

Electrolytes Imbalance in Saltwater Near-Drowning Victims in the Gulf of Thailand

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Background: Near-drowning victims in saltwater are expected to have multiple electrolytes imbalance that affected treatment outcome. There are limited data about these parameters in Thailand to guide the treatment plan.

Objective: To study the characteristic of electrolytes imbalance in saltwater near-drowning victims in the Gulf of Thailand.

Material and Method: Retrospective analytic study of 39 medical records of near-drowning patients admitted to Burapha University Hospital between 2000 and 2010. Characteristics of the patients and serum electrolytes were analyzed by SPSS version 19 for windows.

Results: The study included 23 male, 16 female patients. Average age was 14.46 ± 11.15 years and 19/39 (48.72%) patients were aged 10 or less. The following electrolytes imbalance were identified, hypokalemia 8/39 (20.51%), hypernatremia 12/39 (30.77%), hyperchloremia 15/39 (38.46%), high anion gap 23/39 (58.97%), and hypobicarbonatemia 28/39 (71.79%). Seven out of eight patients in the hypokalemia group were in the high anion gap group. Mean SpO_2 in the patients who had high anion gap was significantly lower than those who had normal anion gap ($87.06 \pm 17.68\%$ vs. $95.8 \pm 5.94\%$ $p = 0.031$) without difference in systolic blood pressure (112.59 ± 14.63 vs. 105.67 ± 13.98 $p = 0.159$). Those who were hypotensive significantly had lower bicarbonate (17.00 ± 3.51 vs. 20.59 ± 3.81 $p = 0.038$) and higher anion gap (19.29 ± 1.799 vs. 16.25 ± 6.25 $p = 0.025$) than normotensive patients.

Conclusion: Hypobicarbonatemia, high anion gap, hypernatremia, and hypokalemia were common in saltwater near-drowning patients in the Gulf of Thailand. The cause of high anion gap was probably due to hypoxia and hypotension.

Keywords: Saltwater near-drowning, Electrolytes imbalance, Hypernatremia, High anion gap, Gulf of Thailand

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Drowning is a leading cause of death in children and adolescence worldwide⁽¹⁾. In Thailand, 35% of the accidental death in schoolchildren is due to drowning⁽²⁾. Risk factors for drowning include unable to swim, risky behavior, alcohol and illicit drug use, unattended children, associated health problems such as seizure or cardiovascular diseases, hyperventilation, and cold weather⁽³⁾. The leading cause of death in drowning victims includes circulatory failure and respiratory failure⁽⁴⁾. Renal involvement is usual since a report from Australia found 50% of near-drowning victims had acute kidney injury (AKI)⁽⁵⁾.

There were several inconsistent reports of electrolytes imbalance in these patients. Types and degree of electrolytes imbalance depend on

characteristic of water they drowned in. A previous study in 1977 by Peterson B did not find that electrolytes imbalance was a problem⁽⁶⁾. In contrast, 96% of the fresh water near-drowning patients in Japan had metabolic acidosis and 6.5% had hyperkalemia⁽⁷⁾. Whereas the patients who drowned in the Dead Sea had significant abnormalities in serum calcium, magnesium, and phosphorus but not sodium, potassium, and chloride⁽⁸⁾. A report from Singapore in 1998 that included 17 patients found higher level of sodium and urea in saltwater compared to freshwater near-drowning patients⁽⁹⁾. Due to the shallowness and strong water inflow from the rivers, the Gulf of Thailand has low salinity. The difference in physiologic properties of the seawater may affect the near-drowning victims differently. There were two large series of near-drowning patients in Thailand. Susiva C et al reported 31 cases of pediatric near-drowning patients admitted to intensive care unit. They found a high incidence of neurologic sequelae in 35.5% and

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high mortality rate 25.8% of the cases⁽¹⁰⁾. A study by Plubrukarn et al reported predictors of outcome in 72 pediatric near-drowning patients. Glasgow coma score of 5 or less, the need for CPR, and blood sugar more than 300 mg/dL were predictive factors for poor outcome in these patients⁽¹¹⁾. None of these studies provides enough information about electrolytes imbalance in saltwater near-drowning patients.

Objective

The present study was conducted to assess the spectrum of electrolytes imbalance in saltwater near-drowning victims in the Gulf of Thailand to guide the management plan in these patients.

