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*Original Article*

# Analysis of neurogenic electrocardiographic changes in acute stroke patients

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**Abstract:** Objective: Our aim was to explore the neurogenic electrocardiographic (ECG) abnormalities in acute stroke patients and the ECG characteristics in different time periods, so as to provide support for clinical data of ECG characteristics in stroke patients. Methods: In this retrospective study, we recruited 260 patients with acute neurogenic stroke who received treatment during January to December 2019. According to the stroke type, we divided them into cerebral hemorrhage (CH) group and cerebral ischemia (CI) group (n=130 each). The ECG changes in all patients were monitored during the acute phase (within 48 hours) and recovery phase (2 weeks after treatment), and the typical abnormalities of the ECG in each group were analyzed. Results: The total incidence of ECG abnormalities in the CH group (79.23%, 103/130) was significantly higher than that in the CI group (68.46%, 89/130; P<0.05). The ECG abnormalities of all patients mainly consisted of P wave abnormalities (44.61%), ST-T depression (46.15%), arrhythmia (38.46%), Q wave abnormalities (3.08%), and QT interval prolongation (3.46%). Furthermore, the incidences of P wave abnormalities and arrhythmia were significantly higher in the CH group than in the CI group in the acute phase (P<0.05), and the incidences of ST-T depression and arrhythmia were markedly lower in the recovery phase than in the acute phase in the CI group (P<0.05). Conclusion: We demonstrate a high incidence of ECG abnormalities in patients with acute neurogenic stroke, among which CH patients show a higher incidence of abnormalities than CI patients, and patients with P wave abnormalities and significant ST-T depression show a comparatively high incidence of cardiovascular sequelae. Therefore, ECG monitoring has certain significance for clinical judgement and observation in patients with acute neurogenic stroke.

**Keywords:** Acute stroke, neurogenic origin, electrocardiographic monitoring, clinical analysis

## Introduction

The number of patients with cerebro- and cardio-vascular diseases (CCVDs) in China is reported to increase at a rate of approximately 2 million per year [1]. Acute stroke is one of the most common severe CCVDs in clinical practice, with a high mortality and disability rate, severely endangering the health and lives of patients [2, 3]. In China, there are about 6 million patients with stroke [4], the treatment and prevention of stroke is still a key chanllenge of public health.

As medical technology develops, much progress has been made in the diagnosis and treatment of CCVDs such as stroke in recent years [5, 6]. Some studies have unveiled that electrocardiographic (ECG) changes at the onset of stroke are related to the disease type or course [7-9]. Besides, it has been reported that the abnormal ECG manifestations in patients with acute neurogenic stroke are associated with the abnormal neuron activity changes, which can lead to a variety of complications, and the timely detection and accurate judgment of stroke type and course are essential for subsequent treatment [10]. As a result, the investigation of the ECG changes, characteristics of different stroke types, and indicators at different phases of treatment plays an important role in the guidance of stroke treatment and prevention.

Herein, we investigated the neurogenic ECG abnormalities in patients with acute stroke and the characteristics at different phases, hoping to provide statistical support for the ECG char-

**Table 1.** General data

| Items | CI group | CH group | $\chi^2$ | P |
|---|---|---|---|---|
| Sex (male/female, n) | 77/53 | 71/59 | 0.565 | 0.452 |
| Age range (year) | 25-79 | 30-77 | | |
| Average age (year) | 59.8±9.3 | 61.3±12.7 | 1.087 | 0.278 |
| Past medical history (n) | | | | |
| Hypertension | 68 | 72 | 0.248 | 0.619 |
| Hyperlipidemia | 57 | 63 | 0.557 | 0.455 |
| Diabetes mellitus | 40 | 35 | 0.468 | 0.494 |

Note: CI: cerebral ischemia; CH: cerebral hemorrhage.

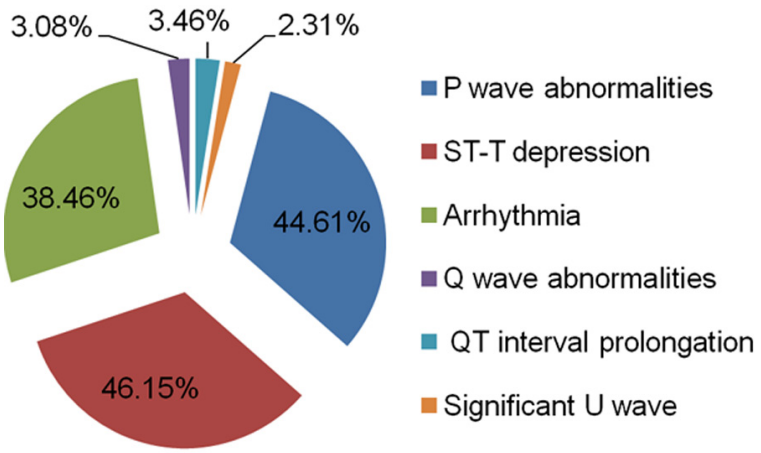


**Figure 1.** ECG abnormalities in the acute phase. ECG: electrocardiographic.

acteristics of patients with different stroke types, and further references for clinical monitoring and observation.

