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ECG Changes in Children with Convulsions at Sohag University Hospital

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ABSTRACT

Background: Convulsion is a common problem encountered in the emergency department and represent a major source of morbidity, many children are admitted to emergency department and PICU with different clinical types of convulsions due to different etiologies. Frequent electrocardiographic (ECG) alterations are commonly observed during and following convulsions, indicating that individuals experiencing convulsions often possess significant risk factors for cardiac strain, which in turn typically correlates with elevated morbidity and mortality rates.

Objective: To identify electrocardiogram (ECG) abnormalities in pediatric patients with various etiologies of convulsions.

Patients and Methods: This cross-sectional hospital-based research was carried out at Pediatric Emergency Department and PICU at Sohag University Hospital during the period from January 2022 to September 2023. 12 leads ECG had been done to all children aged one month to eighteen years old who presented to the Pediatric Emergency Department with convulsions.

Results: 200 children were included in the study, 104 (52%) males and 96 (48%) females with male to female ratio was 1.08:1. The age of children ranged between 1 month to 12 years with mean age was 3.75± 3.19 years. More than half of children (58%) were between 2-10 years and the least group represented was between 11-18 years (3%). Consanguinity was reported in more than half of children (57%). Encephalopathy was the most common cause of convulsions in children (34%), generalized tonic-clonic convulsions was the most frequent type of convulsions (89%). A statistically significant distinction was discovered among types of convulsions related to PR interval ($p<0.001$) as it was highest in epilepsy. However, no significant variance was found among types of convulsions related to QTc interval ($p=0.220$).

Conclusion: QTc interval was not significantly varied amongst the various seizure sources. There was significant variance among various causes of convulsions as regard heart rate and PR interval.

Keywords: Paediatric, ECG, PR interval, Convulsions.

INTRODUCTION

A significant proportion of patients saw a rise in cardiac necrosis and dysfunction indicators after protracted convulsions, which might signal the beginning of myocardial damage [(1)]. While seizures impact several autonomic parameters, the most significant expression is seen in cardiovascular symptoms. During maximal seizures, sympathetic reactions are more common and can result in tachycardia, tachypnea, elevated blood pressure, pupillary dilatation, diaphoresis, and face flushing [(2)]. They might also lead to dysregulation of the functioning ANS [(3)].

Changes in cardiac characteristics like heart rate result from autonomic dysfunction [(4)]. Seizures have also been related to cardiovascular alterations [(5)]. Especially QT prolongation that has the danger of serious dysrhythmia [(6)]. Relevant abnormalities like prolonged QTc interval or cardiac block can be detected by a 12-lead ECG, which is an inexpensive test. Hypocalcemia as a cause of convulsions can be identified on an electrocardiogram (ECG) by a QTc prolongation due to a ST segment elongation, the severity of which is inversely related to the serum calcium level [(7)].

Our study aim was to detect cardiac ECG abnormalities in children with different causes of convulsions.

PATIENTS AND METHODS

This cross-sectional hospital-based research was carried out at Pediatric Emergency Department and PICU at Sohag University Hospital during the period from January 2022 to September 2023.

Children with convulsions as young as one month old to as old as eighteen years old were enrolled in this study. Children with preexisting heart disorders or known cardiac arrhythmias were excluded.

All children subjected to:

Complete history taking, physical examination, cardiac examination, neurological examination (including Glasgow coma scale), laboratory investigation (complete blood count, renal function, and serum electrolytes) and 12-lead electrocardiogram were done to all patients.

ECG was done within 24 hours of admission utilizing a Fukuda Denshi CardiMax FCP 7101 (UK). Analysis of ECG included heart rate, rhythm, PR interval and QT interval. The QT interval was calculated by the time it took for the terminal T wave to return to the isoelectric T-P baseline from the beginning of the QRS complex. Bazett's method used to make adjustments of the QT interval for changes in HR.

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Using certain centile tables for the usual values of ECG waves and intervals according to age, each ECG paper was interpreted [8]. CT or MRI of the brain and echocardiography were performed if indicated.