Material and Method

Burapha University Hospital is located in Eastern Thai, close to the Gulf of Thailand. Given the proximity of Burapha University Hospital to the Bangsaen beach, the hospital received all patients with saltwater near-drowning. Between 2000 and 2010, 102 patients who had nearly drowned in Bangsaen beach visited the emergency department, 39 of them had been tested for electrolytes. We included all saltwater near-drowning victims who had at least one electrolytes tested in to the current study. There was no death in these patients. Data were collected from the medical records by standardized abstraction form. These data included demographic characteristics, clinical examination, pulse oxygen saturation (SpO₂), serum electrolytes (sodium, potassium, chloride, and bicarbonate levels), blood urea nitrogen, creatinine, hematocrit, and discharge status. Statistical differences were calculated by Student's t-test, Chi-square test, Levene's test and Scheffe's test. The study protocol was approved by Ethical committee of Burapha University. This work was funded by Burapha University Health Science Center, Thailand.

Results

Clinical findings

The medical record of 23 male and 16 female patients were reviewed. The age range of the patients was one to 36 years with a mean \pm SD of 14.46 \pm 11.15 years; 19 of them were aged under 10. Seven out of 39 had low blood pressure adjusted to their age. Their systolic blood pressure ranged from 88 to 140 mmHg with a mean \pm SD of 109 \pm 14.59 mmHg. Thirteen of them had SpO₂ less than 95% and 8 of them had SpO₂ less than 90% with a mean \pm SD of 91.03 \pm 14.18%. Almost all patients were normothermic, two of them

had body temperature less than 36 degree Celsius, and only one of them had a body temperature more than 38 degree Celsius. Fifty-one percent of the patients had normal consciousness. All patients got oxygen and intravenous fluid therapy, one third of them received empirical antibiotics. Three patients were transferred to tertiary care hospitals due to a worsened clinical condition.

Laboratory examinations

Laboratory blood analysis was done on arrival (Table 1). Renal function as assessed by blood urea nitrogen and creatinine were normal in most of the patients. Normal reference value of serum electrolytes and anion gap were calculated by fifth and ninety-fifth percentile and mean of pooled 8,000 data from general population in Burapha University Hospital respectively. Significant numbers of patients had abnormal electrolytes including hypobicarbonatemia (71.79%), high anion gap (58.97%), hyperchloremia (38.46%), hypernatremia (30.77%), mild hypokalemia (20.51%) as shown in Table 1 and Fig. 1. Patients with a high anion gap had significantly lower SpO₂ than those with normal anion gap (87.06 \pm 17.68 vs. 95.80 \pm 5.94% p = 0.031). Baseline characteristics were not significantly different between patients who had normal or abnormal laboratory values on arrival. The clinical findings and laboratory blood tests are summarized in Table 1. Hypotensive patients (7/39) had significantly lower bicarbonate (17.00 \pm 3.51 vs. 20.59 \pm 3.81 p = 0.038) and higher anion gap (19.29 \pm 1.799 vs. 16.25 \pm 6.25 p = 0.025) than those who were normotensive as shown in Table 2.

Discussion

There are conflicting results of the electrolytes imbalance in near-drowning victims^(4,12). The severity

Percent of electrolytes imbalance

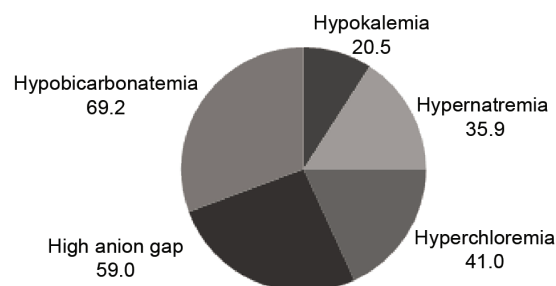


Fig. 1 Percent of electrolytes imbalance in saltwater near-drowning victims.

Table 1. Laboratory parameters on arrival of saltwater near-drowning victims

Variable	Range	Normal laboratory values	Values		Percent with abnormal values*
			Mean	SD	
Age (year)	1-36	-	14.46	11.15	-
sBP (mmHg)	88-140	-	109.78	14.59	17.95
Temperature (°C)	34-38.6	-	36.38	0.73	7.69
SpO ₂ (%)	40-100	-	91.03	14.18	20.51
Pulse rate (per minute)	60-150	-	106.13	19.48	35.90
BUN (mg/dL)	8-19	6-20	12.07	3.15	0.00
Creatinine (mg/dL)	0.3-1.5	0.5-1.2	0.69	0.36	7.14
Sodium (mEq/L)	132-166	132-145	143.53	5.91	35.90
Potassium (mEq/L)	3.2-4.6	3.5-5.5	3.74	0.33	20.50
Chloride (mEq/L)	97-120	94-107	106.79	4.74	41.00
Bicarbonate (mEq/L)	10-28	23-32	19.95	3.97	69.20
Anion gap (mEq/L)	7-34	10-14	16.38	6.32	59.00