## Materials and methods

### *General data*

A total of 260 patients with acute neurogenic stroke who received treatment in the First Affiliated Hospital of Guangzhou Medical University from January 2019 to December 2019 were selected for this retrospective study. The patients were divided into cerebral hemorrhage (CH) group and cerebral ischemia (CI) group, with 130 cases in each group. ECG was monitored during acute phase (within 48 hours) and recovery phase (2 weeks after treatment) in both groups. All patients were informed of the study and signed written informed consent, and ethics approval for the study was given by the Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University.

### *Inclusion and exclusion criteria*

The included patients, aged over 18 years old, were diagnosed as acute stroke (cerebral hemorrhage or infarction) through MRI or CT. All patients, who were conscious, were admitted within 1 day, with no history of coronary heart disease (CHD) or other heart diseases.

Additionally, patients with acute cardiogenic stroke, malignant tumors or other malignant diseases were excluded. Those with history of alcoholism and long-term cigarette smoking, ECG abnormalities before treatment or incomplete clinical trial data were also excluded.

### *Methods*

Routine tests and treatments were carried out upon hospitalization, e.g., routine blood tests and electrolyte tests were performed, the collar-button or tie of each patient was timely unfastened to keep an airway open, and the patients were placed in the supine position or in the reverse Trendelenberg position (e.g., when going downstairs) on the stretchers. Moreover, brain CT scans were arranged for all patients; antithrombotic therapy with aspirin, Plavix and other antiplatelet drugs, and treatments of dehydration and reduction of intracranial pressure were adopted in the CI group and the CH group, respectively. Meanwhile, electrocardiogram was also monitored and recorded in both groups, with focus on changes of P wave, Q wave, QT interval and ST-T segment in the acute phase. After treatment, electrocardiogram was continuously monitored in the recovery phase, and the ECG changes were analyzed.

### *Outcome measures*

The ECG changes in the acute phase after admission were monitored to record the abnormality rates in each group and compare the dif-

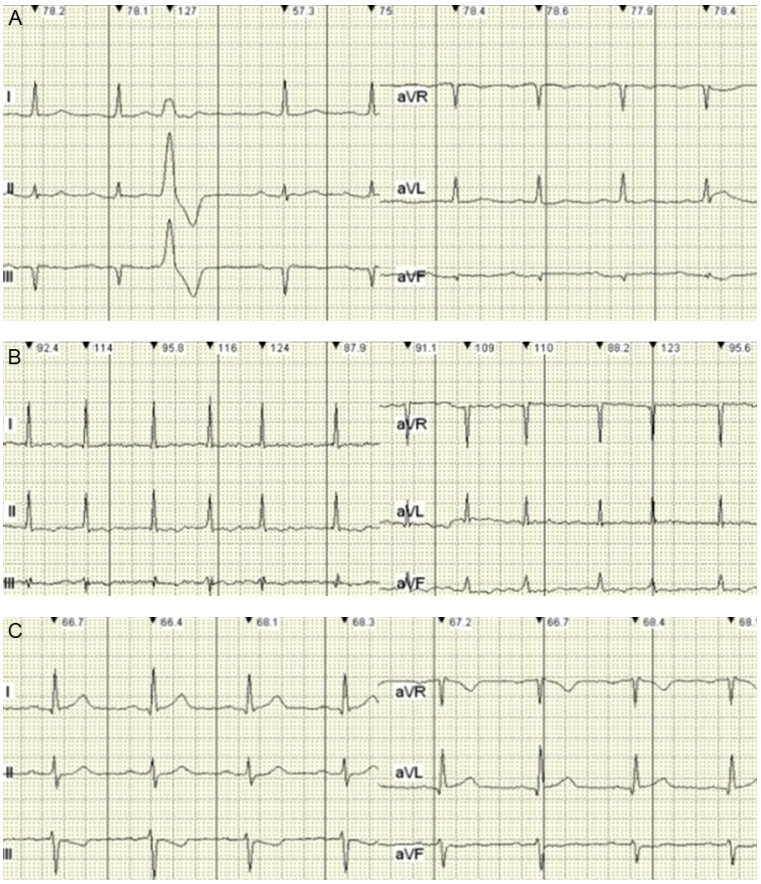


**Figure 2.** Specific ECG abnormalities in the acute phase. A: ST-T depression; B: Arrhythmia; C: P wave abnormalities. ECG: electrocardiographic.

