ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4

Journal of Coastal Life Medicine

Electrocardiographic Changes in Traumatic Brain Injury and Correlation of ECG Changes with Outcome.

Received: 11 February 2023, **Revised:** 13 March 2023, **Accepted:** 17 April 2023

Dr Priyanka G R
POST GRADUATE STUDENT IN M.D EMERGENCY MEDICINE

Dr Babu Kattimani
ASSOCIATE PROFESSOR IN EMERGENCY MEDICINE

Keywords
Electrocardiograph, Glasgow coma scale, Respolarization, Glasgow Outcome scale, Disability, traumatic brain injury.

Abstract
Introduction:
Electrocardiographic changes are frequently seen in patients post traumatic brain injury. The prognosis in patients with traumatic brain injury is poor when there is associated abnormal electrocardiographic changes. Though there are many indicators to assess prognosis in traumatic brain injury, ECG is a easily available point of care test which can help understand the outcome in traumatic brain injury patients at an early stage. This study aims to determine the relation of electrocardiographic changes and severity of the head injury and to assess the usefulness of ECG as a prognostic indicator in the outcome of patients with traumatic brain injury.
Methods:
It is a single centre prospective observational study, conducted between the year 2020 to 2022. Inclusion criteria- all patients with traumatic brain injury diagnosed on computed tomography or magnetic resonance imaging of brain, aged above 18 years and 12 lead ECG taken within 12 hours of arrival to hospital. Patients with history of heart disease, stroke, hypertension, previous documented abnormal ECG were excluded from the study. Initial Glagow coma scale was used to assess the severity of head injury, which was then correlated with the ECG changes. Patients were followed up after 30 days and outcome was assessed by Glasgow Outcome scale. Further, initial ECG changes were correlated with one month outcome.
Results:
In our prospective observational study, results showed electrocardiographic changes to be more frequent in patients with severe head injury. The most common ECG abnormality noted were heart rate variability, T wave changes and repolarization abnormalities. These electrocardiographic changes appeared to have significant positive correlation with outcome in patients with traumatic brain injury.
Conclusion:
Electrocardiography can be used as a preliminary and simple method to assess the severity of head injury as well as predict the prognosis of patients with traumatic brain injury.

1. Introduction

Among various injuries, traumatic head injury majorly contributes to a higher incidence of death and disability. In a year approximately 69 million people suffer from traumatic brain injury, the most common cause being road traffic accident [1]. Patients frequently show changes in their electrocardiography post traumatic brain injury, but their significance remains uncertain [2].

Bramwell was the first to describe the occurrence of ECG changes in brain injury patients in 1934 [3].

Ever since then, a major number of studies have shifted their focus to studying the possible connection between acute brain injury and the cardiovascular system.

Electrocardiographic changes are observed in many neurological and neurosurgical cases, many of these changes are attributed to increased sympathetic tone and elevated catecholamine release. These ECG changes suggest ischemia and primary myocardial dysfunction. The bulk of post-stroke fatalities is attributable to neurological impairment, with cardiovascular issues coming in as the second most common reason for death[4,5]. There are documentations of dysfunction of the cardia in traumatic brain injury and implied as an indicator of

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

poor outcome in paradigms of brain injury where, there seems to be an interaction between the heart-brain-lung leading to dysfunction of the myocardium. In traumatic brain injuries, the changes in electrocardiograph are quite frequent, comprising mainly of morphological changes, and disturbances in rhythm [6] .

In a study, electrocardiograms from 164 Bantu patients who had suffered head injuries were recorded and compared to two control groups. Patients with head injuries had longer Q-Tc intervals, higher P wave voltages, more frequently elevated QRS voltages and inverted T waves. As the level of consciousness declined, there were more electrocardiographic anomalies[7].

Singla et al. in their analysis of craniocerebral injuries and changes in electrocardiograph, observed QTc prolongation, depression of T wave, and diffuse changes of T waves to be associated with increased mortality[8].

Coghlan and coworkers' in their study of patients with subarachnoid hemorrhage of aneurysmal origin, noticed ECG changes were specific, which comprised of heart rate variability, QTc interval, abnormalities of ST segment and T wave. Further, these changes were linked with adverse neurological outcome [9] .