* Percent of abnormal values included hypotension, high temperature, hypoxia, tachycardia, azotemia, hypernatremia, hypokalemia, hyperchloremia, hypobicarbonatemia and high anion gap
BUN = blood urea nitrogen

Table 2. Serum electrolytes and SpO₂ in normotensive patients compared to hypotensive patients

Electrolytes	Normotension (32)		Hypotension (7)		p-value
	Mean	SD	Mean	SD	
Sodium	143.84	6.41	142.14	2.54	0.263
Potassium	3.80	0.32	3.51	0.31	0.060
Chloride	107.00	5.05	105.86	3.02	0.443
Bicarbonate	20.59	3.81	17.00	3.51	0.038
Anion gap	16.25	6.25	19.29	1.79	0.025
SpO ₂	29.76	41.16	52.40	48.04	0.367

and types of electrolytes imbalance are related to characteristics of drowned water. This study shows that in patients with saltwater near-drowning, the most common electrolytes imbalance were hypobicarbonatemia (71.79%), high anion gap (58.97%), hypernatremia (30.77%), and mild hypokalemia (20.51%).

The actual blood pH was not known since arterial blood gas was not done in any of the patients in this study. However, the findings of hypobicarbonatemia along with a high anion gap suggest the presence of high anion gap metabolic acidosis⁽¹³⁾, which is common in near-drowning patients⁽⁵⁾. Hypoxia was found in one fifth of the cases and associated with a high anion gap. Patients with

high anion gap had significantly lower SpO₂ than those with normal anion gap (87.06±17.68 vs. 95.80±5.94 percent p = 0.031) and hypotensive patients had a significantly higher anion gap than normotensive patients (19.29±1.799 vs. 16.25±6.25 p = 0.025). We hypothesized that the cause of high anion gap was due to lactic acidosis associated with hypoxia and hypotension. These findings support the use of oxygen therapy in every case with close follow-up on the patient's oxygenation.

Incidence of hypernatremia was higher than the study of near-drowning patients in the Dead Sea⁽⁸⁾ (30.77 vs. 23%) even with the lower salinity of saltwater in the Gulf of Thailand. Swallowing rather than aspiration of salty water is considered to be the main pathogenic factor of sodium load in these patients⁽¹⁴⁾. All patients recovered from hypernatremia without any significant sequelae. Significant number of the patients in this study had hypokalemia (20.51%); this is higher than previous studies from Japan and Israel^(7,8). Seven out of eight patients in hypokalemic patients also had high anion gap. The cause of hypokalemia was probably due to redistribution since there was no evidence of obvious gastrointestinal or renal potassium loss. We suggest the use of hypotonic solution without glucose (to prevent transcellular potassium shift) as an intravenous fluid of choice in hemodynamically stable saltwater near-drowning patients.

All of the patients in this study had normal serum BUN and only two patients had elevated serum creatinine concentration of 1.4 and 1.5 mg/dL. Contrast to the previous study that reported high serum BUN in saltwater near-drowning victims^(9,15). Spicer et al reported a high incidence of AKI in near-drowning patients, 15 out of 30 cases in their series had some degree of AKI, two patients requiring hemodialysis⁽⁵⁾. Low serum bicarbonate level was a strong predictor for AKI in their study. The difference in these findings is probably due to characteristic of our patients, in which we found only four out of 39 patients in this study had hypotension.

There were some limitations in our study. This retrospective study included 39 out of 102 patients who suffered from saltwater near-drowning. Electrolytes imbalance in the remaining patients were not known. Data from a single study might not represent over all abnormalities of the saltwater near-drowning patients. A future study should include other laboratory examinations such as arterial blood gas, calcium, magnesium, and serum lactate level. Type of intravenous fluid should also be studied to maximize the treatment outcome.

Conclusion

Hypobicarbonatemia, high anion gap, hypernatremia, and hypokalemia are common in saltwater near-drowning victims in the Gulf of Thailand. The immediate aggressive treatment of the cardiovascular and pulmonary complications along with associated conditions such as hypoxia and electrolytes imbalance is of importance.