*Statistical analysis*

Data analyses were performed with the SPSS 18.0 software. A chi-square test ($\chi^2$ test) (with continuity correction) was adopted for the comparison of enumeration data expressed as number and percentage (n, %). The measurement data were expressed as mean ± standard deviation ($\bar{x}$ ± sd), and independent sample t-test was used for the comparison between the two groups. $P<0.05$ was considered statistically significant.

## Results

*General data*

There was no significant difference in sex, average age, past medical history, etc. between the CH and the CI group ($P>0.05$), suggesting the two groups are comparable. See **Table 1**.

*ECG abnormalities in the acute phase*

Electrocardiogram was monitored and recorded in time after admission. As **Figure 1** shows, the ECG abnormalities in the acute phase were manifested mainly as P wave abnormalities (44.61%), ST-T depression (46.15%), arrhythmia (38.46%), Q wave abnormalities (3.08%), QT interval prolongation (3.46%) and significant U wave (2.31%). In addition, the specific ECG abnormalities (P wave abnormalities, ST-T depression and arrhythmia) are shown in **Figure 2**.

*Comparison of total incidence of ECG abnormalities in the acute phase*

The total incidence of ECG abnormalities of the CH group (79.23%, 103/130) was significantly higher than that of the CI group (68.46%, 89/130; $P=0.048$) in the acute phase, indicating that the total incidence of ECG abnormalities is higher in patients with CH than patients with CI. See **Table 2**.

**Table 2.** Comparison of total incidence of ECG abnormalities in the acute phase (n, %)

| Group | Cases | Total incidence of ECG abnormalities |
|---|---|---|
| CH group | 130 | 103 (79.23%) |
| CI group | 130 | 89 (68.46%) |
| $\chi^2$ | | 3.903 |
| P | | 0.048 |

Note: CI: cerebral ischemia; CH: cerebral hemorrhage; ECG: electrocardiographic.

ferences between the two groups. The ECG abnormalities, including P wave and Q wave abnormalities, ST-T depression, arrhythmia, QT interval prolongation, etc. were also compared between the two groups. Besides, the ECG changes of the two groups in the recovery phase (2 weeks after treatment) were monitored and compared with those in the acute phase. Incidence of CHD after treatment = (number of CHD cases after treatment)/total number of abnormal ECG cases * 100%.

**Table 3.** Comparison of incidences of ECG abnormalities in the acute phase (n, %)

| ECG abnormalities | CH group | CI group | $\chi^2$ | P |
|---|---|---|---|---|
| P wave abnormalities | 69 (53.08%) | 47 (36.15%) | 7.534 | 0.006 |
| ST-T depression | 59 (45.38%) | 61 (46.92%) | 0.062 | 0.804 |
| Arrhythmia | 58 (44.62%) | 42 (32.31%) | 4.160 | 0.041 |
| Q wave abnormalities | 4 (3.08%) | 4 (3.08%) | 0.000 | 1.000 |
| QT interval prolongation | 5 (3.85%) | 4 (3.08%) | 0.000 | 1.000 |
| Significant U wave | 4 (3.08%) | 2 (1.54%) | 0.171 | 0.680 |

Note: CI: cerebral ischemia; CH: cerebral hemorrhage; ECG: electrocardiographic.

**Table 4.** Comparison of incidence of autonomic dysfunction (n, %)

| Group | Cases | Autonomic dysfunction | $\chi^2$ | P |
|---|---|---|---|---|
| CI group | 130 | 19 (14.62%) | 4.122 | 0.042 |
| CH group | 130 | 32 (24.62%) | | |

Note: CI: cerebral ischemia; CH: cerebral hemorrhage.