According to studies, any disruption of the circulatory system connections between the brainstem and forebrain portions of the central nervous system could cause arrhythmias of various types to manifest, demonstrating the importance of these regions in the causation of the same [10] .

Patients with subarachnoid hemorrhage (SAH), frequently demonstrate dysfunction of the cardia transiently, inversion of T wave, prolongation of QT interval along with parallel cardiac troponin release[11]. In a study conducted by Frontera et al, ECG changes in sub arachnoid hemorrhage were linked to an elevated risk of extended hospital stays, poor outcomes and death [12].

The presence of an association between electrocardiographic changes and head injury has been demonstrated in earlier studies but many of these studies are retrospective and had few limitations. Electrocardiograph is an easily available inexpensive tool that can help in determining the outcome in patients with traumatic brain injury.

This study aims to determine the relation between ECG changes and severity of the head injury and to assess the usefulness of ECG as a prognostic indicator in the outcome of patients with traumatic brain injury.

2. Methodology

Setting:

This is a prospective observational study conducted at the Department of Emergency Medicine.

Patient:

All patients with CT or MRI-diagnosed traumatic brain injury aged above 18 years were included in the study. Patients with pre-existing heart disease, a history of previous cerebrovascular accidents, hypertension, previous documented abnormal ECG, and on medication that affects the cardiovascular system were not included in the study. After a detailed primary assay , ECG was taken within 12 hours of arrival to emergency . Patients were divided into mild, moderate and severe head injuries based on the initial Glasgow coma scale scores. All the ECG changes were duly noted and correlated with severity of head injury.

Patients were then followed up after 30 days and the outcome was assessed using Glasgow Outcome scale. Further, the ECG changes were correlated with the Glasgow Outcome scale.

Glasgow Outcome scale categories outcome in patients with traumatic brain injury as follows ,

GOS 1: dead

GOS 2 :Persistent vegetative state

GOS 3 :Severe disability: (Conscious but disabled, dependent on others for daily support)

GOS 4 :Moderate disability (Disabled but independent)

GOS 5 : Good recovery (Resumption of normal life despite minor deficits)

3. Result:

Baseline characteristics of the population under study

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

Variables	Results
Age (years)	42.78 +/- 14.55
Gender (M/F) n	Females 131 Males 221
Heart rate (bpm)	87.38 +/- 19.25
GCS (n) Mild Moderate Severe	 96 141 115
GOS (n) 1 (death) 2 (persistent vegetative state) 3 (severe disability) 4 (moderate disability) 5 (mild disability)	 21 31 89 98 113

In the present study, 352 patients were included according to inclusion and exclusion criteria. The demographic details of the patient are shown in above table. Among the 352 patients, 131 were females and 221 were males. The mean age of the study population was 42.78 +/- 14.553 years. Minimum age was 18 years, and the maximum was 85 years.

Correlation of the ECG changes with the severity of the head injury

Variable	Mild (%) n = 96	Moderate (%) n =141	Severe (%) n = 115
Age (years)	41.68 +/- 14.9	42.2 +/- 13.4	44.40 +/- 15.49
Gender Male Female	 51 45	 94 47	 76 39
Heart rate (bpm)	88.29+/- 12.94		82.18+/- 24.409

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

		91.10+/ - 17.152	
Abnormal ECG (n / %)	21 (21.9%)	67 (47.5%)	87 (75.7%)
Sinus tachycardia (n / %)	20 (20.8%)	48 (34%)	29 (25.2%)
Sinus bradycardia (n / %)	1 (1%)	8 (5.7%)	28 (24.3%)
ST depression (n / %)	0 (0%)	6 (4.3%)	11 (9.6%)
ST elevation (n / %)	1 (1%)	1 (0.7%)	2 (1.7%)
T wave inversion Tall T wave	0 (0%) 0 (0%)	1 (0.7%) 4 (2.8%)	14 (12.2%) 4 (3.5%)
Prolonged QTc interval (n / %)	3 (3.1%)	27 (19.11%)	60 (52.2%)

Patients were divided into three groups of severity, according to the Glasgow coma scale. GCS of 13 and above as mild head injury, GCS of 9 to 12 as moderate head injury, and GCS of 8 and less as severe head injury.

