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# The Effect of Early Surgery on Electrocardiographic Changes in Patients with Subarachnoid Hemorrhage

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## ABSTRACT

**AIM:** To investigate the effects of early surgery on electrocardiographic (ECG) parameters in patients with aneurysmal subarachnoid hemorrhage (SAH). We compared the parameters from ECGs performed preoperatively and on the 2nd and 8th days after surgery with those of normal individuals.

**MATERIAL and METHODS:** Eighteen patients with aneurysmal SAH (as the study group) and 22 healthy subjects (as the control group) were enrolled in this study. The demographics and ECG data of the participants were collected, and the groups were compared. The analyzed data included HR, QRS duration, Pmax, Pmin, P wave dispersion (PWD), QT, QTc, Tp-e, JT, JTc, Tp-e/QT, Tp-e/QTc, Tp-e/JT, and Tp-e/JTc. The preoperative and postoperative 2nd and 8th day values were compared.

**RESULTS:** The preoperative QT, QTc, JT, JTc, Pmax, and Pmin values of patients with aneurysmal subarachnoid hemorrhage were significantly higher than those of healthy subjects. There were no significant differences in the 2nd and 8th day ECG parameters of the groups.

**CONCLUSION:** Early and successful surgery for SAH can alleviate ECG changes. This may decrease the requirement for cardiac interventions in these patients.

**KEYWORDS:** Subarachnoid hemorrhage, Electrocardiographic changes, Early surgery

## INTRODUCTION

Electrocardiographic (ECG) changes are frequently encountered in patients with subarachnoid hemorrhage (SAH). These include cardiac arrhythmias such as supraventricular tachycardias, ventricular tachycardias, and premature atrial or ventricular contractions. They occur in approximately 50% of cases (22). The responsible mechanisms may include abnormal serum electrolyte concentrations, parasympathetic and sympathetic imbalance due to hypothalamic dysfunction, stress response-related subendocardial ischemia, and vasospasm in coronary arteries (15).

The incidence of SAH varies between 7.5 and 12.9 per 100,000 in the general population. It is responsible for a quarter of deaths from cerebrovascular events (6). Byer et al. reported ECG changes related to SAH in 1947 (7). Subsequent studies reported the changes as occurring in 1 to 3 out of every 4 cases of SAH (11,26). The ECG changes include ST-segment abnormalities, abnormal Q waves, prolongation of the QT interval, and T wave inversion (16,25). However, the prognostic value of these ECG changes remains controversial (5,16,26).

P wave dispersion (PWD) is defined as the difference between the shortest and longest P wave durations on a 12-lead ECG. PWD reflects the discontinuous anisotropic spread of sinus impulses and non-homogeneous and discontinuous atrial conduction. Comprehensive clinical evaluation of PWD has been performed to evaluate the risk of atrial fibrillation in coronary artery disease, heart valve disease, heart failure, congenital heart disease, rheumatologic disease, and hypertension (2).

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Ventricular repolarization (VR) is represented by the interval between the onset of the QRS complex and the end of the T wave on the surface ECG. Cardiac electrical changes during VR can lead to fatal arrhythmias (18). The QT interval (QT), corrected QT interval (QTc), and QT dispersion (QTD) are associated with ventricular arrhythmic events and high mortality rates in various clinical situations (9,24). The JT interval is a component of the QT interval. It is calculated as the QT interval minus the QRS duration. It has been proposed as a more appropriate measure of VR than QT itself (3,10). The Tp-e interval, a relatively new ECG parameter, shows dispersion of VR even in normal QTc patients (13,19). The interval from the peak of the T wave to the end of the T wave in the ECG (Tpeak to Tend interval, Tp-e) is a measure of the transmural dispersion of repolarization in the left ventricle. The Tp-e/QT ratio has recently been used as a new ECG marker for VR distribution (8). Both the Tp-e interval and the Tp-e/QT ratio are associated with malignant ventricular arrhythmias (1).

This study aimed to investigate the effects of aneurysmal SAH and its surgical treatment on ECG parameters.

## MATERIAL and METHODS

### Study Population and Design

Between January 2018 and October 2019, 18 patients with aneurysmal SAH who were admitted to our hospital (the study group), and 22 healthy volunteers (control group) were enrolled in the study. Subjects who were known to have cardiac disease, thyroid disease, severe renal failure, diabetes mellitus, or hypertension (for longer than one year) were excluded from the control group. The participants' demographic and ECG data obtained from our hospital's electronic database were analyzed and compared. The local ethics committee approved the study protocol (No: 2019/322; Date: 19.12.2019). The study was conducted in accordance with the Declaration of Helsinki. All participants were informed about the study, and their written consent was obtained.

