Prevalence of Electrocardiographic Changes in Patients with Traumatic Brain Injury: A Prospective Hospital-based Study

Mohamed Hamila1*, Khaled Hussein2, Mohamed Fatehy Ismail3, Ahmed Kamal2

1Department of Critical Care Medicine, Beni Suef University, Beni Suef, Egypt; 2Department of Critical Care Medicine, Cairo University, Cairo, Egypt; 3Department of Critical Care Medicine, King Fahad Specialist Hospital, Dammam, Saudi Arabia

*This author takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation

Abstract

BACKGROUND: Head trauma and traumatic brain injury (TBI) are major causes of death and disability worldwide. TBI is associated with a variety of electrocardiographic (ECG) changes.

AIM: We aimed to evaluate the prevalence of ECG changes in TBI.

METHODS: Participants with TBI were included in the study, while participants with chest trauma or cardiovascular diseases were excluded from the study. A consecutive sample of 50 participants (mean age 37.8 ± 14.85 years, 80% males) was selected and referred for 12 lead ECG on admission, 24 h, and 72 h after admission.

RESULTS: The prevalence of sinus bradycardia versus sinus tachycardia, short PR interval, ST segment elevation, and inverted T wave in the study population was 18% versus 38%, 26%, 2%, and 16% in ECG on admission, 5% versus 22%, 14%, 0%, and 10% in ECG 24 h after admission, 5% versus 8%, 4%, 0%, and 8% in ECG 72 h after admission, respectively. Serial ECG was significantly associated with changes in heart rate (χ² [1] = 17.337, p = 0.002) and short PR interval (χ² [1] = 9.695, p = 0.008), respectively. There was a significant association between ECG changes and brain edema (χ² [1] = 4.131, p = 0.042), intracerebral hemorrhage (χ² [1] = 4.539, p = 0.033), and subarachnoid hemorrhage groups (χ² [1] = 5.889, p = 0.015), respectively.

CONCLUSIONS: ECG changes are prevalent in non-cardiac TBI patients. The significant association of serial ECG changes in heart rate and short PR interval and the significant association of ECG changes with brain edema, intracerebral hemorrhage, and subarachnoid hemorrhage highlights the potential role of serial ECG as a screening tool for cardiac dysfunction in patients with TBI.

Introduction

Traumatic brain injury (TBI) is a major cause of morbidity and mortality worldwide with an incidence rate of 69 million (95% CI 64–74 million) individuals per year [1]. Acute myocardial damage and heart failure may occur in non-cardiac TBI patients [2]. Electrocardiographic (ECG) changes associated with TBI include disturbance of rate, rhythm, P wave, QRS complex, PR interval, T wave, ST segment, prolongation of QT interval, or myocardial ischemic-like ECG changes including ST-segment deviations, T wave inversion, and Q-waves [3]. In 2004, early serial ECG has been recommended by Stollberger and Finsterer for assessment of cardiac dysfunction in TBI [4]. Subgroup analysis of the TBI patient population showed that ECG changes occur most often in subarachnoid hemorrhage (49–100%), intracranial hemorrhage, ischemic stroke, cerebral venous thrombosis, head trauma, neurological procedures, cryohypophysectomy, acute meningitis, intracranial space-occupying tumors, and epilepsy [5], [6]. We wanted to evaluate the prevalence of ECG changes in TBI, the association of serial ECG with cardiac dysfunction, and the association of ECG changes with certain types of TBI.

