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AN OBSERVATIONAL STUDY ON ELECTROLYTE DISTURBANCES IN TRAUMATIC BRAIN INJURY: PREVALENCE, PREDICTORS, AND PROGNOSTIC IMPLICATIONS

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ABSTRACT

Background: Traumatic brain injury, especially from road accidents, is a major health crisis in India affecting young adults. It disrupts electrolyte balance, leading to life-threatening complications. These imbalances worsen patient outcomes and contribute to high mortality rates. **Methods:** A prospective observational study was conducted on 102 TBI patients admitted to a tertiary care hospital. Clinical data, including Glasgow Coma Scale (GCS) scores, radiological findings, and serum electrolyte levels, were collected and analysed. **Results:** Road traffic accidents were the primary cause of TBI, with mild injuries being the most common. Electrolyte disturbances were observed in 33.33% of patients, predominantly involving sodium and potassium. Severe TBIs exhibited a higher incidence of electrolyte disturbances, notably hypernatremia and hypokalaemia, correlating with unfavourable outcomes. **Discussion:** Our findings corroborate previous studies, emphasizing the significance of electrolyte monitoring in TBI management. Severe injuries, especially those affecting the frontal lobe, predispose patients to electrolyte disturbances, necessitating vigilant monitoring and prompt correction. **Conclusion:** Electrolyte disturbances are prevalent in TBI patients, particularly in cases of severe injury, and are associated with adverse outcomes. Routine monitoring and timely correction of these disturbances are crucial for optimizing patient care and prognosis. This study underscores the need for further research to elucidate the underlying mechanisms of electrolyte disturbances in TBI and develop tailored management protocols, ultimately improving patient outcomes.

KEYWORDS : Traumatic Brain Injury, Electrolyte disturbances, Road Traffic Accidents

INTRODUCTION

Traumatic Brain Injury (TBI) is a critical medical condition that can lead to significant morbidity and mortality, imposing severe physical, emotional, and financial burdens on patients and their families. It remains a leading cause of death and disability worldwide, particularly affecting children and young adults[1]. In developing countries such as India, traumatic brain injuries resulting from road traffic accidents (RTAs) have reached epidemic proportions. These injuries cause over 100,000 deaths annually, with approximately 50-60% of cases requiring hospitalization due to brain injuries[2,3]. RTAs account for around 60% of head injuries and predominantly impact the intellectually and economically productive age group of 15-29 years[4].

The physiological regulation of body water and electrolytes involves complex neural and hormonal control mechanisms, centrally through the neurohypophysis and peripherally through renal and cardiac functions. Traumatic brain injuries can disrupt this delicate balance, leading to significant electrolyte disturbances . These disturbances may result directly from the brain injury or secondary to medical interventions. Additionally, pre-existing conditions such as renal failure, cirrhosis, or congestive heart failure can exacerbate these disturbances . Electrolyte disturbances are considered one of the preventable secondary injuries in head trauma[5].

The risk of developing electrolyte disturbances in traumatic brain injury patients is influenced by several factors, including the severity of the injury, underlying comorbidities, age, and primary therapeutic interventions. These interventions may include the choice of resuscitation fluids, administration of mannitol or diuretics, the syndrome of inappropriate antidiuretic hormone secretion (SIADH), cerebral salt wasting (CSW), and hyperventilation. Among serum electrolytes, sodium disturbance is the most frequently observed in traumatic brain injury patients. Studies by Suman S et al.[6] and Rafiq et al.[7] has identified hypernatremia as the most common electrolyte disturbance, followed by hyponatremia and hypokalaemia.

Serum electrolyte abnormalities (SEAs) are prevalent in cases of severe traumatic brain injury and are associated with adverse outcomes, including increased mortality, prolonged intensive care unit (ICU) stays, and poor prognostic scores. In addition to sodium, other commonly affected electrolytes include potassium, calcium, magnesium, and phosphate ions. The presence of multiple electrolyte abnormalities can further deteriorate the overall prognosis[7]. Electrolyte disturbances are a significant contributing factor to the high mortality rates associated with head injuries.

Objectives

1. To determine the prevalence of electrolyte disturbances in patients with traumatic brain injury.
2. To determine the relation of electrolytes disturbances with severity of traumatic brain injury.