In the study population, 40.1% had a moderate head injury, 33.7% had a severe head injury, and 27.3% had a mild head injury. Among the 352 patients with TBI, the minimum heart rate noted was 40 beats per minute, and 180 was the maximum heart rate. The mean heart rate noted in the study population was 87.38 beats per minute. 61.9% had normal sinus rhythm, 27.6% had sinus tachycardia, 10.5% had sinus bradycardia. Among patients with a mild head injury, 78.1% had normal sinus, 1% had sinus bradycardia, and 20.8% had sinus tachycardia. In the severe head injury group 50.4% had normal sinus, 24.3% had sinus bradycardia and 25.2%had sinus tachycardia. In the moderate head injury group 60.3% had normal sinus, 5.7% had sinus bradycardia, and 34% had sinus tachycardia. There was a significant association between heart rate and severity of head injury with a p-value of 0.000.

In the present study group, no significant association was present between P-wave changes and severity of head injury (p-value 0.272), PR interval and severity (p-value 0.219), QRS complex and severity of head injury (p-value 0.187).

ST depression was noted in 4.3% of patients with a moderate head injury and 9.6% of patients with a severe head injury, while ST elevation was present in 1% of mild head injury, 0.7% of moderate head injury

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

and 1.7% of severe head injury. ST segment changes were significantly associated with the severity of head injury with a p-value of 0.005.

T wave changes were greatly associated with the severity of head injury (p-value 0.000). T wave inversions were present in 0.7% of patients with mild and 12.2% of patients with severe head injury. Tall T were present in 2.8% of patients with moderate and 3.5% of patients with severe head injuries. No significant association was present between p-wave changes and the severity of the head injury. PR wave was prolonged in 1.4% of patients with a moderate head injury and 2.6% of patients with a severe head injury. No significant association was present between PR interval and severity of head injury. ST-segment elevation was present in 1%,0.7%, and 1.7% of patients with mild, moderate and severe head injury respectively. St depression was present in 4.3% of patients with moderate and 9.6% of patients with severe head injury. The p-value for ST changes and severity is 0.005.

QTc was prolonged in 3.1%, 19.1%, and 52.2% of mild, moderate and severe head injuries respectively. There was a significant positive association between QTc interval and the severity of head injury.

U waves were prominent in only 1.7% of patients. No significant association was noted between U waves and severity of head injury (p-value 0.141).

Correlation of ECG changes and the outcome

Variables	GOS 1 (21)	GOS 2 (31)	GOS 3 (89)	GOS 4 (98)	GOS 5 (113)
Age (years)	39.29+/-12.5	42.1+/-16.89	45.39+/-14.8	43.22+/-13.7	41.16+/-14.59
Gender					
Male	14 (66.7%)	19 (61.3%)	59 (66.3%)	65 (66.3%)	64 (56.6%)
Female	7 (33.3%)	12 (38.7%)	30 (33.7%)	33 (33.7%)	49 (43.4%)
Abnormal ECG	19 (90.5%)	27 (87.1%)	55 (61.8%)	49 (50%)	25 (22.1%)
Rate (bpm)	77.71 +/-32.9	79.61 +/-24.9	90.45 +/-18.8	88.57 +/-18.79	87.87 +/-13.15
Sinus tachycardia	4 (19%)	8 (25.8%)	31 (34.8%)	32 (32.7%)	22 (19.5%)

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

Sinus bradycardia	8 (38.1 %)	10 (32.3%)	8 (9%)	9 (9.2%)	2 (1.8%)
ST depression	8 (38.1 %)	4 (12.9%)	1 (1.1%)	3 (3.1%)	1 (0.9%)
ST elevation	0 (0%)	0 (%)	2 (2.2%)	0 (0%)	2 (1.8%)
T wave Inverted T Tall T	5 (28.3 %) 1 (4.8%)	4 (12.9%) 2 (6.5%)	6 (6.7%) 1 (1.1%)	0 (0%) 4 (4.1%)	0 (0%) 0 (0%)
QTc prolongation	16 (76.2 %)	21 (67.7%)	35 (39.9%)	14 (14.3%)	4 (3.5%)

All 352 patients were followed up after a month and their outcome was assessed by a Glasgow outcome scale. At the end of one month 21 were dead, 31 had persistent vegetative state, 89 had severe disability, 98 had moderate disability and 113 patients had good recovery. ECG abnormalities were 90.5%, 87.1%, 61.8%,50% and 22.1% in the above groups respectively. There was a significant positive association between heart rate and the Glasgow outcome scale with a p-value of 0.00. There was a significant association between ST changes, T wave changes, and QTc interval with the severity of head injury with a p-value of 0.00. There was no significant correlation between p waves, u waves, or bundle branch block with the outcome.

