Daily Sodium Intake during Acute Medical Management of Severe Pediatric Traumatic Brain Injury

Anwarul Haque[1] Naveedur Rehman Siddiqui[1] Sidra Kaleem Jafri[1] Gohar Javed[2]

[1] Department of Pediatrics and Child Health, Aga Khan University Hospital, Karachi, Pakistan
[2] Department of Neurosurgery, Aga Khan University Hospital, Karachi, Pakistan

Address for correspondence Anwarul Haque, MBBS, Department of Pediatrics and Child Health, Aga Khan University Hospital, Stadium Road, Karachi 74800, Pakistan (e-mail: anwar.haq@aku.edu).

Indian J Neurotrauma 2015;12:99–102.

Abstract

Aim The objective of this study is to assess the daily intake of sodium in first 3 days of all children with severe traumatic brain injury (TBI) admitted in pediatric intensive care unit (PICU) retrospectively in last 5 years.

Methods This was a retrospective chart review of all children (age: 1 month to 16 years) with severe TBI who received continuous infusion of 3% hypertonic saline for first 48 hours as a part of their acute medical management in PICU from January 2007 to December 2012. All children were managed as multidisciplinary team and acute medical management according to the published guidelines. Daily intake of sodium for first 48 hours was calculated.

Results A total of 79 patients were included in study cohort. The median age was 4.2 years and 75% were males. Fall ($n = 48$, 60%) and motor vehicle accident ($n = 22$, 27.8%) were the major mechanism of severe TBI. A total of 45% (36) required neurosurgical interventions. Overall, 86.1% ($n = 68$) were survived to discharge home with good neurological outcome. The daily sodium intake were 8.6 ± 3.8 mEq/kg and 9.6 ± 3.8 mEq/kg on day 1 and day 2, respectively. There were no significant complications associated with hypertonic saline infusion.

Conclusion The daily intake of sodium was high in initial management of severe TBI in children.

Keywords
- sodium
- children
- traumatic brain injury

Introduction

Traumatic brain injury (TBI) in children is common worldwide. Severe TBI in children is different from adult for few reasons. Children are more susceptible for diffuse injury and prone for cerebral edema (CE) and intracranial hypertension (ICH).[1,2] Hyponatremia is a known risk factor for CE and hyponatremic encephalopathy which is associated with high neurological morbidity and mortality.[3,4] Last two decades, there was an increased use of sodium in severe TBI for prevention and treatment of ICH and CE in the form of intravenous or oral use of hypertonic saline to keep normal or high-normal serum sodium in such cases.[5] Normal daily physiological requirement of sodium in children is 2 to 4 mEq/kg/d.[6,7] Very little information is currently available regarding daily intake of sodium in acute phase treatment of children with severe TBI.[8] The objective of this study is to calculate daily sodium intake in children with severe TBI during first 3 days of treatment in PICU.

received
June 11, 2015
accepted
October 6, 2015
published online
December 17, 2015

DOI http://dx.doi.org/10.1055/s-0035-1570096.
ISSN 0973-0508.

Methods

This is a retrospective chart review of all children admitted with a diagnosis of severe traumatic brain injury who received continuous infusion of hypertonic saline (CIHTS) in pediatric intensive care unit (PICU) of Aga Khan University Hospital, Karachi from January 2007 to December 2012. The PICU is a closed multidisciplinary cardiothoracic unit with annual admission of 600 per year. Patients were not included in study if children who developed diabetes insipidus or one who received intermittent hypertonic saline boluses or received infusion less than 48 hours were excluded. The ethical review committee of the local institution has approved this project (2062-Ped-ERC-13).

Protocol for Conventional Management of Head Trauma

All patients were treated according to the guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents.[9] Multidisciplinary team approach was involved in the care of severe TBI. All patients were mechanically ventilated and received invasive hemodynamic monitoring in PICU. Medical interventions in the PICU included elevation of head upto 30 degrees, sedation, analgesia, and paralysis, controlled moderate hyperventilation ($PaCO_2$, 30–35 mm Hg), mild hypothermia (33–35°C) with external cooling blanket, treat fever aggressively, maintain euvolemia (by keeping central venous pressure 8–10 cm of H_2O), and high normal systolic blood pressure for age by using inotropic and vasopressor agents. The high risk candidates for seizure or who had seizure were started on antiepileptic drugs such as phenytoin and leviacteram. We initiated enteral nutrition as soon as possible if there is no contraindication. We routinely check optic nerve sheet diameter for raised intracranial pressure on bedside of patients two or three times per day or as needed during first few days in PICU.[10]

Protocol for Continuous Infusion of Hypertonic Saline in Severe Traumatic Brain Injury

All children with severe TBI in PICU received CIHTS as has been described previously by Peterson et al.[11,12] The initial rate of CITHS was provided according to age at the rate mL/h (e.g., at the age of 4 year, the initial rate of CIHTS would be 4 mL/h). The target sodium level was 145–155 mEq/L.[13] Serum sodium, potassium, spot blood glucose, and arterial blood gas was checked every 6 hours during first 48 hours. After 48 hours, CIHTS was gradually tapered like by decreasing 1 mL every 2 to 4 hours to stop while watching for rebound. There was daily monitoring for side effects of CIHTS such as acute kidney injury, venous thrombosis, and infectious complications. Daily intake of sodium (mEq/kg/d) was calculated and recorded during the CIHTS.

