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Is There a Relationship between the Types and Severity of Acute Traumatic Brain Injuries in Children and Adolescents and the Incidence of Cardiac Arrhythmias?

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Abstract

Background: Traumatic Brain Injury (TBI) in children is one of the most common causes of death and disability in children. Cardiac arrhythmias can be cited as one of the main factors influencing the mortality and morbidity of these children. The purpose of this study was to investigate the frequency and types of cardiac arrhythmias in children with TBI in the Intensive Care Unit (ICU) of Bahonar Hospital in Kerman.

Methods: This study is a cross-sectional descriptive-analytical study examining patients under 18 years of age who were admitted to the ICU with TBI during 2018-2019 for cardiac arrhythmias. Data were collected using a checklist, including demographic characteristics and other variables in the patient's file. Finally, the data were analyzed using SPSS version 22.

Results: Forty-six of the 240 traumatized patients admitted to the ICU developed cardiac arrhythmias, the most common of which was sinus tachycardia. The incidence of arrhythmias was significantly higher in patients with subarachnoid hemorrhage (SAH), cerebral contusion, and intracerebral hemorrhage (ICH) than in those with other brain lesions. Most bradycardia was seen in mixed lesions. Dangerous arrhythmias, such as bradycardia and ventricular tachycardia (VT), were also significantly more common in the severe trauma group.

Conclusion: It seems that in children with a head injury, the incidence of cardiac arrhythmias is significantly associated with the Glasgow Coma Scale (GCS) and some lesions due to brain trauma such as SAH, ICH, and brain contusion.

Key Words: Brain lesions, Cardiac arrhythmias, Glasgow Coma Scale (GCS), Head injury, Intensive care unit (ICU), Pediatrics, Traumatic Brain Injury (TBI).

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1- INTRODUCTION

Traumatic brain injury (TBI) in children is an important problem, especially in developing countries (1). Trauma is the most common cause of death in children aged 1-14 years, and TBI accounts for 40% of deaths due to fatal trauma in pediatrics (2). The main causes of TBI in children are falls and accidents (3). In the USA, 475,000 children per year are admitted to the emergency room due to TBI (4).

Arrhythmias and electrocardiographic (ECG) changes are due to catecholamine and cytokine release and occur in the first few days after concussion (5). Cardiac problems after subarachnoid hemorrhage (SAH) include myocardial dysfunction and electrical (ECG) changes (6). Regional wall motion abnormalities are mostly due to catecholamine-induced myocardial injury (7). ECG changes after TBI often occur in the absence of coronary vessel injuries (8, 9), and it is usually seen in patients with severe TBI and high intracranial hypertension. The most common ECG changes reported in these patients include prolongation of the QT interval, ST segment abnormalities, flat or inverted T waves, U waves, peaked T waves, Q waves, and widened QRS complexes (10). Most of the ECG changes due to TBI are transient and resolve within 2 weeks (11). Among these changes, prolonged QTc syndrome is closely related to SAH and the severity of brain injury; and may predispose the patients to ventricular arrhythmias such as torsade s de pointes (12).

The most common cause of myocardial injury after severe TBI is sympathetic hyperactivity (13), leading to an increased afterload related to hypertension and tachycardia and a secondary increase in myocardial O_2 demand. The catecholamine surge may also cause direct injury to the myocardium and sub endocardial hemorrhage, which is reported in up to 50% of patients who died from a head injury (14). In 15.7% of patients with fetal head trauma, global systolic dysfunction and regional wall motion abnormalities were reported (15). Left ventricular dysfunction is a consequence of sympathetic hyperactivity, which is often reversible (16). ECG abnormalities, particularly symmetrical T wave inversion or prolonged QTc, are risk factors for left ventricular systolic dysfunction (17).

In some cases, bradycardia is observed due to the Cushing triad. Depression of sympathetic activity may be due to brainstem dysfunction or neurogenic shock (18). In one study, neurogenic hypotension occurred in 13% of patients with an isolated head injury and was associated with higher mortality than hemorrhagic hypotension (19).

The most important measures include treating brain problems and eliminating the underlying causes of arrhythmias such as hypothermia (20). The aim of this study was to investigate the prevalence of various cardiac arrhythmias in children after TBI and their relationship with the severity of TBI and the type of brain lesions.