In the GOS 1 group (dead at by one month) sinus bradycardia was present in 38.1% and tachycardia was present in 19%. In the GOS 2 group, 32.3% had sinus bradycardia and 25.8% had sinus tachycardia. In GOS 3 group 9% had sinus bradycardia, and 34.9% had sinus tachycardia. In GOS 4 group 9.2% has sinus bradycardia, and 32.7% had sinus tachycardia. In GOS 5 group 1.8% had sinus bradycardia and 19.5% had sinus tachycardia. There was a significant association between heart rate and outcome at the end of one month in patients with traumatic brain injury (p-value 0.000).

No significant association was present between the p-wave and outcome (p-value 0.685). No significant association was present between PR interval and outcome (p-value 0.117). No significant association was present between QRS complex and outcome (p-value 0.338) ST segment was elevated in 2.2% of patients with severe disability and 1.8% of patients with good recovery. ST segment was depressed in 38.1%, 12.9%, 1.1%, 3.1%, and 0.9% of patients with GOS 1, GOS 2, GOS 3, GOS 4, and GOS 5 respectively. There was a significant association between ST segment changes and outcome (p-value 0.000)

T wave was inverted in 23.8%, 12.9%, and 6.7% of patients with GOS 1, GOS 2, and GOS3 respectively.Tall T waves were seen in 4.8% of GOS 1, 6.5% of patients with GIS 2, 1.1% of patients with GOS

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

3, and 4.1% of patients with GOS 3.A significant positive association was present between T wave changes and outcome. No significant association was present between U waves and outcome.

QTc was prolonged in 76.2% of patients with GOS 1 (dead), 67.7% of patients with persistent vegetative state (GOS 2), 39.3% of patients with severe disability (GOS 3) 14.3% of patients with moderate disability (GOS 4) and 3.5% of patients with good recovery (GOS 5). A significant positive association was noted between QTc and outcome (p-value 0.000).

4. Discussion

The incidence of road traffic accidents and resultant traumatic brain injury has increased globally and especially in India. Most of the patients who suffer traumatic brain injury remain bedridden and dependent on others for life or are dead, this increases the socioeconomic burden of the country. The outcome of patients with neurological injury is affected by many factors including age, associated premorbid conditions, and operative interventions, however, none of these factors can independently predict the outcome of a patient with traumatic brain injury. The electrocardiographic changes observed in patients with traumatic head injuries have a major role in predicting the outcome of such patients [13-16]. Our study aimed to understand the association between the ECG changes and the severity of the head injury, and correlate ECG changes with one-month outcome using Glasgow outcome scale.

This present prospective study was conducted for 18 months. The study was conducted on a total of 352 patients after considering the inclusion and exclusion criteria. Initial electrocardiography was done for all patients and diagnostic imaging was done of the brain was done (CT or MRI). Patients were divided into three categories that are mild, moderate and severe head injury based on the Glasgow coma scale. Patients were then followed up after a month of the traumatic brain injury and the outcome was recorded as 1: dead, 2: Persistent vegetative state, 3: severe disability, 4: moderate disability, 5: good recovery.

In a retrospective study conducted by Vijay Krishnamoorthy, 22% of patients with acute brain injury had tachycardia. Studies have shown electrocardiographic changes are common in cases with brain injury and they seem to influence the outcome. QTc prolongation and depolarisation abnormalities are frequent, patients with subarachnoid haemorrhage and ST changes on ECG have adverse neurological outcomes compared to those without any ECG changes.

In a study conducted by Bramwell in 1934, there was a 12 to 99% incidence of ECG changes in patients with traumatic brain injury [3]. Coghlan and coworkers in their study of patients with subarachnoid haemorrhage noticed ECG changes which mostly comprised of heart rate variability[9]. In our study of 352 patients, 96 patients had mild head injuries, 141 patients suffered moderate head injuries and 115 had severe head injuries. Abnormal ECG was found 87%of patients with a severe head injury, indicating that ECG changes occur frequently in severe head injury. Furthermore, the most common ECG abnormality noted was variation in heart rate. Sinus tachycardia is commoner than bradycardia in head injuries however, the incidence of sinus bradycardia is higher in severe type of head injuries.