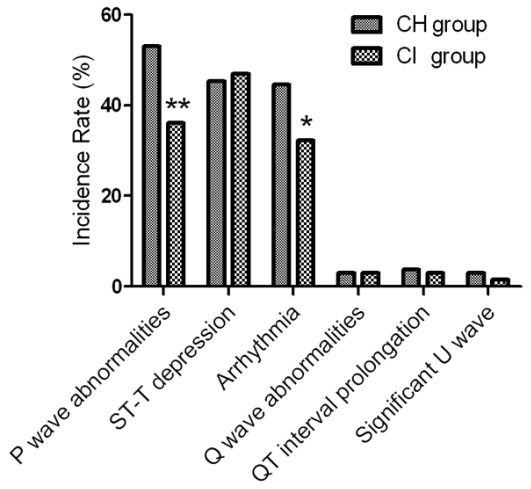


**Figure 3.** Comparison of incidences of ECG abnormalities in the acute phase. Compared with the CH group, *P<0.05; **P<0.01. CI: cerebral ischemia; CH: cerebral hemorrhage; ECG: electrocardiographic.

*Comparison of incidences of ECG abnormalities in the acute phase*

There were no significant differences in the incidences of ST-T depression, Q wave abnormalities, QT interval prolongation and significant U wave between the two groups (all P>0.05), while incidences of P wave abnormalities and arrhythmia were significantly higher in the CH group than in the CI group (P=0.006 and P=0.041, respectively). See **Table 3**.

It can be seen from **Table 4** that the incidence of autonomic dysfunction was markedly higher in the CH group than in the CI group (P=0.042). As shown in **Table 3**, there was an extremely significant difference in the incidence of P wave abnormalities between the two groups. The results suggest that P wave abnormalities in acute phase may be associated with autonomic dysfunction, which provides a certain clinical reference.

Furthermore, as **Figure 3** shows, the common ECG abnormalities in the acute phase were P wave abnormalities, ST-T depression and arrhythmia; significant differences in the incidences of P wave abnormalities and arrhythmia were found between the two groups (both P<0.05).

*Comparison of incidences of ECG abnormalities and cardiac sequelae between the acute and recovery phase*

The CH group showed a more downward trend in the incidence of ECG abnormalities in the recovery phase than in the acute phase, with the most significant decrease in the incidence of ST-T depression (P<0.01), See **Table 5**. The CI group also showed a more downward trend in the incidence of ECG abnormalities in the recovery phase than in the acute phase, with the most significant decreases in incidences of ST-T depression and arrhythmia in the recovery phase (P=0.002 and P=0.035, respectively). See **Table 6**. The results indicate that ECG abnormalities in stroke patients at different time points are reversible and can return to normal gradually after treatment.

Additionally, the incidence of CHD after treatment in the CI group (22.47%) was significantly lower than that in the CH group (42.72%) after treatment (P=0.027). See **Table 7**. The result, combined with the ECG findings in **Tables 5** and **6** in the recovery phase, reveals that CH patients with P wave abnormalities and ST-T depression in the acute phase show a comparatively high incidence of CHD after treatment.

## Discussion

Stroke is one of the most common CCVDs in clinical practice, which severely endangers the

**Table 5.** Comparison of incidences of ECG abnormalities between the acute and recovery phase in CH group (n, %)

| ECG abnormalities | Acute phase | Recovery phase | $\chi^2$ | P |
|---|---|---|---|---|
| P wave abnormalities | 69 (53.08%) | 55 (42.31%) | 3.022 | 0.082 |
| ST-T depression | 59 (45.38%) | 33 (25.38%) | 11.372 | 0.001 |
| Arrhythmia | 58 (44.62%) | 47 (36.15%) | 1.933 | 0.164 |
| Q wave abnormalities | 4 (3.08%) | 3 (2.31%) | 0.147 | 0.702 |
| QT interval prolongation | 5 (3.85%) | 3 (2.31%) | 0.129 | 0.720 |
| Significant U wave | 4 (3.08%) | 2 (1.54%) | 0.171 | 0.680 |

Note: CH: cerebral hemorrhage; ECG: electrocardiographic.

**Table 6.** Comparison of incidences of ECG abnormalities between the acute and recovery phase in CI group (n, %)

| ECG abnormalities | Acute phase | Recovery phase | $\chi^2$ | P |
|---|---|---|---|---|
| P wave abnormalities | 47 (36.15%) | 33 (25.38%) | 3.539 | 0.060 |
| ST-T depression | 61 (46.92%) | 37 (28.46%) | 9.433 | 0.002 |
| Arrhythmia | 42 (32.31%) | 27 (20.77%) | 4.439 | 0.035 |
| Q wave abnormalities | 4 (3.08%) | 1 (0.77%) | 0.816 | 0.366 |
| QT interval prolongation | 4 (3.08%) | 2 (1.54%) | 0.171 | 0.680 |
| Significant U wave | 2 (1.54%) | 0 (0%) | 0.504 | 0.478 |

Note: CI: cerebral ischemia; ECG: electrocardiographic.