MATERIALS AND METHODS

This study was conducted as an prospective observational study at a single tertiary care hospital, focusing on patients admitted with TBI to the Department of Neurosurgery from January 2021 to May 2023. A total of 102 patients were included in the study and informed consent was taken from all the patients. The inclusion criteria encompassed patients of all age groups with head injuries resulting from trauma. Patients with pre-existing conditions such as end-organ failure, diabetes mellitus, diabetes insipidus, and those on chronic diuretic therapy were excluded from the study. Upon admission, the level of consciousness of each patient was assessed using the Glasgow Coma Scale (GCS) score. A GCS score ≤ 8 means severe TBI, 9 to 12 means moderate TBI, and 13 to 15 means mild TBI. Additionally, a non-contrast computed tomography (NCCT) scan of the head was performed to evaluate the type and extent of the traumatic brain injury. Blood samples were collected using sterile techniques in plain vacutainer tubes and were promptly sent to the biochemistry laboratory for the assessment of serum sodium and serum potassium levels. Initial blood samples were collected at the time of admission, and follow-up samples were obtained 24 hours post-admission following resuscitation. All patients received standard treatment for TBI as per the institutional protocol. All samples were analysed using the Siemens ADVIA 1800 chemistry system. The study variables included age, sex, mechanism of injury, GCS score, CT scan findings, and serum levels of sodium and potassium at admission and 24 hours post-resuscitation. These data were systematically recorded for analysis. The reference ranges and SEAs were defines as following: The normal reference ranges for the serum Sodium was 135-145 mmol/L with Hyponatremia considered as level <135 mmol/L and Hypernatremia considered as level >145 mmol/L. The normal reference ranges for the Serum Potassium was 3.5-5.0 mmol/L with Hyponatremia considered as level <3.5 mmol/L and Hypernatremia considered as level >5.0 mmol/L. There were no cases of loss to follow-up, as all patients were admitted to the neuro-intensive care unit and monitored for outcomes 24 hours post-injury.

RESULTS

A total of 102 patients were included in this study. Table 1 shows Demographic and Clinical Characteristics. The age distribution of the patients showed that the majority patients 60 (58.82%) were in the 18-50 years age group, with 22 patients (21.56%) under 18 years and 20 patients (19.60%) over 50 years. The mean age of the patients was 38.51 years, with a range from 2 to 81 years. Among the participants, 71 (69.60%) were male and 31 (30.39%) were female. The most common mechanism of traumatic brain injury was road traffic accidents (RTAs), accounting for 86 patients (84.31%). Other mechanisms included falls from height (9 patients, 8.82%) and other causes such as assaults and injuries from heavy objects (7 patients, 6.86%). Upon admission, the distribution of Glasgow Coma Scale (GCS) scores indicated that mild head injuries were most common with distribution as follows: Mild (GCS > 13): 68 patients (66.66%), Moderate (GCS 9-12): 19 patients (18.62%), Severe (GCS ≤ 8): 15 patients (14.70%). Initial NCCT scan of brain revealed multiple types of injuries, with 47 patients (46.07%) having skull fractures, 45 patients (44.11%) with subarachnoid haemorrhage (SAH), 42 patients (41.17%) with haemorrhagic contusions, 29 patients (28.43%) with extradural hematomas (EDH), 25 patients (24.50%) with subdural haemorrhage (SDH), and 9 patients (8.82%) with diffuse axonal injury (DAI). We observed that individual patients exhibited multiple radiological findings, including combinations such as EDH with skull fracture, EDH with contusion, and EDH with SDH with contusion, among others. Consequently, the total number of findings identified surpassed the actual study population. Electrolyte disturbances were observed in a significant portion of the patients in the blood sample collected at the time of admission. Hyponatremia was present in 16 patients (15.68%), hypernatremia in 9 patients (8.82%), hypokalaemia in 10 patients (9.80%), and hyperkalaemia in 6 patients (5.88%) (Table 2). Severe head injuries were strongly associated with electrolyte disturbances; among the 15 patients with severe head injuries, 12 patients (80%) had sodium disturbance and 6 patients (40%) had potassium disturbance. Overall, 34 patients (33.33%) developed electrolyte disturbances following their traumatic brain injury, with 18 patients exhibiting sodium disturbances, 9 patients showing potassium disturbances, and 7 patients having both sodium and potassium disturbances. Among the 34 patients with electrolyte disturbances, 32 showed clinical improvement, while 2 patients, who had severe head injuries, succumbed to their injuries; one had hypernatremia and the other had hypokalaemia (Table 3). This suggests a potential link between severe electrolyte disturbances and poor outcomes in severe traumatic brain injury cases. Table 4 shows Distribution of Electrolyte Derangement in Traumatic Brain Injury patients based on brain region involved. It was observed that the frontal lobe was the most commonly affected region in patients with electrolyte disturbances, indicating that injuries to this region are more likely to be associated with such disturbances compared to injuries in other brain regions.