In a study conducted on 164 Bantu patients, the ECG changes in traumatic brain injury patients were compared with two control groups, it was observed that patients with head injury had higher P wave voltages[7]. In our study group there were no significant P wave changes and they did not show any correlation with the severity or the outcome of traumatic brain injury. Studies have shown the frequent presence of abnormal T wave, and QTc prolongation in patients with acute brain injury[2,6]. In our study, results showed significant association between T-wave changes and the severity of the head injury as well as the outcome. The most occurring T wave abnormality was T wave inversion as compared to tall T wave. Among 352 patients, 14% of severe head injury patients had T wave inversion and 4% had tall T wave in their initial ECG. With regard to one month outcome and T wave changes, 5 out of 21 patients who were dead had inverted T waves while 1 had tall T wave. There was a significant correlation between T-wave changes and one month outcome (p-value 0.00).

In a study conducted by Rudehill et al, QTc prolongation was observed in 23% of patients with sub-arachnoid haemorrhage [17]. In our study, QTc was prolonged in 60% of patients with a severe head injury and 27% with a mild head injury. 76% of patients with

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

GOS of 1(dead) had prolonged QTc when arrived, and 21% of patients with GOS 2 (persistent vegetative state) had prolonged QTc. Our study showed a significant correlation between QTc prolongation and outcome in traumatic brain injury.

The study did not show any significant changes in the P wave, U wave and QRS interval. Limitations of the study : The study did not include ECG changes specific to different types of traumatic brain injuries, repeat ECGs were not performed after admission, and no echocardiography was done to rule out an old insult in the heart.

Thus the study showed abnormal electrocardiographic changes to be significantly associated with poor outcomes at the end of one month in patients with severe head injuries. The most common ECG abnormality noted in brain injury was sinus tachycardia, repolarisation abnormality (T wave changes and QTc interval), and ST segment changes. All these were associated with poorer outcomes. Therefore, it is essential to acknowledge the value of the electrocardiograph as a straightforward technique to detect circulatory alterations in patients with traumatic brain damage. However, additional prospective studies are required to add changes in cardiac enzyme levels, concomitant echocardiography abnormalities, and their relationships to ECG results and the overall outcome of this findings.

5. Conclusion:

Electrocardiographic changes in patients are significantly associated with the outcome in patients with traumatic brain injury. The most common ECG changes that are found are sinus tachycardia, sinus bradycardia, T wave changes, and prolongation of QT interval. Repolarization abnormalities such as prolongation of the QT interval and changes in the ST segment and T wave morphology are associated with poorer neurological outcome and higher mortality. ECG abnormality significantly correlated with poor outcomes at the end of one month.

Patients with good recovery at the end of the month (Glasgow Outcome scale of 5) had the least changes in the electrocardiograph. ECG changes are significant in predicting the prognosis of patients with traumatic brain injury. Electrocardiograph thus appears to have a important role in determining the mortality and morbidity in patients with traumatic brain injury.

References

[1] Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M, Agrawal A, Adeleye AO, Shrime MG, Rubiano AM, Rosenfeld JV. Estimating the global incidence of traumatic brain injury. Journal of neurosurgery. 2018 Apr 27;130(4):1080-97.https://doi.org/10.3171/2017.10.JNS17352

[2] Fan X, DU FH, Tian JP. The electrocardiographic changes in acute brain injury patients. Chinese Medical Journal. 2012 Oct 5;125(19):3430-3.https://doi.org/10.3760/cma.j.issn.0366-6999.2012.19.013

[3] Bramwell C. Can a head injury cause auricular fibrillation?. The Journal of Nervous and Mental Disease. 1934 Dec 1;80(6):716.https://doi.org/10.1016/S0140-6736(01)02445-X

[4] Chen Z, Venkat P, Seyfried D, Chopp M, Yan T, Chen J. Brain–heart interaction: cardiac complications after stroke. Circulation research. 2017 Aug 4;121(4):451-68.https://doi.org/10.1161/CIRCRESAHA.117.311170