**Table 7.** Comparison of cardiovascular disease incidence (n, %)

| Group | Cases of ECG abnormalities in the acute phase | Cases of CHD after treatment | $\chi^2$ | P |
|---|---|---|---|---|
| CI group | 89 | 28 (31.46%) | 4.917 | 0.027 |
| CH group | 103 | 44 (42.72%) | | |

Note: CI: cerebral ischemia; CH: cerebral hemorrhage; ECG: electrocardiographic; CHD: coronary heart disease.

health and lives of patients. For stroke patients, effective clinical judgment and valid drug treatment are of great importance to the rehabilitation and prognosis [11-13]. A previous study reported that neurogenic ECG abnormalities mostly occurred in the acute stroke patients, particularly in patients with hemorrhagic stroke, within 2 days after onset with an incidence rate of 60-90% [14]. ECG waveform abnormalities may also last for more than 2 weeks in stroke patients, and up to about 4 weeks in a few patients [15]. In this study, we monitored acute ECG changes in patients with acute neurogenic stroke and the results showed that the incidence of ECG abnormalities in all patients was 73.85%, and the incidence of ECG abnormalities in hemorrhagic stroke patients was 79.23%, confirming a high incidence of stroke combined with cardiac diseases. Moreover, previous studies of ECG changes in stroke patients have unveiled that ECG changes are associated with stroke location and recovery status, and stroke patients were more likely to develop cardiac sequelae, e.g., those with P wave abnormalities and significant ST-T depression in the acute phase have a high rate of cardiovascular sequelae [16, 17].

In this study, ECG changes were analyzed in patients with acute stroke and the abnormal waveforms mainly consisted of P wave abnormalities, ST-T depression and arrhythmia. As to P wave abnormalities, it mainly referred to high amplitude P wave, whose incidence rate in hemorrhage stroke patients was up to 53.08%. In the recovery phase (2 weeks after treatment), P wave amplitude gradually decreased, while no significant difference was found between P wave abnormalities in the acute and recovery phase, indicating that a longer observation time may be needed. As to ST-T depression, the results demonstrated a flat or inverted T wave and the highest detection rate (46.15%) among ECG abnormalities; the highly improved detection rate during recovery suggests that ECG abnormalities in stroke patients are reversible and can be back to normal gradually through treatment. In line with our study, Sudhish et al. also reported that patients with acute ischemic stroke showed a significant ST-T depression with gradual recovery [18]. As to arrhythmia, severe arrhythmia, especially torsades de pointes, caused by neurogenic stroke might lead to death. This may be because parasympathetic regulation was easily affected by cerebral functional impairment, thus causing arrhythmia, or cardiovascular dysfunction resulting from intracranial hemorrhage led to cardiac damage. Therefore, it's essential to monitor P wave and heart rhythm during recovery, with particular focus on the occur-

rence of cardiovascular diseases. In this study, we showed that the incidences of P wave abnormalities and arrhythmia were higher in the CH group than the CI group in the recovery phase, while no significant change was observed between the incidences during the acute and recovery phase. Furthermore, this study demonstrated markedly higher incidences of CHD and autonomic dysfunction in the CH group than the CI group. This may be because hypothalamic injury resulting from hemorrhage stroke led to activation of the sympathetic-adrenal system. Hence, we speculated that the ECG changes may be one of the auxiliary indicators for assessing the rehabilitation status of patients and the risk of sequelae.

Currently, the specific causes and mechanisms of ECG changes in acute stroke patients are still not very clear. Some physician scientists believe that it may be related to the structure of diencephalon and brainstem [19, 20]. The changes in release of mediators caused by alterations of sympathetic and vagal nervous tension resulted in ECG abnormalities. For example, the anterior cranial fossa may cause ECG changes, and cerebellar tonsillar damage may cause infarct-like ECG changes [21]. Several limitations still remain in this study though we have achieved certain positive results. The disease types were not various, and the monitoring time was limited in the recovery phase, so more studies are needed to get a more precise conclusion in the future.

In summary, we report a high incidence of ECG abnormalities in acute neurogenic patients, and a reduced abnormality rate in most patients during recovery after treatment. CH patients show a higher incidence of abnormalities than CI patients, and CH patients with P wave abnormalities and significant ST-T depression in the acute phase show a comparatively high incidence of cardiovascular sequelae. Hence, ECG monitoring has certain clinical significance for clinical observation and prognosis in patients with acute neurogenic stroke.

## Disclosure of conflict of interest

None.

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