Methods

Study design

Our study was a 1-year prospective, open-labeled, non-randomized, single cohort study conducted at a single Intensive Care Unit (ICU) in a trauma care center. Investigators weren’t blinded to the study group. The study design was approved by the hospital ethics committee review board, all study participants’ substitute decision-makers for healthcare signed written informed consents, study procedures were carried out following the Code of Ethics of the World Medical Association (Declaration of Helsinki), all study data and ECGs were anonymized, and the privacy rights of the study participants were observed diligently.
Study participants

Study participants were patients referred to the ICU. The study participants’ family members were subjected to history taking and data collection for age, gender, risk factors including hypertension, and diabetes mellitus. The study participants’ bystanders were asked about the mechanism of TBI. The study participants were subjected to comprehensive clinical examination including measurement of vital signs on admission (systolic and diastolic blood pressure, heart rate, respiratory rate, and body temperature), Glasgow Coma Scale (GCS) assessment, brain computerized tomography (CT) scan, complete blood count, prothrombin time, activated partial thromboplastin time, international normalized ratio, serum creatinine, sodium and potassium, aspartate aminotransferase and alanine aminotransferase, creatinine kinase and creatine kinase-MB, troponin, and serial 12 lead ECGs on admission, 24 h, and 72 h after admission. Data documented with serial ECGs included RR interval, P wave, PR interval, PR segment, QRS complex, ST segment, T wave, ST interval, and QT interval. Normal values for ECG waves and intervals were referenced to the American College of Cardiology/American Heart Association Task Force on Assessment of Diagnostic and Therapeutic Cardiovascular Procedures (Committee on Electrocardiography) report [7]. TBI was categorized based on GCS into severe (GCS ≤ 8), moderate (GCS 9–12), and mild (GCS 13–14) [8]. Screened participants were enrolled if they had head trauma with CT brain showing brain edema, subdural hemorrhage, extradural hemorrhage, intracerebral hemorrhage, subarachnoid hemorrhage, intraventricular hemorrhage, or skull fractures. Screened participants with severe chest trauma, history of cardiovascular diseases, or on any cardiac medication were excluded from the study.

Study procedures

Fifty eligible participants were admitted to ICU, enrolled, consecutively assigned, and allocated in a single cohort. The enrolled study participants underwent serial ECG on admission, 24 h, and 72 h after admission.

End points

The study evaluated the prevalence of ECG changes in TBI, the association of serial ECG with cardiac dysfunction, and the association of ECG changes with certain types of TBI.

Statistical analysis

The ECG assessment outcomes were coded, and the data were analyzed with the Statistical Package for the Social Sciences software® version 20. Quantitative (continuous) data were expressed as means and standard deviations, while qualitative (categorical) data were expressed as frequencies and percentages. Comparisons between parametrically distributed quantitative variables were done with the Independent two-tailed t-test, between non-parametrically distributed quantitative variables with Mann-Whitney test, and between qualitative variables with Chi-square test, respectively [9], [10]. The confidence interval was set to 95% and the margin of error accepted was set to 5%. Any comparison considered statistically significant was at p < 0.05 or less.

Results

Study participants and procedures

We recruited 50 patients from one hospital in one country from August 2014 through April 2015. The study group was balanced with regards to baseline characteristics (Table 1) and risk factors (Figure 1). The key socio-demographic feature of the enrolled participants was male predominance (Mean age 37.84 ± 14.85 years, 80% males, 20% females) (Figure 2). All enrolled participants completed the study, and there were no withdrawals. Brain CT evaluation showed brain edema, subdural hemorrhage, extradural hemorrhage, intracerebral hemorrhage, subarachnoid hemorrhage, intraventricular hemorrhage, and fracture skull base in 38%, 4%, 20%, 36%, 26%, 10%, and 28% of the study population, respectively (Table 2).

Table 1: Patients characteristics and demographic data (n=50)

| Age (Years) | Mean ± SD |
|-------------|-----------|
| 37.84 ± 14.85 |

| Ages38 years | N | % |
|--------------|---|---|
| 28 | 56 |

| Age>38 years | N | % |
|--------------|---|---|
| 22 | 44 |

| Male | N | % |
|------|---|---|
| 40 | 80.0 |

| Female | N | % |
|--------|---|---|
| 10 | 20.0 |

| Diabetes Mellitus | N | % |
|-------------------|---|---|
| 11 | 22.0 |

| Hypertension | N | % |
|--------------|---|---|
| 16 | 32.0 |

| Glasgow Coma Moderate Brain Injury | N | % |
|-----------------------------------|---|---|
| 23 | 46.0 |