[5] Krishnamoorthy V, Mackensen GB, Gibbons EF, Vavilala MS. Cardiac dysfunction after neurologic injury: what do we know and where are we going?. Chest. 2016 May 1;149(5):1325-31.https://doi.org/10.1016/j.chest.2015.12.014

[6] Krishnamoorthy V, Prathep S, Sharma D, Gibbons E, Vavilala MS. Association between electrocardiographic findings and cardiac dysfunction in adult isolated traumatic brain injury. Indian journal of critical care medicine: peer-reviewed, official publication of Indian Society of Critical Care Medicine. 2014 Sep;18(9):570. 10.4103/0972-5229.140144

[7] HERSCH C. Electrocardiographic changes in head injuries. Circulation. 1961 Jun;23(6):853-60.https://doi.org/10.1016/S1875-4597(09)60044-8

[8] Singla SL, Garg P, Mehta RK. Electrocardiographic changes in craniocerebral trauma-- could they serve as prognostic indicators?. Journal of the Indian Medical Association. 2002 Mar 1;100(3):188-90.

ISSN: 2309-5288 (Print)
ISSN: 2309-6152 (Online)
CODEN: JCLMC4
Journal of Coastal Life Medicine

[9] Coghlan LA, Hindman BJ, Bayman EO, Banki NM, Gelb AW, Todd MM, Zaroff JG, IHAST Investigators. Independent associations between electrocardiographic abnormalities and outcomes in patients with aneurysmal subarachnoid hemorrhage: findings from the intraoperative hypothermia aneurysm surgery trial. Stroke. 2009 Feb 1;40(2):412-8.

[10] Lacy PS, Earle AM. Central neural control of blood pressure and cardiac arrhythmias

[11] during subarachnoid hemorrhage in rats. Stroke. 1985 Nov;16(6):998-102.

[12] https://doi.org/10.1161/01.STR.16.6.998

[13] Wybraniec MT, Mizia-Stec K, Krzych Ł. Neurocardiogenic injury in subarachnoid hemorrhage: A wide spectrum of catecholamin-mediated brain-heart interactions. Cardiology Journal. 2014;21(3):220-8. 10.5603/CJ.a2014.0019

[14] Frontera JA, Parra A, Shimbo D, Fernandez A, Schmidt JM, Peter P, Claassen J, Wartenberg KE, Rincon F, Badjatia N, Naidech A. Cardiac arrhythmias after subarachnoid hemorrhage: risk factors and impact on outcome. Cerebrovascular diseases. 2008;26(1):71-8. https://doi.org/10.1159/000135711

[15] Padilla-Zambrano HS, Garcia-Ballestas E, Rojas AN, Moscote-Salazar LR, Ghosh A, Pal R, Agrawal A. “Broken heart syndrome” Cardiovascular manifestations of traumatic brain injury. Heart and Mind. 2018 Jan 1;2(1):12.10.4103/hm.hm_12_18

[16] Astarabadi M, Khurrum M, Asmar S, Bible L, Chehab M, Castanon L, Ditillo M, Douglas M, Joseph B. The impact of non-neurological organ dysfunction on outcomes in severe isolated traumatic brain injury. Journal of Trauma and Acute Care Surgery. 2020 Aug 1;89(2):405-10. 10.1097/TA.0000000000002771

[17] Collier BR, Miller SL, Kramer GS, Balon JA, Gonzalez III LS. Traumatic subarachnoid hemorrhage and QTc prolongation. Journal of Neurosurgical Anesthesiology. 2004 Jul 1;16(3):196-200.10.1097/00008506-200407000-00003

[18] Samudrala VD, Kumar A, Agrawal A. Electrocardiographic changes in patients with isolated traumatic brain injury and their correlation with outcome. Indian Journal of Neurotrauma. 2016 Aug;13(02):070-4. 10.1055/s-0036-1586237

[19] Rudehill A, Olsson GL, Sundqvist K, Gordon E. ECG abnormalities in patients with subarachnoid haemorrhage and intracranial tumours. Journal of Neurology, Neurosurgery & Psychiatry. 1987 Oct 1;50(10):1375-81. http://dx.doi.org/10.1136/jnnp.50.10.1375