2- MATERIALS AND METHOD

This study was registered in the research department of Kerman University of Medical Sciences. Patients under 18 years old admitted to the ICU due to TBI from June 2017 to June 2019 were evaluated for incidence and type of arrhythmia during the first 3 days of hospitalization. Also, the average urinary level of vanillylmandelic acid (VMA) during this period was measured and compared with cardiac findings and the Glasgow Coma Scale (GCS) of patients. All patients with ECG changes were consulted by a pediatric cardiologist, and if necessary, echocardiography was requested to rule out the underlying heart disease.

2-1. Inclusion and exclusion criteria

Inclusion criteria encompassed trauma patients under 18 years of age admitted to the ICU of Shahid Bahonar Hospital in Kerman during the first 24 hours of trauma.

Exclusion criteria were chest trauma, hypoxemia, hypercapnia, severe hypotension, electrolyte disturbance, previous heart disease, severe acidosis, and arrhythmogenic drug use in the last 24 hours.

2-2. Data Analysis

Data (including age, sex, type of brain lesion, GCS, and type of arrhythmia) were collected and statistically analyzed using SPSS version 22 (SPSS Inc., Chicago, Ill, USA). *P* values less than 0.05 were considered statistically significant.

3- RESULTS

From among the 240 patients, 159 were male and 81 were female, while out of the 46 (19.1%) patients who underwent ECG, 27 (58.7%) were male and 19 (41.3%) were female. There was no significant relationship between the frequency of cardiac arrhythmias and gender *(P* = 0.228).

The mean age of patients was 10.18 ± 5.21 years, the mean age of patients with arrhythmia was 9.93 ± 5.18 years, and the mean age of other patients without arrhythmia was 10.25 ± 5.23 years. There was no relationship between the frequency of arrhythmias and mean age (*P* = 0. 704; **Table 1**).

Table-1: Relationship between patients' demographic information and arrhythmia prevalence.

Variables	Total		With arrhythmia	Without arrhythmia	*P* value
Sex	Male	159 (66.2%)	27 (58.7%)	132 (68%)	0.228
	Female	81 (33.8%)	19 (41.3%)	62 (32%)	
Age	10.18 ± 5.21		9.93 ± 5.18	10.25 ± 5.23	0.704

The most common arrhythmia were Sinus Tachycardia (50%), PAC (17.3%), Bradycardia (10.8%), PVC (6.5%), SVT (6.5 %), VT (4.3%), and JET (4.3%) Respectively (**Table 2**).

Table-2: Prevalence of arrhythmias in children with TBI

Arrhythmia type	Sinus tachycardia	PAC [a]	Bradycardia	PVC [b]	SVT [c]	VT [d]	JET [e]
Prevalence %	23 (50%)	8 (17.3%)	5 (10.8%)	3 (6.5%)	3 (6.5%)	2 (4.3%)	2 (4.3%)

a) premature atrial contraction, b) Premature ventricular contraction, c) Supraventricular tachycardia, d) Ventricular tachycardia, e) Junctional ectopic tachycardia

The incidence of cardiac arrhythmias based on the type of brain lesions included 14 cases (30.4%) in SAH, 10 cases (21.7%) in brain contusion, 8 cases (17.4%) in intracerebral hemorrhage (ICH), 6 cases (13%) in mixed pathologies, 4 cases (8.7%) in diffuse axonal injury (DAI), and 4 cases (8.7%) in intraventricular hemorrhage (IVH), respectively. Evidence shows that patients

with SAH, brain contusion, and ICH significantly had, respectively, more cardiac arrhythmias than other brain pathologies (P = 0. 001).

Thirty-one (67.4%) of arrhythmias were in the severe TBI group, 13 (28.3%) in the moderate group, and 2 (4.3%) in the mild TBI group (*P* = 0. 001). Also, 10 (71%) of the 14 cases manifested elevated urinary catecholamine metabolites at the initial presentation. Also, the mean urinary level of VMA was 1.7 times the upper normal limit; however, in patients with arrhythmia, it was 2.4 times, and in patients without arrhythmia, it was 1.3 times the upper normal limit (related to patients' age)which was statistically significant (P = 0. 01; **Table 3**).