| Glasgow Coma Severe Brain Injury | N | % |
|----------------------------------|---|---|
| 27 | 54.0 |

| Systolic Blood Pressure (mmHg) | Mean ± SD |
|-------------------------------|-----------|
| 126.00 ± 18.54 |

| Diastolic Blood Pressure (mmHg) | Mean ± SD |
|---------------------------------|-----------|
| 77.60 ± 10.21 |

| Respiratory Rate per Minute | Mean ± SD |
|---------------------------|-----------|
| 20.36 ± 2.46 |

| Body Temperature (°C) | Mean ± SD |
|-----------------------|-----------|
| 37.08 ± 0.32 |

Prevalence of ECG changes in TBI

As per ECG assessment, the prevalence of sinus bradycardia versus sinus tachycardia, short PR interval, ST segment elevation, and inverted T wave in the study population was 18% versus 38%, 26%, 2%, and 16% in ECG on admission, 5% versus 22%, 14%, 0%, and 10% in ECG 24 h after admission, 5% versus
**Association of serial electrocardiography with ECG changes in TBI**

Serial ECG was significantly associated with changes in heart rate ($\chi^2 [1] = 17.337$, $p = 0.002$) and short PR interval ($\chi^2 [1] = 9.695$, $p = 0.008$), respectively (Table 4).

Table 2: Types of traumatic brain injury distribution in the study group (n=50)

| Brain edema | n | % |
|-------------|---|---|
| Normal | 19 | 38 |
| Bradycardia | 9 | 18 |
| Tachycardia | 10 | 20 |
| Intracerebral hemorrhage | 13 | 26 |
| Intraventricular hemorrhage | 5 | 10 |
| Fracture skull base | 14 | 28 |

Table 2 showing the percentage of traumatic brain injury patients with brain edema (38%), subdural hemorrhage (20%), extradural hemorrhage (20%), and intraventricular hemorrhage (10%), and fracture skull base (28%), respectively.

**Table 3: Prevalence of ECG changes in traumatic brain injury study group (n=50)**

| Heart rate | Normal | Abnormal |
|------------|--------|----------|
| Normal | 22 | 44 |
| Bradycardia | 9 | 18 |
| Tachycardia | 10 | 20 |
| Rhythm | Short | Normal |
| Normal | 37 | 74 |
| Elevation | 0 | 0 |
| QRST complex | Normal | Short |
| Normal | 50 | 100 |
| Short | 0 | 0 |
| QT interval | Normal | Short |
| Normal | 50 | 100 |
| Short | 0 | 0 |

Table 3 showing the prevalence rate of sinus arrhythmia, short PR interval, ST segment elevation, and inverted T wave in ECG on admission, 24 h, and 72 h after admission, respectively.

**Table 4: Association of serial electrocardiography with electrocardiographic changes in traumatic brain injury study group**

| Electrocardiographic findings | On admission | 24 h after admission | 72 h after admission | Chi-square test |
|------------------------------|--------------|----------------------|----------------------|-----------------|
| Heart rate | Normal | 22 | 44 | 34 | 68 | 41 | 82 | 17.337 | 0.002* |
| Bradycardia | 9 | 18 | 5 | 10 | 5 | 10 | 8.425 | 0.004* |
| Tachycardia | 10 | 20 | 11 | 22 | 4 | 8 | 0.933 | 0.333 |
| Rhythm | Short | 50 | 100 | 50 | 100 | 50 | 100 | 1.725 | 0.422 |
| Normal | 37 | 74 | 43 | 86 | 48 | 96 | 9.695 | 0.008* |
| QRST complex | Normal | 50 | 100 | 50 | 100 | 50 | 100 | 1.000 | 0.301 |
| QST interval | Normal | 50 | 100 | 50 | 100 | 50 | 100 | 0.000 | 0.040 |
| ST segment | Elevated | 1 | 2 | 0 | 0 | 0 | 0 | 2.013 | 0.156 |
| Normal | 49 | 98 | 50 | 100 | 50 | 100 | 0.725 | 0.392 |
| T wave | Inverted | 8 | 16 | 5 | 10 | 4 | 8 | 1.725 | 0.422 |
| Normal | 42 | 84 | 45 | 90 | 46 | 92 | 0.000 | 0.002 |