Data Collection and Statistical Analysis

The following data were collected on structured data collection sheet from chart review, including demographic (age and gender), pertinent clinical variables, and daily intake of sodium (mEq/kg/d) for the first 2 days in PICU. Descriptive statistics was applied for analysis.

Outcome

The outcome of this study was to estimate the daily intake of sodium (mEq/kg/d) during the first two days in acute medical management of children with severe TBI in PICU of a developing country.

Results

During study period, 79 children were admitted with diagnosis of severe TBI in PICU. Baseline characteristics of patients were described in ►**Table 1**. The median age was 4.2 years and 75% ($n = 59$) were boys. The best initial Glasgow coma score after resuscitation was lower than 8. The most common mechanism of trauma were fall (60%, $n = 48$), motor vehicle accidents (27.8%, $n = 22$), and the rest of them were due to effect of bomb blast-related injuries. All children after resuscitation underwent for CT imaging: normal ($n = 7$), hematoma ($n = 15$), diffuse axonal injury ($n = 5$) and skull fracture ($n = 12$), and combination of bleed and contusion ($n = 35$). A total of 36 patients (45%) required neurosurgical treatment. The surgical treatments were as follows: 6 patients underwent external ventricular drain (EVD) for intracranial pressure monitoring, 13 patients required decompressive craniotomy, 15 patients underwent for evacuation of hematoma, and 2 patients for elevation of depressed skull fracture.

Only 6% ($n = 5$) have hyponatremia on presentation. To keep serum sodium between 145 and 155 mEq/L, sodium supplementation was given as CIHTS to all patients on a sliding scale. The intake of sodium was 8.6 ± 3.8 mEq/kg on day 1 and 9.6 ± 8.6 mEq/kg on day 2 in PICU. The daily serum sodium, urine output, fluid intake, and sodium intake was shown in ►**Table 2**. Only three subjects have serum sodium > 155 mEq/L in our cohort. We found no evidence of significant adverse effects of CIHTS in our cohort of patients. The survival rate was 86% ($n = 68$) with good neurological outcome.

Discussions

We found that the average daily intake of sodium was 8.9 mEq/kg/d during acute medical management of severe traumatic brain injury in PICU. We report our experience with use of CIHTS in children with severe traumatic brain injury in PICU of a developing country. HTS after TBI was first described in use since 1919 by Weed and Mckibben when its administration was found to reduce brain volume in cats. HTS has been shown to be effective in management of CE and ICH through multiple mechanisms of action. There are sufficient evidence permit for use of HTS to be included as an option for hyperosmolar therapy in the pediatrics.[14] As few studies have demonstrated the clinical beneficial effect in controlling ICH and a better outcome in terms of the mortality of prolonged use of HTS as a continuous infusion in severe TBI in children.[11,15,16]

Table 1 Characteristics of patients with traumatic brain injury

Characteristics	*N* =79 (100%)
Age median (IQR)	4.2 y (2–10 y)
Gender	
Male	59 (74.7)
Therapeutic hypothermia	13 (16.5)
Use of inotropes	21 (26.6)
Neurosurgical procedure	36 (45.6%)
EVD insertion	6
Decompressive craniotomy	13
Removal of hematoma (EDH/SDH)	15
Elevation of depressed fracture	2
Computed tomographic scan finding	
Hemorrhage	15 (18.98)
Fracture	12 (15.18)
Diffuse axonal injury	12 (15.18)
Mixed	47 (50.76)
Mechanism of injury	
Fall	48 (60.81)
Motor vehicle accidents	22 (27.8)
Miscellaneous	9 (11.39)
Outcome	
Survived	68(86.1%)
Expired	11(13.9%)

Abbreviations: EDH, epidural hemorrhage; EVD, external ventricular drain; IQR, inter-quartile range; SDH, subdural hemorrhage.