### Electrocardiography

The ECG parameters were measured by two cardiologists using a magnifying glass and digital caliper (TorQ 150 mm Digital Caliper LCD) in a blinded manner. The mean of two measurements was used in the statistical analyses. The heart rate (HR), QRS (durations), Pmax, Pmin, PWD, QT, QTc, Tp-e, JT, JTc, Tp-e/QT, Tpe/QTc, Tp-e/JT, and Tp-e/JTc were obtained from the patients' ECG recordings and the preoperative and postoperative 2nd and 8th day values were compared.

The QT interval was measured from the start of the QRS complex to the end of the T wave (taken as its return to the TP baseline; the U-wave was not included). The difference between the maximum and minimum QT interval in different leads was defined as the QTD. The R-R interval was measured and used to compute the heart rate and correct QTc using the Hodges formula. The distance from the peak of the T wave to its end was defined as the Tp-e interval. The end of the T wave was taken as the intersection of the tangent to the downslope of the T wave and the isoelectric line. Measurement of the Tp-e interval was performed using the precordial leads. The interval from the end of the QRS complex (J point) to the end of the T wave (JT end interval) was called the JT interval. JTc was calculated using Hodges formula: [$JTc = JT + 0.00175 \times (HR-60)$]. We also measured or calculated the following parameters: Tp-e/QT, Tpe/QTc, Tp-e/JT, and Tp-e/JTc ratios.

### Statistical Analysis

Preoperative and postoperative variables were compared using the one-way ANOVA test for repeated measurements. The post-hoc Bonferroni test was used for paired group comparisons. The T-test was used for independent groups to compare the control and study groups. A P-value of less than 0.05 was considered statistically significant.

## RESULTS

Eighteen SAH patients and 22 control subjects were enrolled in the study. Table I shows their demographic features. The QRS durations of the SAH patients were significantly decreased after surgery ($p=0.019$). The other ECG parameters were not statistically different in the study group. The ECG parameters are shown in Table II.

There were significant differences in certain ECG parameters between the healthy and SAH subjects. The preoperative QT, QTc, JT, JTc, Pmax, and Pmin values of the SAH patients were significantly higher than those of the control group ($p<0.05$) (Table III). HR, Pmax, Pmin, PWD, QT, QTc, Tp-e, JT, JTc, Tp-e/QT, Tp-e/QTc, Tp-e/JT, and Tp-e/JTc were not significantly different between the preoperative, postoperative 2nd day, and postoperative 8th day ECG recordings of the SAH patients ($p>0.05$).

There were no significant differences in ECG parameters between the control group and study group for the postoperative 2nd and 8th days ($p>0.05$) (Tables IV, V). The QT, QTc, JT, JTc, Pmax, and Pmin values decreased on the 2nd and 8th days after surgery and were similar to the control group values in the postoperative period (Tables IV, V).

The HR, QRS durations, PWD, Tp-e, Tp-e/QT, Tp-e/QTc, Tp-e/JT, and Tp-e/JTc did not differ between the preoperative study and control subjects ($p>0.05$ for all). Pmax ($p=0.041$), Pmin ($p=0.025$), QT ($p=0.010$), QTc ($p=0.001$), JT ($p=0.01$), and JTc ($p=0.001$) levels were significantly different between

**Table I:** Demographics Characteristics of The Study Groups

| | Study Group | Control Group | p |
|---|---|---|---|
| Number of patients (n) | 18 | 22 | |
| Mean Age (years) | 58 ± 12 | 54 ± 9 | 0.18 |
| Gender | | | |
| Male | 5 (28.0%) | 8 (36.0%) | 0.58 |
| Female | 13 (72.0%) | 14 (64.0%) | |