Table-3: Relationship between the type of brain lesion urinary VMA level and the prevalence of cardiac arrhythmias

Variables		Total	With arrhythmia	Without arrhythmia	P value
Brain lesion type	DAI [a]	84 (35%)	4 (8.7%)	80 (41.5%)	0.001
	Contusion	79 (32.9%)	10 (21.7%)	68 (35.2%)	
	IVH [b]	9 (3.8%)	4 (8.7%)	5 (2.6%)	
	SAH [c]	37 (15.4%)	14 (30.4%)	23 (11.9%)	
	ICH [d]	20 (8.3%)	8 (17.4%)	12 (6.2%)	
	MIX	11	6 (13%)	5 (2.6%)	
GCS [e]	>12	42 (17.6%)	2 (4.4%)	40 (20.7%)	0.001
	12-9	125 (52.3%)	13 (28.3)	112 (58%)	
	<9	72 (30.1%)	31 (67.4%)	41 (21.2%)	
Mean urinary level of VMA[f]/upper normal limit		1.7	2.4	1.3	0.01

a) Diffuse axonal injury, b) Intraventricular hemorrhage, c) Subarachnoid hemorrhage, d) Intracerebral hemorrhage, e) Glasgow Coma Scale, f)Vanillylmandelic acid

As can be seen in **Table 4**, comparing the mean urinary level of VMA with different TBI groups showed that mean urinary VMA was 1.2 times the upper normal limit in the mild brain injury group (GCS > 12), 1.6 times the upper normal limit in the moderate TBI group (GCS 9-12), and 2.5 times the upper normal limit in the severe TBI group (GCS < 9) for patients age. Based on these findings, there is a significant relationship between the urinary level of VMA and the severity of brain injury; thus, with increasing severity of TBI, the level of VMA also increased significantly (*P* = 0. 01; **Table 4**).

Table-4: Relationship between GCS and urinary VMA level

Variables		Mean urinary level of VMA /upper normal limit	P value
GCS e	>12	1.2	0. 01
	12-9	1.6	
	<9	2.5	

Out of the 46 subjects of cardiac arrhythmia, 5 cases were bradycardia (all of them were in the severe TBI group). Out of the 8 cases of PAC, 4 cases (50%) were in the severe TBI group and 4 cases (50%) in the moderate TBI group. Out of

the 23 patients with sinus tachycardia, 12 cases (52.2%) were in the severe TBI group, 9 cases (39.1%) in the moderate TBI group, and 2 cases (8.7%) were in the mild TBI group. All of the patients with supraventricular tachycardia (SVT), junctional ectopic tachycardia (JET), ventricular tachycardia (VT), and PVC (Premature ventricular contractions) were in the severe TBI group.

4- DISCUSSION

Out of 240 head trauma pediatrics, 46 (19.1%) patients had ECG changes. Our results showed no significant relationship between the frequency and the type of cardiac arrhythmia with age and sex of patients. However, the incidence of arrhythmias was significantly associated with the severity of TBI; thus, 67.4% of arrhythmias were observed in the severe TBI group, 28.3% in the moderate group, and 4.3% in the mild TBI group. There was a significant relationship between the types of brain lesions and the incidence of arrhythmias; thus, 30.4% of arrhythmias occurred in patients with SAH, 21.7% in patients with brain contusions, 17.4% in patients with ICH, 13% in patients with mixed lesions, 8.7% in patients with DAI, and 8.7% in patients with IVH.

So far, several studies have been performed to identify the predisposing factors and frequency of arrhythmias in children with TBI. For instance, Grunsfeld et al. showed that the most common post-traumatic arrhythmias were sinus tachycardia, PAC, PVC, and AF)Atrial fibrillation), usually seen in the first 7 days after TBI. Severe and dangerous arrhythmias such as VF and torsade s de point were less common (21). In our study, the most common arrhythmias after TBI were sinus tachycardia, PAC, bradycardia, and PVC, respectively. SVT and then VT and JET, were observed less frequently. The slight differences in the results of these two studies may be due to differences in the statistical population and differences in age groups of patients. Many studies have suggested the effect of sympathetic hyperactivity after brain trauma and its association with the incidence of cardiac arrhythmias. Gregory and Smith (2012) found that increased sympathetic system activity after a severe TBI caused myocardial damage. Also, most neurogenic arrhythmias were benign, and fatal arrhythmias (such as VT) occurred less frequently. Further, 38% of SAH patients developed arrhythmias, of which 5%-8% developed life-threatening arrhythmias such as VT (22).