Ethical approval:

Sohag Medical Ethics Committee of the Sohag Faculty of Medicine gave its approval to this study. Before any child participant was recruited for the study, the parents of all the participant were informed in writing of the study's aims and they gave their consent. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis

SPSS version 25.0 was utilised for data analysis after being input into the computer. The qualitative data were described in terms of numbers and percentages. The Shapiro-Wilk test was used to make sure the the sample was normally distributed. The quantitative data were characterised using the following metrics: mean, standard deviation, median, interquartile range (IQR), and range values. The Kruskal-Wallis test and Spearman's technique of correlation analysis were applied. A P value of less than 0.05 was deemed significant.

RESULTS

A total of 200 participants, comprising 104 (52%) males and 96 (48%) females were involved in the study. The male to female ratio was calculated to be 1.08:1. The age of the children in the study varied from 1 month to 12 years. 58%, fell into the age range of 2 to 10 years. A prevalence rate of 57% was observed for consanguinity among the children included in the study (Table 1).

Table (1): Demographic data among the studied children.

		Studied patients (N= 200)	
		N	%
Gender	Male	104	52.0%
	Female	96	48.0%
Age (years)	Mean± SD	3.75± 3.19	
	Range	1 month – 12 years	
Age groups	<2 years	78	39.0%
	2-10 years	116	58.0%
	11-18 years	6	3.0%
Consanguinity	No	86	43.0%
	Yes	114	57.0%

Encephalopathy emerged as the predominant etiology for convulsions in children, accounting for 34% of cases. This was followed by epilepsy, which was identified in 22% of cases (Table 2).

Table (2): Primary illness among the studied children

		Studied patients (N= 200)	
		N	%
Primary illness	Encephalopathy	68	34.0%
	Epilepsy	44	22.0%
	CNS infection	26	13.0%
	Genetic	20	10.0%
	Febrile convulsion	16	8.0%
	Electrolyte disturbance	12	6.0%
	Trauma	6	3.0%
	Poisoning	4	2.0%
	Others	4	2.0%

Generalized tonic-clonic convulsions was the most frequent type of convulsions found in most children (89%). The median duration of convulsions was 6 minutes and ranged from 2 minutes to 5 days as shown in table (3).

Table (3): Clinical characteristics among the studied children

		Studied patients (N= 200)	
		N	%
Type of convulsion	G.T.C	178	89.0%
	Focal tonic-clonic	12	6.0%
	Tonic convulsion	8	4.0%
	Myoclonic	2	1.0%
Duration of convulsions (months)	Median (IQR)	6.0 (5.0- 15.0)	
	Range	2 minutes – 5 days	

N: Number, %: Percentage, IQR: Interquartile range, G.T.C: Generalized tonic-clonic.

ECG was done for the studied children and the results revealed that sinus tachycardia occurred in 165 patient 82.5%. Significant difference was found between different causes of convulsions as regard heart rate (Table 4).

Table (4): Relation between heart rate and causes of convulsions.

		Heart rate						
		Mean	**SD**	**Median**	**IQR**		**Range**	
Causes of convulsion	CNS infection	145.4	20.6	142.0	130.0	157.0	120.0	182.0
	Electrolyte Disturbance	115.3	32.2	113.5	83.0	150.0	75.0	157.0
	Encephalopathy	131.0	26.8	125.0	115.0	150.0	81.0	214.0
	Epilepsy	108.5	23.0	107.0	93.0	121.0	71.0	157.0
	Febrile convulsion	145.5	14.0	150.0	139.0	157.0	115.0	157.0
	Genetic	124.1	30.4	120.0	115.0	125.0	91.0	200.0
	Poisoning	119.5	26.0	119.5	97.0	142.0	97.0	142.0
	Trauma	160.0	22.9	157.0	136.0	187.0	136.0	187.0
	Others	148.0	32.3	148.0	120.0	176.0	120.0	176.0
Test value		KW=55.76						
P-value		<0.001						

There was significant negative correlation between heart rate and GCS and age (Table 5).

Table (5): Correlation between and heart rate and different parameters in children with convulsions

	Heart rate	
	r	**p- value**
Age (years)	-0.408	<0.001
Duration of convulsion (minutes)	0.105	0.144
GCS	-0.230	0.001
Na^+	0.070	0.327
K^+	0.053	0.464
Ionized Ca	0.117	0.103
pH	0.086	0.234
PCO_2	0.024	0.735
BE	0.023	0.752
HCO_3	0.028	0.698

r: Spearman coefficient.

The median PR interval value was 120, with a range spanning from 60 to 180. Significant difference was found between different causes of convulsions as regard PR interval (Table 6).