DISCUSSION

TBI remains a significant cause of morbidity and mortality, often accompanied by electrolyte disturbances that can exacerbate perioperative complications and worsen outcomes. Therefore, the effective management of electrolyte disturbances in patients with TBI is essential to mitigate these complications. Maintaining fluid balance is a critical component of treatment in these cases. Various factors, including the type of intravenous fluids used for resuscitation, the use of osmotic diuretics, massive blood loss, and underlying intracranial pathology, can contribute to electrolyte abnormalities in patients with TBI. Properly addressing and correcting these disturbances can significantly enhance patient outcomes.

In our study, 58.82% (60 out of 102) of the participants were aged between 18 and 50 years. Additionally, 21.56% (22 patients) were below 18 years of age, and 19.60% (20 patients) were above 50 years of age. This age distribution aligns with the findings of Jha et al.[1] and Suman S et al.[6], where the majority of TBI patients also fell within the 18-50 year age group. Similarly, Gupta et al.[8] reported a mean age of 37.78 years (ranging from 15 to 73 years) in their study, slightly lower than our mean age of 38.51 years, which spanned from 2 to 81 years. Our study showed a male predominance, with 69.60% (71 out of 102) of the participants being male, and 30.39% (31 patients) female. These observations are consistent with the studies by Jha et al.[1], Suman S et al.[6], and Gupta et al.[8], all of which reported a similar male predominance. Rafiq et al.[7] also found that 59.1% of their participants were male, suggesting a higher incidence of TBIs among males, likely due to greater involvement in outdoor activities.

The most common mechanism of TBI in our study was road traffic accidents, accounting for 84.31% (86 out of 102) of the cases. Falls from a height caused 8.82% (9 patients) of the injuries, while other causes, such as assaults and injuries from heavy objects, accounted for 6.86% (7 patients). These findings are consistent with those of Jha et al.[1] and Suman S et al.[6], who also identified road traffic accidents as the leading cause of TBI. Regarding the severity of TBIs, 66.66% (68 out of 102) of the patients in our study had mild TBIs (GCS score >13), 18.62% (19 patients) had moderate TBIs (GCS score of 9-12), and 14.70% (15 patients) had severe TBIs (GCS score ≤ 8). These results are in line with the findings of Jha et al.[1] and Suman S et al.[6], where mild TBIs were most prevalent. The most common radiological finding on NCCT scans at admission was a skull fracture, present in 46.07% (47 out of 102) of the patients. This was followed by subarachnoid haemorrhage in 44.11% (45 patients), haemorrhagic contusions in 41.17% (42 patients), extradural hematoma in 28.43% (29 patients), subdural haemorrhage in 24.50% (25 patients), and diffuse axonal injury in 8.82% (9 patients). These findings are consistent with those reported by Jha et al.[1], where out of 210 patients the most common CT scan finding was also skull fracture (21%), followed by EDH (20.47%), SDH (18.57%), SAH (14.76%), DAI (14.28%), and brain contusions (10.95%). In the study by Suman S et al.[6], out of 315 patients SAH (35%)was the most common NCCT finding at admission followed by SDH (22.53%), EDH (16.5%), DAI (9.5%), Intra Cerebral Haemorrhage (ICH) (6.5%) and Diffuse TBI (4.5%). These results highlight the variability in radiological findings among TBI patients.