Table 4 showing significant association of serial ECG with sinus arrhythmia, short PR interval, ST segment elevation, and inverted T wave in ECG on admission, 24 h, and 72 h after admission, respectively.

**Association of ECG changes with certain types of traumatic brain injury**

The percent of patients in the TBI cohort who had ECG changes was 74%, while the percent of patients in the TBI cohort who had normal ECG was 26%, respectively. There was a statistically significant association between ECG changes and brain edema ($\chi^2 [1] = 4.131$, $p = 0.042$), intracerebral hemorrhage...
Hamila et al. Electrocardiographic Changes in Patients with Traumatic Brain Injury

(χ² [1] = 4.539, p = 0.033), and subarachnoid hemorrhage groups (χ² [1] = 5.889, p = 0.015), respectively (Table 5).

| Types of traumatic brain injury | ECG findings | χ² | p-value |
|--------------------------------|--------------|-----|---------|
| Normal (n=13) | Abnormal (n=37) | No. | % | No. | % | |
| Brain edema | 5 | 38.46 | 26 | 70.27 | 3.892 | 0.022* |
| Subdural hemorrhage | 1 | 7.69 | 5 | 13.51 | 0.004 | 0.953 |
| Extradural hemorrhage | 4 | 30.77 | 15 | 40.54 | 0.084 | 0.772 |
| Intracerebral hemorrhage | 4 | 30.77 | 24 | 64.86 | 3.255 | 0.027* |
| Subarachnoid hemorrhage | 3 | 23.08 | 23 | 62.16 | 4.425 | 0.011* |
| Intraventricular hemorrhage | 0 | 0.00 | 2 | 5.41 | 0.043 | 0.972 |
| Fracture skull base | 5 | 38.46 | 15 | 40.54 | 0.040 | 0.842 |

*Significant

Table 5: Association of electrocardiographic changes with certain types of traumatic brain injury

Strengths and limitations

Our study did not have missing data allowing robust per protocol analysis and the investigators who analyzed and reported the anonymous ECG changes were blinded to the identity and clinical data of the study participants and hence minimizing observer bias. On the other hand, the study has important limitations. It was a single centered study with a small sample size. Being a short prospective study with a lack of lengthy follow-up did not allow us to investigate the chronological relationship between the ECG changes and the clinically driven outcomes in the TBI patient population.

Conclusions and Recommendations

ECG changes are prevalent in non-cardiac TBI patients. The significant association of serial ECG with changes in heart rate and short PR interval and the significant association of ECG changes with brain edema, intracerebral hemorrhage, and subarachnoid hemorrhage highlights the potential role of ECG as a screening tool for cardiac dysfunction in patients with TBI. Large prospective studies are warranted to correlate ECG changes with cardiovascular clinical outcomes in patients with TBI, especially in patients with brain edema, intracerebral hemorrhage, and subarachnoid hemorrhage.