Table (6): Relation between PR interval and causes of convulsions (primary illness)

		PR interval						
		Mean	**SD**	**Median**	**IQR**		**Range**	
Causes of convulsion	CNS infection	100.3	16.0	100.0	80.0	120.0	80.0	120.0
	Electrolyte Disturbance	120.0	27.0	120.0	100.0	140.0	80.0	160.0
	Encephalopathy	112.6	19.6	120.0	100.0	120.0	80.0	160.0
	Epilepsy	123.2	20.5	120.0	120.0	140.0	80.0	160.0
	Febrile convulsion	97.5	16.1	100.0	80.0	110.0	80.0	120.0
	Genetic	115.6	28.7	100.0	100.0	120.0	80.0	180.0
	Poisoning	120.0	0.0	120.0	120.0	120.0	120.0	120.0
	Trauma	93.3	10.3	100.0	80.0	100.0	80.0	100.0
	Others	90.0	34.6	90.0	60.0	120.0	60.0	120.0
Test value		KW=37.32						
P-value		<0.001						

There was significant positive correlation between PR interval and GCS, HCO_3, and age. While, there was significant negative correlation between PR interval and heart rate (Table 7).

Table (7): Correlation between and PR interval and different parameters in children with convulsions

	PR interval	
	r	**p- value**
Age (years)	0.396	<0.001
Duration of convulsion (minutes)	-0.048	0.502
GCS	0.215	0.002
Heart rate	-0.677	<0.001
Na^+	0.015	0.830
K^+	-0.062	0.388
Ionized Ca	0.001	0.993
pH	-0.120	0.095
OCO_2	-0.072	0.313
BE	0.065	0.365
HCO_3	0.144	0.045

r: Spearman coefficient

13 children (6.5%) had prolonged QTc interval (> 460 ms). The median QTc interval measured 400 milliseconds, with a range spanning from 340 milliseconds to 498 milliseconds. No significant variance was found among causes of convulsions regarding QTc interval (Table 8).

Table (8): Relation between QTc interval and causes of convulsions.

		QTc interval						
		Mean	**SD**	**Median**	**IQR**		**Range**	
Causes of convulsion	CNS infection	399.6	31.4	399.0	388.0	424.0	340.0	450.0
	Electrolyte Disturbance	417.1	60.9	399.5	389.5	424.0	388.0	452.0
	Encephalopathy	407.3	45.1	401.0	381.0	430.0	350.0	498.0
	Epilepsy	398.5	23.6	395.0	381.0	406.5	373.0	438.0
	Febrile convulsion	405.8	17.5	415.5	394.0	419.5	370.0	420.0
	Genetic	430.3	55.4	404.0	395.0	468.0	386.0	468.0
	Poisoning	413.0	12.7	413.0	402.0	424.0	402.0	424.0
	Trauma	401.0	17.1	391.0	389.0	423.0	389.0	423.0
	Others	378.0	37.0	378.0	346.0	410.0	346.0	410.0
Test value		KW=1.025						
P-value		0.248						

KW: Kruskal Wallis test.

There was significant negative correlation between QTc interval and serum ionized calcium (r=-0.149, p=0.037). Also, there was significant negative correlation between QTc interval and HCO^3 (r=-0.216, p=0.002) (Figures 1, 2).