*Values are expressed as mean (SD) or n (%).*

**Table II:** Electrocardiography Values of Study Population

| | Preop | Postop 2nd day | Postop 8th day | p[a] |
|---|---|---|---|---|
| HR | 70.91 ± 11.41 | 73.83 ± 13.78 | 77.73 ± 22.81 | 0.174 |
| QRS | 91.45 ± 11.33 | 90.67 ± 9.66 | 85.18 ± 11.9 | **0.019**[b] |
| Pmax | 110.09 ± 12.96 | 100.75 ± 11.42 | 98.64 ± 14.99 | 0.078 |
| Pmin | 83.64 ± 12.77 | 77.25 ± 14.13 | 71.18 ± 15.11 | 0.101 |
| PWD | 26.45 ± 9.26 | 23.58 ± 12.73 | 32.91 ± 24.65 | 0.491 |
| QT | 397.73 ± 34.44 | 373.58 ± 41.37 | 369.36 ± 51.19 | 0.059 |
| QTc | 427.18 ± 27.63 | 409.75 ± 29.06 | 409.82 ± 26.15 | 0.277 |
| Tp-e | 88.91 ± 15.82 | 89.42 ± 16.03 | 84.82 ± 15.59 | 0.904 |
| JT | 304.27 ± 34.43 | 282.08 ± 37.68 | 284.18 ± 42.18 | 0.051 |
| JTc | 328.18 ± 30.89 | 309 ± 27.77 | 314.91 ± 23.3 | 0.168 |
| Tp-e/QT | 0.23 ± 0.05 | 0.24 ± 0.05 | 0.23 ± 0.05 | 0.187 |
| Tp-e/QTc | 0.21 ± 0.04 | 0.22 ± 0.04 | 0.21 ± 0.04 | 0.684 |
| Tp-e/JT | 0.3 ± 0.07 | 0.32 ± 0.07 | 0.3 ± 0.07 | 0.118 |
| Tp-e/JTc | 0.27 ± 0.05 | 0.29 ± 0.06 | 0.27 ± 0.06 | 0.509 |

*[a]One-way repeated measures ANOVA.*

**Table III:** Comparison of Electrocardiography Values of Control Group and Preoperative Findings of the Study Group

| | Control | Preop-SAH | p |
|---|---|---|---|
| HR | 70.43 ± 13.41 | 70.91 ± 11.41 | 0.920 |
| QRS | 90.65 ± 10.65 | 91.45 ± 11.33 | 0.842 |
| Pmax | 100.87 ± 11.24 | 110.09 ± 12.96 | **0.041** |
| Pmin | 73.74 ± 10.78 | 83.64 ± 12.77 | **0.025** |
| PWD | 27.09 ± 6.93 | 26.45 ± 9.26 | 0.825 |
| QT | 367.09 ± 25.54 | 395.73 ± 34.44 | **0.010** |
| QTc | 394.13 ± 23.1 | 427.18 ± 27.63 | **0.001** |
| Tp-e | 83.7 ± 9.77 | 88.91 ± 15.82 | 0.244 |
| JT | 277.09 ± 23.83 | 304.27 ± 34.43 | **0.011** |
| JTc | 297.17 ± 20.34 | 328.18 ± 30.89 | **0.001** |
| Tp-e/QT | 0.23 ± 0.03 | 0.23 ± 0.05 | 0.765 |
| Tp-e/QTc | 0.21 ± 0.03 | 0.21 ± 0.04 | 0.469 |
| Tp-e/JT | 0.3 ± 0.03 | 0.3 ± 0.07 | 0.659 |
| Tp-e/JTc | 0.28 ± 0.04 | 0.27 ± 0.05 | 0.458 |

*Independent samples t-test was used.*
***Preop-SAH:** Preoperative subarachnoid hemorrhage.*

**Table IV:** Comparison of Electrocardiography Values of Control Group and Postoperative 2nd Day Findings of the Study Group

| | Control | Postop-SAH 2nd day | p |
|---|---|---|---|
| HR | 70.43 ± 13.41 | 73.83 ± 13.78 | 0.486 |
| QRS | 90.65 ± 10.65 | 90.67 ± 9.66 | 0.997 |
| Pmax | 100.87 ± 11.24 | 100.75 ± 11.42 | 0.976 |
| Pmin | 73.74 ± 10.78 | 77.25 ± 14.13 | 0.417 |
| PWD | 27.09 ± 6.93 | 28.5 ± 12.73 | 0.296 |
| QT | 367.09 ± 25.54 | 373.58 ± 41.37 | 0.569 |
| QTc | 394.13 ± 23.1 | 409.75 ± 29.06 | 0.092 |
| Tp-e | 83.7 ± 9.77 | 89.42 ± 16.03 | 0.198 |
| JT | 277.09 ± 23.83 | 282.08 ± 37.68 | 0.634 |
| JTc | 297.17 ± 20.34 | 309 ± 27.77 | 0.160 |
| Tp-e/QT | 0.23 ± 0.03 | 0.24 ± 0.05 | 0.317 |
| Tp-e/QTc | 0.21 ± 0.03 | 0.22 ± 0.04 | 0.670 |
| Tp-e/JT | 0.3 ± 0.03 | 0.32 ± 0.07 | 0.295 |
| Tp-e/JTc | 0.28 ± 0.04 | 0.29 ± 0.06 | 0.554 |