In our study, the most common electrolyte disturbance was hyponatremia, observed in 15.68% (16 out of 102) of the patients, followed by hypokalaemia in 9.80% (10 patients), hypernatremia in 8.82% (9 patients), and hyperkalaemia in 5.88% (6 patients). The findings from Jha et al.[1] were consistent with our study, with hyponatremia being the most common electrolyte disturbance, followed by hypokalaemia, hypernatremia, and hyperkalaemia. Similar observations were made in studies by Gupta et al.[8] and Adiga et al.[9]. Sodium disorders were prevalent in 24.50% of our study population, aligning with the findings of Suman S et al.[6] and Jha et al.[1]. Hyponatremia was more common than hypernatremia in these cases. Hyponatremia in TBI patients can occur as a result of conditions such as the SIADH and CSW syndrome, characterized by natriuresis. Additionally, dilutional hyponatremia and brain natriuretic peptide may contribute to the development of hyponatremia in TBI patients. Hypernatremia in TBI patients can be caused by factors such as diabetes insipidus, hypothalamic-pituitary dysfunction (common in TBI), and the use of mannitol and hypertonic saline.

In our study, potassium derangements were observed in 15.88% (16 out of 102) of patients. Hypokalaemia were found in 9.68% (9 patients), while Hyperkalaemia levels were observed in 5.88% (6 patients). These changes in potassium levels may be attributed to various factors related to brain trauma. Low serum potassium levels can be influenced by increased urinary loss, which may occur as a result of brain trauma-related conditions such as SIADH and CSW syndrome. High potassium levels may be associated with the release of large amounts of catecholamine, known to accompany severe head trauma. The stimulation of beta2-adrenergic receptors by catecholamine can lead to the activation of the Na^+-K^+ pump, potentially resulting in increased serum potassium levels[10].

We observed that, severe TBI patients had a higher incidence of electrolyte disturbances. Among the 15 severe TBI patients, 80% (12 patients) had sodium disturbance, and 40% (6 patients) had potassium disturbance. Similarly, in the study conducted by Jha et al.[1], a higher prevalence of electrolyte abnormalities was observed in severe TBI patients. Among the 48 severe TBI patients, 95.83% (46 patients) had abnormal sodium levels, and 68.75% (33 patients) had abnormal potassium levels. The exact mechanism underlying the development of electrolyte disorders in severe TBI patients remains unclear. However, it is believed that shifts of electrolytes from the extracellular compartment to the intracellular compartment and electrolyte loss through polyuria in TBI contribute to these disturbances. In our study, among the 34 patients with electrolyte disturbances, 32 patients showed improvement, while 2 patients unfortunately expired. 1 patient had severe TBI with hypernatremia, and the other had severe TBI with hypokalaemia. This suggests that these specific electrolyte disturbances, when combined with severe TBIs, were associated with unfavourable outcomes. Similarly, in the study conducted by Dheeraj Kumar Raj et al.[11], poor outcomes were reported in patients with hypernatremia and hypokalaemia. Table 5 shows the comparison of result of our study with the study done by Jha et al.[1] and Suman S et al.[6].

Our study focused on the occurrence of electrolyte disturbances in patients following TBI. Among the 34 patients included in our analysis, we found that the most frequently affected region was the frontal lobe. Based on this observation, we have concluded that injuries specifically affecting the frontal lobe are associated with a higher incidence of electrolyte disturbances compared to injuries in other lobes of the brain. This suggests a potential link between frontal lobe injury and disruptions in electrolyte homeostasis, which may have important implications for the management and prognosis of patients with TBI. Given the potential implications for patient outcomes after TBI, it is crucial to routinely measure serum electrolyte levels in all patients with TBI, particularly in those with severe TBI. Disturbances in these electrolytes can go unnoticed for an extended period, leading to poor outcomes.