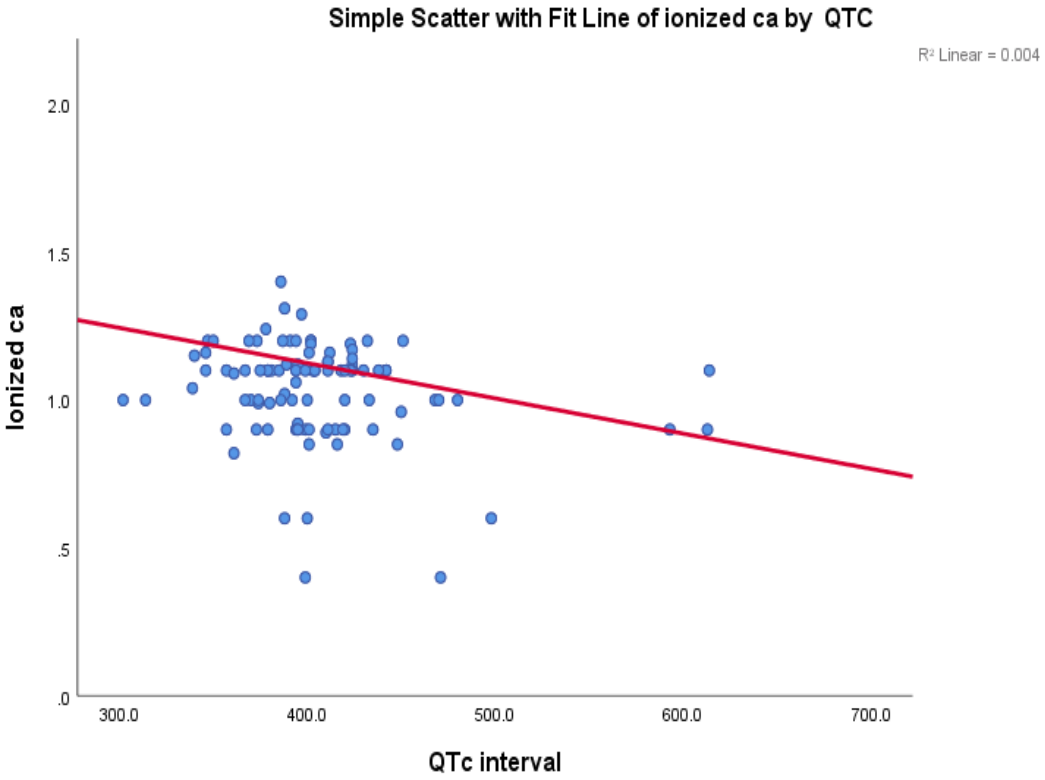

Figure (1): Scatter plot showing negative correlation between QTc interval and serum ionized calcium.

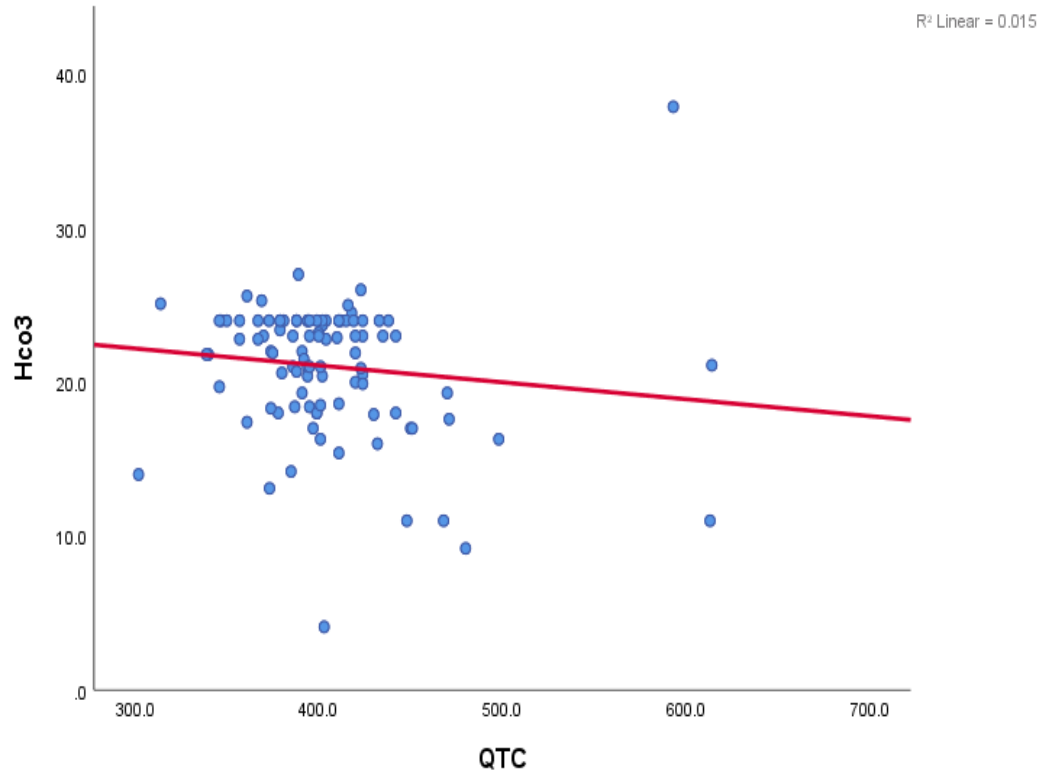

Figure (2): Scatter plot showing negative correlation between QTc interval and HCO_3.