*Independent samples t-test was used.*
***Postop-SAH:** Postoperative subarachnoid hemorrhage.*

**Table V:** Comparison of Electrocardiography Values of Control Group and Postoperative 8th Day Findings of the Study Group

| | Control | Postop-SAH 8th day | p |
|---|---|---|---|
| HR | 70.43 ± 13.41 | 77.73 ± 22.81 | 0.248 |
| QRS | 90.65 ± 10.65 | 85.18 ± 11.09 | 0.176 |
| Pmax | 100.87 ± 11.24 | 98.64 ± 14.99 | 0.630 |
| Pmin | 73.74 ± 10.78 | 71.18 ± 15.11 | 0.574 |
| PWD | 27.09 ± 6.93 | 32.91 ± 24.65 | 0.295 |
| QT | 367.09 ± 25.54 | 369.36 ± 51.19 | 0.863 |
| QTc | 394.13 ± 23.1 | 409.82 ± 26.15 | 0.085 |
| Tp-e | 83.7 ± 9.77 | 84.82 ± 15.59 | 0.799 |
| JT | 277.09 ± 23.83 | 284.18 ± 42.18 | 0.534 |
| JTc | 297.17 ± 20.34 | 314.91 ± 23.3 | **0.030** |
| Tp-e/QT | 0.23 ± 0.03 | 0.23 ± 0.05 | 0.832 |
| Tp-e/QTc | 0.21 ± 0.03 | 0.21 ± 0.04 | 0.607 |
| Tp-e/JT | 0.3 ± 0.03 | 0.3 ± 0.07 | 0.945 |
| Tp-e/JTc | 0.28 ± 0.04 | 0.27 ± 0.06 | 0.468 |

*Independent samples t-test was used.*
***Postop-SAH:** Postoperative subarachnoid hemorrhage.*

preoperative study and control subjects. None of the ECG parameters were significantly different between the postoperative 2nd or 8th day and the control subjects (p>0.05).

## DISCUSSION

In the patients with aneurysmal SAH, the QT, QTc, JT, and JTc intervals in the preoperative period were significantly higher than in the control group. Nonetheless, in the postoperative period, these intervals, in the study group, were similar to those of the control group. Since the higher ECG intervals are associated with an increased risk of arrhythmias, the similarity of ECG parameters between the groups might indicate a reduced risk of arrhythmias after surgery. As a result, early surgical intervention may also have an important role in reducing the risk of cardiac arrhythmias in these patients, in addition to managing the SAH.

ECG changes are not unusual during an SAH (12). In a Belgian study, the authors reported that approximately 67% of subjects with SAH had ECG changes of varying degrees (21). A recent study reported that the QT interval was associated with disease severity and clinical prognosis in SAH patients (14). We demonstrated that prolonged QT, QTc, JT, and JTc parameters were improved after surgical treatment. Therefore, even within the normal range, these parameters could be related to SAH and may indicate the arrhythmia-prone period during the pre-surgical follow-up. SAH causes significant deterioration in the heart. It stimulates a wide range of ECG changes, which may even result in mistreatment. (22). ST-segment elevation mimicking acute MI has been reported in SAH patients (4). Moreover, several studies have reported left ventricular wall motion abnormalities in these patients, in the absence of coronary occlusion (20). One study concluded that a prolonged QTc was associated with myocardial injury in SAH patients (23). Similarly, in the present study, we found the prolongation of QT, QTc, JT, and the JTc wave improved after surgical treatment in SAH patients. However, Pmin, Pmax, and PWD did not differ between pre and postoperative SAH patients and healthy subjects.

Arrhythmias associated with SAH are a significant cause of morbidity that needs appropriate treatment. The literature suggests that ECG abnormalities often reflect subendocardial damage (17). These arrhythmias might be a consequence of increased sympathetic tone in the whole body since they respond well to sympathetic blockers, such as propranolol. The ECG changes responded well to the surgical treatment of SAH patients in our study.

Our study had two major limitations complicating the interpretation of the results. First, the study population was relatively small; however, it should be noted that surgically treated aneurysmal SAH is not a frequent disease, making it difficult to enroll enough subjects within a certain period. Second, the control group was too small to compare ECG findings with those of SAH patients.

## CONCLUSION

In conclusion, to the best of our knowledge, this is the first study to suggest that early surgical treatment of SAH may improve ECG changes and reduce the necessity for cardiac intervention. However, prospective case-control studies with larger cohorts are needed to confirm our results.

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