CONCLUSION

TBI remains a significant cause of morbidity and mortality, with electrolyte disturbances frequently observed among affected patients. Effective management of these disturbances is critical for improving patient outcomes. Our study revealed that the majority of TBI patients fell within the age group of 18-50 years, with a higher prevalence observed among males. Road traffic accidents were identified as the leading cause of TBIs, emphasizing the need for targeted prevention strategies. Our findings indicated that mild TBIs were most common, with skull fractures being the predominant radiological finding. Hyponatremia emerged as the most frequent electrolyte disturbance, followed by hypokalaemia, hypernatremia, and hyperkalaemia. These results were consistent with previous studies, highlighting the importance of routine monitoring of serum electrolyte levels in TBI patients. Severe TBI patients exhibited a higher incidence of electrolyte disturbances, with sodium disorders being particularly prevalent. The study underscores the complexity of managing electrolyte homeostasis in TBI patients, suggesting that injuries to specific brain regions, such as the frontal lobe, may predispose patients to these disturbances. The association of severe head injuries with unfavourable outcomes in patients presenting with significant electrolyte abnormalities, such as hypernatremia and hypokalaemia, underscores the necessity for vigilant monitoring and timely correction of these disturbances. This comprehensive understanding of the patterns and implications of electrolyte disturbances in TBI patients can guide clinical practices, ultimately enhancing patient care and prognosis. Further research is warranted to explore the underlying mechanisms of electrolyte shifts in TBI and to develop optimized protocols for their management. By prioritizing the identification and correction of electrolyte disturbances, healthcare providers can significantly mitigate the perioperative complications and improve the overall outcomes for TBI patients.

Table 1: Demographic and Clinical Characteristics

Parameters		Number of Patients (n=102)	Percentage
Age	<18 years	22	21.56%
	18-50 years	60	58.82%
	>50 years	20	19.60%
Sex	Male	71	69.60%
	Female	31	30.40%
Mechanism of Injury	Road Traffic Accident	86	84.31%
	Fall from height	9	8.82%
	Others (Assault, Injury by heavy objects)	7	6.86%

Severity of Head Injury	Mild (13-15)	68	66.66%
	Moderate (9-12)	19	18.62%
	Severe (≤8)	15	14.70%
NCCT findings	Skull Fracture	47	46.07%
	Extra Dural Hemorrhage	29	28.43%
	Sub Dural Hemorrhage	25	24.50%
	Sub Arachnoid Hemorrhage	45	44.11%
	Diffuse Axonal Injury	9	8.82%
	Hemorrhagic Contusion	42	41.17%

NCCT: non-contrast computed tomography

Table 2: Distribution of Electrolyte Derangements in Traumatic Brain Injury Patients by Severity

Electrolyte	Type of Electrolyte Derangement	Severity of Traumatic Brain Injury			Number of Patients (Percentage)
		Mild (GCS 13-15)	Moderate (GCS 9-12)	Severe (GCS ≤8)	
Sodium	Hyponatremia	2	6	8	25 (24.50%)
	Hypernatremia	3	2	4	
Potassium	Hypokalemia	2	4	4	16 (15.68%)
	Hyperkalemia	3	1	2	

GCS: Glasgow Coma Scale

Table 3: Patient Outcomes After Resuscitation Based on Type of Electrolyte Derangement

Type of Electrolyte Derangement	Number of patients improved after resuscitation	Number of patient expired
Hyponatremia	16	0
Hypernatremia	8	1
Hypokalemia	9	1
Hyperkalemia	6	0

Table 4: Distribution of Electrolyte Derangement in Traumatic Brain Injury Patients Based on Brain Region Involved

Region Involved	Number of Patients
Frontal Lobe	5
Frontal and Temporal Lobe	4
Frontal, Temporal and Parietal Lobe	16
Frontal and Parietal Lobe	2
Diffuse Axonal Injury	7
Posterior Fossa	0

Table 5: Comparison of Study Criteria with Previous Studies

Criteria	Our Study	Jha et al., 20161	Suman et al., 20166
Age	18-50 years (58.82%)	18-50 years (58.09%)	18-50 years (89%)
Gender (M:F)	3:1	3:1	3:1
Most common Mechanism of Injury	RTA (84.31%)	RTA (56.67%)	RTA (67%)
Most common NCCT findings	Skull Fracture (46.07%)	Skull Fracture (21%)	Subarachnoid Hemorrhage (35%)
Most common type of TBI	Mild (66.66%)	Mild (44.3%)	Mild (55%)
Most common Electrolyte derangement	Sodium> Potassium	Sodium> Potassium> Calcium	Sodium> Potassium> Calcium
Most common pattern of Electrolyte derangement	Hypo-natremia> Hypo-kalemia> Hyper-natremia> Hyper-kalemia	Hypo-natremia> Hypo-kalemia> Hyper-natremia> Hyper-kalemia	Hyper-natremia> Hypo-kalemia> Hypo-natremia> Hyper-kalemia

M: Male, F: Female, RTA: Road Traffic Accident, TBI: Traumatic Brain Injury

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