DISCUSSION

After convulsions, a significant proportion of patients exhibited elevated biomarkers associated with cardiac necrosis and dysfunction, potentially suggesting the initiation of myocardial harm [(1)].

The principal aim of this study was to assess ECG parameters in pediatric patients presenting with various causes of convulsions. **Ibrahim *et al.*** [(1)] performed a similar prospective observational study to determine the effect of cardiac injury on the clinical course of paediatric patients with convulsive status epilepticus. Echocardiography, cardiac troponin, and ECG were used to assess cardiac injury. They comprised 74 CSE patients (mean age, 6.92 ± 2.34), ranging in age from 1 month to 12 years (43 males and 31 females). They came to the conclusion that in patients with convulsive status epileptics, signs of cardiac damage were linked to a poor clinical outcome and an increased risk of mortality, and that thorough regular cardiovascular examination is crucial in these patients.

Noori *et al.* [(9)] conducted a case-control study to assess the alterations in electrocardiography observed in children with epileptic and non-epileptic seizures in comparison to a control group. The research was carried out on a sample of 360 children ranging in age from 0.5 to 5 years who had been diagnosed with epilepsy, febrile convulsion, and breath-holding spells. Out of the total participants, a proportion of 160 individuals, accounting for 44.4%, were females. The proportion of female participants in the epilepsy, febrile convulsion, breath-holding episodes, and control groups was 45.6%, 42.2%, 38.9%, and 51.1%, respectively [(9)].

Chan *et al.* [(10)] investigated the potential influence of epilepsy duration as an autonomous variable on electrocardiographic alterations in pediatric epilepsy. The study incorporated a sample size of 127 youngsters, with a total of 323 ECGs being analyzed. After determining that focal onset impaired awareness/focal onset to bilateral tonic-clonic seizures accounted for 33% of all seizure types, and that generalised onset tonic-clonic seizures accounted for 16%, they came to the conclusion that the length of epilepsy may increase the likelihood of cardiac changes.

In this study sinus tachycardia occurred in 165 patient 82.5% of patients. Significant difference was found between different causes of convulsions as regard heart rate ($p<0.001$), trauma, febrile convulsions and CNS infection patients had higher levels of heart rates than others. Sinus tachycardia has been documented as the prevailing cardiac rhythm alteration in several studies, alongside conduction problems [(11)].

In this study the median PR interval value was 120, with a range spanning from 60 to 180. Significant difference was found between different causes of convulsions as regard PR interval ($p<0.001$), epileptic patients had longer PR interval than other causes of convulsions. This result implies that these patients may be susceptible to cardiac conduction block as a result of abnormal depolarization.

Our results agreed with that of **Asadollahi *et al.*** [(12)], in a study assessing interictal electrocardiographic changes in patients with drug-resistant epilepsy, discovered that patients with epilepsy had significantly longer mean PR intervals, shorter mean QRS durations, shorter mean QTc intervals, and longer corrected QT interval dispersion (QTcd) than subjects without epilepsy.

Our results showed that there was significant positive correlation between PR interval and GCS ($r=0.215$, $p=0.002$), HCO_3 ($r=0.144$, $p=0.045$) and age ($r=0.396$, $p<0.001$). While, there was significant negative correlation between PR interval and heart rate ($r=-0.677$, $p<0.001$).

The symptoms of acidosis included a significant drop in heart rate and an increase in P-R interval, but no discernible change in the length of the QRS complex. The consequences of acidosis did not seem to be caused by altered transmitter release from the heart's damaged autonomic nerve terminals [(13)]. Age has a well-established impact on the P-R interval. The P-R is substantially shorter in children than in adults, which can be explained by the fact that a child's heart is several times smaller than an adult's. Additional research on adults shows that even at stable heart rates, the P-R rises with age. It was discovered that the P-R interval was significantly influenced by both age and heart rate [(14)].

In this study, 13 patients (6.5%) exhibited a prolonged QTc interval. The study found that the median QTc interval was 399 milliseconds, with a range of 340 milliseconds to 498 milliseconds. No significant difference was observed in the QTc interval between different causes of convulsions ($p>0.05$).

