine check-up)	Admission ^a 7-26-10 (09:20)	7-26-10 (21:25)	7-27-10 (09:08)	7-28-10 (04:38)
Sodium (135–145 mEq/L)	134 ^b	120	122	123	132
Potassium (3.5–5.1 mEq/L)	4.4	4.1	3.3	3.8	3.2
Chloride (98–107 mEq/L)	96	91	87	88	96
Co ₂ (22–29 mEq/L)	30	21	21	24	26
Glucose (70–110 mg/dL)	92	125	110	96	97
Creatinine (0.7–1.2 mg/dL)	1.2	1.7	1.3	1.4	1.3
BUN (8–23 mg/dL)	18	50	35	33	21
Calcium (8.8–10.2 mg/dL)	10	8.1	7.9	7.9	8.2
eGFR (>60 mL·min ⁻¹ ·1.73m ⁻²)	>60	44	52	48	52
WBC × 10 ³ (4.8–10.8 mm ³)		13.5		4.8	
CPK (39–190 U/L)		2259	818		148
CKMB (0.0–7.6 ng/mL)		41.5	17.7		6.8
Troponin T (0.00–0.033 ng/mL)		0.015	0.052		0.021
BNP (0–1800 pg/mL)		6174			1770
Plasma osmolality (284–300 mOsm/kg)		266			
Urine osmolality (300–1230 mOsm/kg)		364			
Urine sodium (mEq/L)		21			

BUN, blood urea nitrogen; eGFR, estimated glomerular filtration rate; WBC, white blood cell count; CPK, creatine phosphokinase; CKMB, creatine kinase–myocardial band; BNP, brain-type natriuretic peptide.

^a The top column head represents the date and the bottom represents the actual time (hours:minutes) during hospitalization (July 2010) when the laboratory measures were collected. All laboratory chemistry analyses represent blood values unless otherwise specified.

^b Patient had been on a regimen of losartan/hydrochlorothiazide for 4 years, with the average blood sodium concentration over the last 4 years being 137 mEq/L (range of 6 sequential values between 134 and 140 mEq/L).

through sweat.⁸ Thus, exercise-induced nonosmotic AVP stimulation may cause water retention at lowered plasma osmolalities, with modest fluid intakes only serving to worsen any hyponatremia.

A number of environmental factors may also serve as potential nonosmotic stimuli to AVP secretion during a wilderness hike. Factors such as a relatively high environmental temperature⁹ and altitude¹⁰ may also stimulate or potentiate AVP stimulation. In the current case, water and sodium intake and availability were also environmental factors that may have exacerbated the development of EAH in this hiker. As such, fluid consumption beyond the capacity for excretion could have contributed to the development of EAH,¹¹ while augmented sodium supplementation during the hike may have potentially attenuated the decline in blood [Na⁺] past critical levels.¹²

The critical hyponatremia (blood sodium 120 mEq/L) with delirium and pulmonary edema seen in this 85-year-old experienced hiker highlights the complexity of fluid and sodium balance under cumulative strain from multiple factors, which by themselves would be largely benign. A total body sodium depletion (hypovolemic) component of EAH from chronic use of a thiazide diuretic was supported in this patient by 1) an initial urine

sodium concentration of <30 mEq/L (21 mEq/L) in hospital;² 2) a precipitous drop in blood [Na⁺] (>14 mmol/L from typical baseline values) despite ingesting only a modest (approximately 3 L) intake of fluid over 9 hours; and 3) oliguria during the hike. A total body water overload (dilution) component of EAH from a SIADH mechanism (euvolemic) was also supported in this patient by 1) a urine osmolality greater than maximally dilute (364 mOsm/kg H₂O) combined with a serum osmolality below 275 mOsm/kgH₂O (266 mOsm/kg); 2) minimal increase in blood [Na⁺] with administration of 0.9% saline at the hospital;³ and 3) oliguria during the hike. Thus, both depletion and dilutional mechanisms appeared likely to have contributed to the pathogenesis of critical EAH in this older man, suggesting a “mixed” pathophysiological mechanism. It is important to note that oliguria can occur with both depletion hyponatremia (a marker of hypovolemia) and dilutional hyponatremia (euvolemia with inappropriate AVP secretion and antidiuresis). Thus, the inability to urinate during hiking exercise may be easily misdiagnosed as “dehydration” when antidiuretic hormone levels are osmotically inappropriate, as it appeared in the case.

Table 2. Classification (volemic status), expected pathophysiological findings, and possible etiologies of hypotonic hyponatremia in a more critical analysis of the patient's clinical findings^a

<i>Hypovolemic hyponatremia (sodium depletion)</i>	<i>Euvolemic hyponatremia (water retention with dilution)</i>	<i>Hypervolemic hyponatremia (CHF or nephrotic syndrome)</i>
Spot urine [Na ⁺] <30 mEq/L (+) ↑ BUN, creatinine (+) ↑ BUN/creatinine ratio (+) Clinical signs of volume depletion (−)	Spot urine [Na ⁺] >30 mEq/L (−) Normal to ↓ BUN (−) Urine osmolality (+) >100 mOsm/kg	Spot urine [Na ⁺] <30 mEq/L (+) ↑ BNP (+) Signs of ECF volume expansion or peripheral edema (−)
Oliguria (+) Responds to 0.9% saline challenge with ↑ blood [Na ⁺] (−)	Oliguria (+) Does not respond to 0.9% saline challenge with ↑ blood [Na ⁺] (+)	Oliguria (−) Responds to sodium restriction and loop diuretic (−/+)
Chronic HCTZ use (+) Sweat sodium losses (+)	Contributing etiological factors Stress (hypothermic event) (+) Drinking beyond thirst (+)	Renal insufficiency (+) Pulmonary hypertension (+)

CHF, congestive heart failure; BUN, blood urea nitrogen; BNP, brain-type natriuretic peptide; ECF, extracellular fluid; HCTZ, hydrochlorothiazide.

^a The (+) indicates finding is supportive of volemic classification; the (−) indicates finding is not supportive of volemic classification.²

Comparisons of clinical findings that typically support each volemic variant of hypotonic hypovolemia are detailed in Table 2. The conflicting data underscore the complexity of EAH, particularly with regard to treatment algorithms and underlying fluid regulatory dysfunction. Chronic thiazide diuretic usage may have contributed to low total body sodium stores at commencement of the hike.¹³ Therefore, the inability of this patient to internally mobilize osmotically inactive sodium stores may have contributed to the development of hyponatremia.⁷ However, this theory remains speculative owing to our inability to perform a detailed post-hoc fluid and sodium balance analysis during the hike and ensuing hospitalization period. Mobilization of previously inactive sodium stores in bone and skin appears to require a minimum of 1 to 2 weeks under chronic conditions of hyponatremia¹⁴ and low sodium intake¹⁵ before such mobilization can occur.

In conclusion, contributions from both depletion (low starting sodium stores with under-replaced solute losses) and dilutional (fluid retention and overload) mechanisms contributed to the development of EAH in this hiker. For the wilderness medicine professional, this case highlights the need both to measure blood [Na⁺] in anyone who has altered mental status after sustained exercise and to recognize that oliguria may arise from either dehydration or inappropriate AVP secretion during exercise in austere environments.

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