References

1. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M, et al. Estimating the global incidence of traumatic brain injury. J Neurosurg. 2018;130(4):1-18. https://doi.org/10.3171/2017.10.JNS17352
2. Polderman KH, Bloemers FW, Peerdeman SM, Girbes AR. Hypomagnesemia and hypophosphatemia at admission in patients with severe head injury. Crit Care Med. 2000;28(6):2022-5. https://doi.org/10.1097/00003246-200006000-00057
PMid:10280658

3. Collier BR, Miller SL, Kramer GS, Balon JA, Gonzalez LS. Traumatic subarachnoid hemorrhage and QTc prolongation. J Neurosurg Anesthesiol. 2004;16(3):196-200. https://doi.org/10.1097/00008506-200407000-00003
PMid:15211156

4. Stöllberger C, Finsterer J. Cardiovascular findings in sudden unexplained/unexpected death in epilepsy (SUDEP). Epilepsy Res. 2004;59(1):51-60. https://doi.org/10.1016/j.epilepsires.2004.03.008
PMid:15135167

5. Surawicz B. Electrolytes, Hormones, Temperature, and Miscellaneous Factors: Electrophysiologic Basis of ECG and Cardiac Arrhythmias. Baltimore, MD: Williams and Wilkins; 1995. p. 426-53.

6. Davis TP, Alexander J, Lesch M. Electrocardiographic changes associated with acute cerebrovascular disease: A clinical review. Prog Cardiovasc Dis. 1993;36(3):245-60. https://doi.org/10.1016/0033-0620(93)90017-8
PMid:8347777

7. Schlant RC, Adolph RJ, DiMarco JP, Dreifus LS, Dunn MI, Fisch C, et al. Guidelines for electrocardiography. A report of the American College of Cardiology/American heart association task force on assessment of diagnostic and therapeutic cardiovascular procedures (committee on electrocardiography). Circulation. 1992;85(3):1221-8. https://doi.org/10.1161/01.cir.85.3.1221
PMid:1537123

8. Zasler ND, Katz DI, Zafonte RD, Arciniegas DB, Bullock MR, Kreutzler JS. Brain Injury Medicine: Principles and Practice. New York: Demos Medical Publishing; 2012.

9. Chan YH. Biostatistics 102: Quantitative data parametric and non-parametric tests. Singapore Med J. 2003;44(8):391-6. PMid:14700417

10. Chan YH. Biostatistics 103: Qualitative data tests of independence. Singapore Med J. 2003;44(10):498-503. PMid:1524452

11. Rutland-Brown W, Langlois JA, Thomas KE, Xi YL. Incidence of traumatic brain injury in the United States, 2003. J Head Trauma Rehabil. 2006;21(6):544-8. https://doi.org/10.1097/00001199-200611000-00009
PMid:17122685

12. Sharma D, Brown MJ, Curry P, Noda S, Chesnut RM, Vavilala MS. Prevalence and risk factors for intraoperative hypotension during craniotomy for traumatic brain injury. J Neurosurg Anesthesiol. 2012;24(3):178-84. https://doi.org/10.1097/ANA.0b013e318254fb70
PMid:22504924

13. Samuels MA. The brain-heart connection. Circulation. 2007;116(1):77-84. https://doi.org/10.1161/CIRCULATIONAHA.106.678995
PMid:17606855

14. Grunsfeld A, Fletcher JJ, Nathan BR. Cardiopulmonary complications of brain injury. Curr Neurol Neurosci Rep. 2005;5(6):488-93. https://doi.org/10.1007/s11910-005-0039-7
PMid:16263062

15. Junttila E, Vaara M, Koskenkari J, Ohtonen P, Karttunen A, Raatikainen P, et al. Repolarization abnormalities in patients with subarachnoid and intracerebral hemorrhage: Predisposing factors and association with outcome. Anesth Analg. 2013;116(1):190-7. https://doi.org/10.1213/ANE.0b013e318270034a
PMid:23115256

16. Fan X, DU FH, Tian JP. The electrocardiographic changes in acute brain injury patients. Chin Med J (Engl). 2012;125(19):3430-3. PMid:23044301

17. Krishnamoorthy V, Prathep S, Sharma D, Gibbons E, Vavilala MS. Association between electrocardiographic findings and cardiac dysfunction in adult isolated traumatic brain injury. Indian J Crit Care Med. 2014;18(9):570-4. https://doi.org/10.4103/0972-5229.140144
PMid:25249741.