The study results disagree with that of **Noori *et al.*** [(15)] who performed a case-control study examined the electrocardiography (ECG) results of children diagnosed with epilepsy in comparison to a control group of healthy children. Ninety patients, ages six months to eighteen, who were matched with an equivalent number of healthy youngsters made up the research sample. The findings of the study concluded that the QTd and QTcd intervals were significantly prolonged in patients with epilepsy.

This study also disagrees with that of **Noori *et al.*** [(16)] in a case-control study that assess the results of electrocardiography in kids experiencing febrile seizures. Ninety children, aged six to sixty months, who were paired with an equivalent number of healthy children made up the study sample. Compared to children who were healthy, the QTd, QTc, and QTcd values of children who had febrile convulsions were shown to be considerably greater.

Kolsal *et al.* [17] investigated the predictive capability of heart rate variability in relation to epilepsy. The study incorporated a cohort of 20 children diagnosed with refractory epilepsy, with a control group consisting of 20 children with well-controlled epilepsy and an additional 20 healthy children. The study group demonstrated a notably higher level of pathological QTc dispersion compared to the control groups. The study group had a notable decrease in heart rate variability, characterized by less parasympathetic activity and lower values in both the low frequency (LF) and high frequency (HF) bands.

In their study, **Noori *et al.*** [9] conducted a case-control investigation to assess the electrocardiographic alterations observed as compared to a control group in children experiencing both epileptic and non-epileptic seizures. The researchers observed a significant difference in QTd between the group of individuals with epilepsy and both the control group and the group of patients with breath-holding spells ($P < 0.001$). This disagreement is mostly because this study is a cross-sectional study and other studies are case control studies which give more accurate results.

This study showed that there was significant negative correlation between QTc interval and serum ionized calcium (r=-0.149, p=0.037); it means that prolonged QTc interval was related to hypocalcemia. Also, there was significant negative correlation between QTc interval and HCO_3 (r=-0.216, p=0.002). The relationship between plasma calcium, blood pH and QT Interval is well documented[18,19].

Individuals diagnosed with epilepsy exhibit a higher propensity for experiencing deviations in many electrocardiographic parameters, including aberrant QTc intervals, ST segment abnormalities, raised T waves, early repolarization patterns, increased p-wave dispersion, and prolonged PR intervals, in comparison to individuals without epilepsy [20].

In this study there was a statistically significant variation in heart rate across different causes of convulsions ($p<0.001$). Febrile convulsions and CNS illness exhibited the highest heart rates, whereas epilepsy was associated with the lowest heart rate. Also, a statistically significant distinction among various causes of convulsions in relation to the PR interval ($p<0.001$) was observed. Specifically, the PR interval was seen to be maximum in cases of epilepsy, while it was comparatively lower in instances of febrile convulsions and trauma. This discrepancy can be attributed to the elevated heart rate observed in patients with febrile convulsions and CNS infection, as compared to patients with epilepsy mostly because of the high-grade fever associated with these conditions. Significantly, within our study cohort, we saw individuals exhibiting QTc prolongation ranging up to 498 ms, whereas conversely, one patient displayed a QTc interval of 340 ms. The presence of conflicting outcomes may be attributed to the heterogeneity of the study cohorts as regard the age, risk factors, etiology of seizures, and duration of convulsive episodes.

Several investigations have documented both QTc prolonging and shortening in patients with epilepsy during ictal/postictal phases [21,22].

It appears that individuals diagnosed with epilepsy should undergo regular screening for QTc prolongation or shortening, as this condition has been linked to an elevated likelihood of experiencing sudden cardiac death [12].

CONCLUSION

Sinus tachycardia was present in most of our patient population. There was significant variance between different causes of convulsions as regards heart rate and PR interval. HR was higher in children with febrile convulsions, trauma and CNS infection than other causes of convulsions. Children with epilepsy had higher PR measurements than other causes of convulsions. But no significant variance was found among different reasons of convulsions as regards QTc interval.

RECOMMENDATIONS

Children with convulsions should undergo electrocardiographic testing to detect important abnormalities, which can help in diagnosis and management of their condition and participate in better outcome.