Table 2 Variable estimates

Variables	Day 1	Day 2
Serum sodium (mEq/L) mean (SD)	140.3 ± 5	143.34 ± 8.6
Urine output (mL/kg/d) mean (SD)	2.94 ± 1.29	3.3 ± 2.45
Fluid intake (mL/kg/d) mean (SD)	79.7 ± 27.7	89.5 ± 54.8
Daily sodium intake (mEq/kg/d) mean (SD)	8.6 ± 3.8	9.5 ± 7.2

Historically, the daily intake of sodium was 2 to 4mEq/kg/d was recommended in children. This was recommended from observation of urinary sodium excretion and dietary requirements of sodium about more than half century ago.[17] There was less information available regarding the hormones such as aldosterone and naturetic peptides, etc., during these days especially in the acute management of head trauma. However, the electrolyte requirement may vary a lot in various diseases. Sodium homeostasis is of great importance in pediatric neurocritically ill children. Hyponatremia is the most common electrolyte abnormalities in neurocritically ill children and is associated with significance morbidity and mortality.[3,4] It has been observed that the high requirement of sodium intake is necessary to maintain desired concentration of sodium during acute medical management of severe traumatic brain injuries in PICUs. Berkenbosch et al described the high intake of sodium from 3.7 to 15.6 mEq/kg/d in small case series of hyponatremia patients with acute brain injury in children.[8] Similarly, there was high intake of sodium during the CIHTS in the treatment of acute brain injury in children.[11,15] This is the first report which specifically designed to assess the need of sodium intake during the acute management of severe traumatic brain injuries in children.

There were several limitations in our reports. The retrospective, a single-center and small sample size are the few limitations. The strength of this study is that this is the first report described the daily intake of sodium during acute treatment of severe TBI in children from a developing country.

References

1 Bayir H, Kochanek PM, Clark RS. Traumatic brain injury in infants and children: mechanisms of secondary damage and treatment in the intensive care unit. Crit Care Clin 2003;19(3):529–549
2 Huh JW, Raghupathi R. New concepts in treatment of pediatric traumatic brain injury. Anesthesiol Clin 2009;27(2):213–240
3 Carpenter J, Weinstein S, Myseros J, Vezina G, Bell MJ. Inadvertent hyponatremia leading to acute cerebral edema and early evidence of herniation. Neurocrit Care 2007;6(3):195–199
4 Donati-Genet PC, Dubuis JM, Girardin E, Rimensberger PC. Acute symptomatic hyponatremia and cerebral salt wasting after head injury: an important clinical entity. J Pediatr Surg 2001;36(7):1094–1097
5 Bennett TD, Statler KD, Korgenski EK, Bratton SL. Osmolar therapy in pediatric traumatic brain injury. Crit Care Med 2012;40(1):208–215
6 Meyers RS. Pediatric fluid and electrolyte therapy. J Pediatr Pharmacol Ther 2009;14(4):204–211
7 Jospe N, Forbes G. Fluids and electrolytes—clinical aspects. Pediatr Rev 1996;17(11):395–403, quiz 404
8 Berkenbosch JW, Lentz CW, Jimenez DF, Tobias JD. Cerebral salt wasting syndrome following brain injury in three pediatric patients: suggestions for rapid diagnosis and therapy. Pediatr Neurosurg 2002;36(2):75–79
9 Kochanek PM, Carney N, Adelson PD, et al; American Academy of Pediatrics-Section on Neurological Surgery; American Association of Neurological Surgeons/Congress of Neurological Surgeons; Child Neurology Society; European Society of Pediatric and Neonatal Intensive Care; Neurocritical Care Society; Pediatric Neurocritical Care Research Group; Society of Critical Care Medicine; Paediatric Intensive Care Society UK; Society for Neuroscience in Anesthesiology and Critical Care; World Federation of Pediatric Intensive and Critical Care Societies. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents—second edition. Pediatr Crit Care Med 2012;13(Suppl 1):S1–S82
10 Marin J. Novel applications in pediatric emergency ultrasound. Clin Pediatr Emerg Med 2011;12(1):53–64

11 Peterson B, Khanna S, Fisher B, Marshall L. Prolonged hypernatremia controls elevated intracranial pressure in head-injured pediatric patients. Crit Care Med 2000;28(4):1136–1143
12 Qureshi AI, Suarez JI. Use of hypertonic saline solutions in treatment of cerebral edema and intracranial hypertension. Crit Care Med 2000;28(9):3301–3313
13 Bhardwaj A, Ulatowski JA. Hypertonic saline solutions in brain injury. Curr Opin Crit Care 2004;10(2):126–131
14 Kochanek PM, Carney N, Adelson PD, et al. Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. Chapter 8. Use of hyperosmolar therapy in the management of severe pediatric traumatic brain injury. Pediatr Crit Care Med 2012;13(Suppl1): S36–S41
15 Khanna S, Davis D, Peterson B, et al. Use of hypertonic saline in the treatment of severe refractory posttraumatic intracranial hypertension in pediatric traumatic brain injury. Crit Care Med 2000;28(4):1144–1151
16 Simma B, Burger R, Falk M, Sacher P, Fanconi S. A prospective, randomized, and controlled study of fluid management in children with severe head injury: lactated Ringer's solution versus hypertonic saline. Crit Care Med 1998;26(7):1265–1270
17 Holliday MA, Segar WE. The maintenance need for water in parenteral fluid therapy. Pediatrics 1957;19(5):823–832