What is already known on this topic?

Saltwater near-drowning victims may have some electrolytes imbalance especially calcium, magnesium, phosphorus, and azotemia but not sodium, potassium, and chloride.

What this study adds?

Saltwater near-drowning victims in the Gulf of Thailand had a high incidence of electrolytes imbalance that includes hypobicarbonatemia, high anion gap, hypernatremia, and mild hypokalemia. Acute kidney injury in these patients was rare.

Potential conflicts of interest

None.

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ความผิดปกติของดุลเกลือแร่ในผู้ป่วยจมน้ำทะเลในอ่าวไทย

สมชาย ยงศิริ, ผกาพรรณ ดินชูไท, จิรนุช ธรรมคำภีร์, สุรียา โปร่งน้ำใจ, รัชนิพร ชื่นสุวรรณ, ศิริพร ตั้งจาศูรนต์รัศมี, เพ็ชรงาม ไชยวานิช

ภูมิหลัง: ผู้ป่วยที่ได้รับบาดเจ็บจากการจมน้ำมักมีความผิดปกติของดุลเกลือแร่ในร่างกายที่มีผลต่อการรักษา ปัจจุบันยังไม่มีรายงานเกี่ยวกับความผิดปกติของดุลเกลือแร่ในผู้ป่วยจมน้ำทะเลในอ่าวไทย

วัตถุประสงค์: เพื่อศึกษาลักษณะความผิดปกติของดุลเกลือแร่ในผู้ป่วยจมน้ำทะเลในอ่าวไทย บริเวณชายหาดบางแสน ที่เข้ารับการรักษาในโรงพยาบาลมหาวิทยาลัยบูรพาเพื่อใช้ในการวางแผนการรักษาต่อไป

วัสดุและวิธีการ: ศึกษาเวชระเบียนผู้ป่วยจมน้ำทะเลบริเวณชายหาดบางแสนที่รับการรักษาในโรงพยาบาลมหาวิทยาลัยบูรพา ย้อนหลังเป็นเวลา 10 ปี นำข้อมูลที่ได้มาวิเคราะห์หาความแตกต่างด้วย *Student's t-test*, *Chi-square test*, *Levene's test* และ *Scheffe's test*

ผลการศึกษา: กลุ่มตัวอย่างประกอบด้วยผู้ป่วยเพศชาย 23 ราย เพศหญิง 16 ราย อายุเฉลี่ย 14.46 ± 11.15 ปี มีผู้ป่วยอายุน้อยกว่าหรือเท่ากับ 10 ปี 19 ใน 39 ราย (ร้อยละ 48.72) ความผิดปกติของดุลเกลือแร่ที่พบบ่อยตามลำดับคือ *hypokalemia* ร้อยละ 20.51 *hypernatremia* ร้อยละ 30.77 *hyperchloremia* ร้อยละ 38.46 *high anion gap* ร้อยละ 58.97 *hypobicarbonatemia* ร้อยละ 71.79 ผู้ป่วย *hypokalemia* จำนวน 7 ราย จาก 8 ราย มีภาวะ *high anion gap* ร่วมด้วย ระดับความอิ่มตัวของออกซิเจนในเลือดของผู้ป่วยที่มี *high anion gap* ต่ำกว่าผู้ป่วยที่มี *normal anion gap* อย่างมีนัยสำคัญ ($87.06 \pm 17.68\%$ vs. $95.8 \pm 5.94\%$ $p = 0.031$) โดยที่มีระดับ *systolic blood pressure* ไม่แตกต่างกัน กลุ่มผู้ป่วยที่มีระดับความดันโลหิตต่ำมีระดับ *bicarbonate* ต่ำกว่า (17.00 ± 3.51 vs. 20.59 ± 3.81 $p = 0.038$) และ *anion gap* สูงกว่า (19.29 ± 1.799 vs. 16.25 ± 6.25 $p = 0.025$) กลุ่มที่มีความดันโลหิตปกติก็น่าจะมีความดันโลหิตต่ำ

สรุป: ความผิดปกติของดุลเกลือแร่ในผู้ป่วยจมน้ำทะเลที่พบบ่อยคือ *hypobicarbonatemia*, *high anion gap*, *hypernatremia* และ *hypokalemia* สาเหตุของ *high anion gap* น่าจะมาจากภาวะพร่องออกซิเจน และความดันโลหิตต่ำ