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REFERENCES

1. **Ibrahim A, Megahed A, Salem A *et al.* (2022):** Impact of cardiac injury on the clinical outcome of children with convulsive status epilepticus. Children, 9(2):122. doi: 10.3390/children9020122.
2. **Devinsky O (2004):** Effects of seizures on autonomic and cardiovascular function. Epilepsy Curr., 4(2):43-46.
3. **Shmuely S, Van der Lende M, Lamberts R *et al.* (2017):** The heart of epilepsy: current views and future concepts. Seizure, 44: 176-83.
4. **Lahiri M, Kannankeril P, Goldberger J (2008):** Assessment of autonomic function in cardiovascular disease: physiological basis and prognostic implications. Journal of the American College of Cardiology, 51(18):1725-33.
5. **Scantlebury M, Heida J (2010):** Febrile seizures and temporal lobe epileptogenesis. Epilepsy Research, 89(1):27-33.
6. **Murasawa T, Sakai Y, Sakai S *et al.* (2008):** QT dispersion increases during hemodialysis procedures in patients undergoing maintenance dialysis: association with an RA system and Holter electrocardiogram. Nihon Jinzo Gakkai Shi., 50(4): 481-7.

7. **Ashwin Reddy S (2019):** Ventricular arrhythmia precipitated by severe hypocalcaemia secondary to primary hypoparathyroidism. Case Rep Cardiol., 19: 4851073. doi: 10.1155/2019/4851073.
8. **Rijnbeek R, Witsenburg M, Schrama E *et al.* (2002):** New normal limits for the paediatric electrocardiogram. Eur Heart J., 22(8): 702-11.
9. **Noori N, Teimouri A, Khajeh A *et al.* (2022):** Electrocardiography changes in children with epileptic and non-epileptic seizures compared to controls, Int Cardiovasc Res J., 16(1):36-44.
10. **Chan S, Dervan L, Watson R *et al.* (2021):** Epilepsy duration is an independent factor for electrocardiographic changes in pediatric epilepsy. Epilepsia Open, 6(3):588-596.
11. **Costagliola G, Orsini A, Coll M *et al.* (2021):** The brain-heart interaction in epilepsy: implications for diagnosis, therapy, and SUDEP prevention. Ann Clin Transl Neurol., 8(7):1557-1568.
12. **Asadollahi M, Shahidi M, Ramezani M *et al.* (2019):** Interictal electrocardiographic alternations in patients with drug-resistant epilepsy. Seizure, 69:7-10.
13. **Aberra A, Komukai K, Howarth F *et al.* (2001):** The effect of acidosis on the ECG of the rat heart. Exp Physiol., 86(1):27-31.
14. **Alimurung M, Massell B (1956):** The Normal P-R Interval in Infants and Children, Circulation, 3(2): 257-262.
15. **Noori N, Khajeh A, Akhlaghi E *et al.* (2019):** Electrocardiography findings in children with Epilepsy Compared with Healthy Children. Int J Pediatr., 7(8): 9783-92.
16. **Noori N, Khajeh A, Teimouri A (2021):** Electrocardiography Findings in Children with Febrile. Convulsion Journal of Pediatric Neurology, 19(04): 227-234.
17. **Kolsal E, Serdaroğlu A, Cilsal E *et al.* (2014):** Can heart rate variability in children with epilepsy be used to predict seizures? Seizure, 23(5):357-62.
18. **Daniel R, Moodie E (1979):** Relationship between plasma calcium and QT interval, of electrocardiogram in dairy cows. Journal of Dairy Science, 62(6): 1014-1018.
19. **Yenigun E, Aypak C, Turgut D *et al.* (2016):** Effect of metabolic acidosis on QT intervals in patients with chronic kidney disease. The International Journal of Artificial Organs, 39(6):272-76.
20. **Gigli L, Sala S, Preda A *et al.* (2023):** Electrocardiogram changes in the postictal phase of epileptic seizure: Results from a prospective study. J Clin Med., 12(12):4098. doi: 10.3390/jcm12124098.
21. **The H, Tan H, Loo C *et al.* (2007):** Short QTc in epilepsy patients without cardiac symptoms. Med J Malasia , 62: 104-108.
22. **Surges R, Taggart P, Sander J *et al.* (2010):** Too long or too short? New insights into abnormal cardiac repolarization in people with chronic epilepsy and its potential role in sudden unexpected death. Epilepsia, 51: 738-744.