Goldstein et al. showed that sympathetic hyperactivity in children with TBI was an important factor in the development of cardiac arrhythmias and that plasma levels of catecholamine might be useful in determining the prognosis and recovery rate of TBI children (23). Krishnamoorthy et al. found that TBI increased the activity of the neuroendocrine system and the release of large amounts of catecholamines. Besides myocardial dysfunction and arrhythmia, increased intracranial pressure (ICP) also caused the release of catecholamines from the ends of the sympathetic fibers (24). Our results also showed a direct relationship between the urinary level of VMA as a metabolite of epinephrine and the severity of brain trauma, which can cause arrhythmia in severe brain injury in children and adolescents.

According to Abhik et al., in TBI children, the most common arrhythmias were observed in those with ICP more than 30 mm Hg; they mentioned that the most important cause of arrhythmias in these patients was autonomic system hyperactivity (25). Grosse-Wortmann et al. (2006) reported an 8-year-old child with TBI who developed a variety of arrhythmias during the hospital stay period, including SVT and PVC, prolonged QT interval and ventricular fibrillation, JET, and reentry tachycardia.

Each arrhythmia had a separate pathogenic pathway, and not all were associated with high ICP (26). However, Novkoski et al. showed a direct relationship between ICP and patients' clinical conditions. In patients with lower GCS, they observed higher ICP (27).

The present study used GCS as a measure of the severity of brain injury. As in the above studies, with a decrease in GCS, we observed an increase in the incidence of arrhythmias; thus, 67.4% of arrhythmias were observed in the severe trauma group, and the prevalence of dangerous arrhythmias (such as bradycardia and VT) was higher in this group. The protective effect of mild hypothermia in TBI patients was proven; however, Bourdages et al., aiming to evaluate the effect of therapeutic hypothermia on the incidence of cardiac arrhythmias in pediatrics with TBI, found that 77% of children who developed cardiac arrhythmias were hypothermic (28). Kanev found that the prevalence of cardiac arrhythmia was significantly higher in hypothermic TBI children than in normothermic patients. Severe hypothermia (temperature < 30 °C) causes long QT and inverted T waves (29). Also, Osborn found that severe hypothermia (core temperature < 32 °C) could lead to dangerous cardiac arrhythmias in TBI children (30). Due to the direct effect of hypothermia on the prevalence of various arrhythmias in trauma patients, we eliminated their hypothermia before the evaluation of ECG changes. However, in the study by Bourdages et al., the prevalence of arrhythmia in head injury children with normothermia was 22%, which is consistent with our study (19.1%).

Abrisham kar et al. showed that patients with severe TBI were at risk for electrolyte disorders (including hypokalemia); hypocalcemia and hypomagnesemia could lead to prolonged QT and fatal arrhythmias (31). Suman et al. indicated that out of 18 severe injuries, 10 (55.5%) had abnormal sodium levels and 3 (16.6%) had abnormal potassium levels, leading to the prolongation of the QT interval and lethal arrhythmias (32). Mierzewska-Schmidt and Gawecka concluded that neurogenic stunned myocardium (NSM; a sudden onset of myocardial dysfunction after severe brain injury) was a result of an imbalance in the autonomic nervous system. The most common ECG changes include the prolonged QT interval, ST segment changes, T-wave inversion, and new Q-wave or U-wave (33). Kerro et al. revealed that NSM that followed SAH could result in many complications such as arrhythmias, pulmonary edema, and prolonged intubation, which can negatively impact long-term recovery from SAH; and increase morbidity and mortality. This necessitates the need to accurately diagnose and treat NSM (34).

5- CONCLUSION

It seems that in children, there is a direct relationship between the severity of TBI and the risk of cardiac arrhythmia.

Also, the highest rates of arrhythmias were in patients with SAH, brain contusion, ICH, mixed lesions, DAI, and IVH, respectively. In children with moderate to severe TBI, continuous cardiac monitoring should be established in addition to correcting the underlying causes of arrhythmia.

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