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# EFFECTS OF TEAS USING DIFFERENT ACUPOINT COMBINATIONS ON PERIOPERATIVE VENTRICULAR REPOLARIZATION IN NEUROSURGERY

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**Abstract:** Objective: To evaluate the effects of transcutaneous electrical acupoint stimulation (TEAS) delivered using different acupoint combinations on perioperative ventricular repolarization and indices of depolarization-repolarization balance in patients undergoing neurosurgery. Methods: Sixty patients scheduled for elective neurosurgery were randomized in a 1:1:1 ratio to a control group (C), a Governor Vessel-based acupoint combination group (EAA), or a Pericardium Meridian-based acupoint combination group (EAB), with 20 patients per group. The EAA protocol included Lingtai (GV10), Shendao (GV11), bilateral Neiguan (PC6), and bilateral Shenmen (HT7); the EAB protocol included bilateral Neiguan (PC6), Ximen (PC4), Daling (PC7), and Shenmen (HT7). In the control group, identical electrodes were applied to the corresponding acupoints without effective electrical stimulation. TEAS was delivered continuously from induction of anesthesia until the end of surgery. Standard 12-lead electrocardiograms were obtained before anesthesia induction (T0), after completion of the principal lesion-related surgical step (T1), at the end of surgery (T2), and 24 h postoperatively (T3). QT interval, QRS duration, and the Tpeak-to-Tend (Tp-e) interval were measured in lead V5. The corrected QT interval (QTc) was calculated using Bazett's formula, and the Tp-e/QT ratio and index of cardio-electrophysiological balance (iCEB) were derived. Arrhythmias occurring during the study observation period were also recorded. Complete data were available for 50 patients and were included in the complete-case analysis (C, n=18; EAA, n=16; EAB, n=16). Results: At T0, QTc, Tp-e, Tp-e/QT, and iCEB did not differ among groups (all $P>0.05$). For QTc, the overall group effect was not significant ($P=0.529$), whereas the time effect ($P=0.010$) and group-by-time interaction ($P=0.040$) were significant. QTc increased from baseline at T1 and T2 in the control group, while the corresponding changes were smaller in both TEAS groups. For Tp-e, the overall group effect, time effect, and group-by-time interaction were all significant ($P=0.002$, $P<0.001$, and $P=0.020$, respectively); the EAB group showed comparatively limited fluctuations across time points. No significant group, time, or interaction effects were observed for Tp-e/QT ($P=0.072$, $P=0.366$, and $P=0.057$, respectively). For iCEB, the overall group effect and interaction were not significant ($P=0.138$ and $P=0.373$), whereas the time effect was significant ($P=0.029$). During the observation period, arrhythmias were recorded in 3 patients in the control group, 1 patient in the EAA group, and no patients in the EAB group. Conclusions: Different TEAS acupoint combinations were associated with distinct perioperative trajectories of QTc and Tp-e in patients undergoing neurosurgery, with comparatively smaller Tp-e fluctuations observed in the EAB group. No consistent between-group dynamic differences were demonstrated for Tp-e/QT or iCEB. The specific effects and clinical relevance of different acupoint combinations on perioperative ventricular repolarization and depolarization-repolarization balance require confirmation in larger, rigorously monitored studies.
**Keywords:** Transcutaneous electrical acupoint stimulation; Neurosurgery; Ventricular repolarization; QTc; Tpeak-to-tend interval

## 1 INTRODUCTION

Patients with neurologic disease may exhibit a broad spectrum of electrocardiographic abnormalities, making perioperative cardiac electrophysiology an important consideration in neurosurgical care. In acute nontraumatic brain injury, ST-T abnormalities, corrected QT (QTc) prolongation, and arrhythmias are common and have been associated with adverse clinical outcomes [1]. Abnormalities in QTc, the Tpeak-to-Tend (Tp-e) interval, the Tp-e/QT ratio, and the index of cardio-electrophysiological balance (iCEB) have also been reported in patients with subarachnoid hemorrhage [2]. These findings are consistent with the increasingly recognized bidirectional heart-brain axis, whereby disruption of central autonomic regulation and perioperative stress may augment sympathetic outflow and disturb sympathovagal balance, thereby affecting myocardial electrical activity and ventricular repolarization stability [3]. Adjunctive strategies capable of modulating autonomic function while preserving perioperative electrophysiological stability therefore warrant investigation.

Transcutaneous electrical acupoint stimulation (TEAS) is a noninvasive and technically straightforward form of acupoint stimulation. A systematic review and meta-analysis suggested that acupuncture may influence heart rate variability by modulating autonomic activity and increasing parasympathetic tone [4]. In neurosurgical populations, randomized controlled studies have shown that TEAS can reduce remifentanil requirements and attenuate hemodynamic fluctuations during intracranial aneurysm clipping [5], and may reduce postoperative nausea, vomiting, and pain after craniotomy [6]. Separately, clinical reports of the Tiaoxin Anshen acupuncture approach for arrhythmias have

continued to use Lingtai (GV10), Shendao (GV11), Neiguan (PC6), and Baihui (GV20) as key acupoints [7], while studies focused on Neiguan (PC6) have suggested potential effects on arrhythmia-related autonomic regulation [8].
Building on prior acupuncture research in arrhythmia and taking into account the operative field, patient positioning, and practical constraints specific to neurosurgery, we simplified and adapted the original acupoint combinations. We then compared two TEAS protocols with respect to perioperative QTc, Tp-e, Tp-e/QT, iCEB, and observed arrhythmias, with the aim of characterizing their effects on ventricular repolarization and depolarization-repolarization balance.

## 2 METHODS

### 2.1 Study Design and Participants

This was a single-center, prospective, randomized controlled study. Sixty adult patients scheduled for elective neurosurgery at Guiyang Second People's Hospital between January and December 2022 were enrolled. Eligibility criteria were age 18-70 years, either sex, body mass index 18-25 kg/m², American Society of Anesthesiologists (ASA) physical status II-III, and New York Heart Association (NYHA) functional class I-III. Exclusion criteria were refusal to participate, preoperative arrhythmia, severe valvular heart disease, clinically significant preoperative hepatic or renal dysfunction, or any other condition that, in the investigators' judgment, rendered participation inappropriate.
The study was approved by the Ethics Committee of Guiyang Second People's Hospital (approval no. [2021] Ethics Review No. 49). Written informed consent was obtained from all participants or their legally authorized representatives. The trial was registered with the Chinese Clinical Trial Registry (ChiCTR2100054967).

### 2.2 Randomization and Blinding

A computer-generated randomization sequence was used to allocate participants in a 1:1:1 ratio to the control group (C), Governor Vessel-based acupoint combination group (EAA), or Pericardium Meridian-based acupoint combination group (EAB), with 20 participants assigned to each group. The sequence was generated and retained by an investigator who had no role in study intervention, perioperative management, or outcome assessment. Acupoint stimulation was administered by an independent investigator according to group allocation. Participants and investigators responsible for perioperative data collection were blinded to allocation. Electrocardiographic measurements and statistical analyses were performed independently by investigators who were also blinded to group assignment.

### 2.3 Acupoint Selection and TEAS Intervention

After arrival in the operating room, the skin over the prespecified acupoints was cleaned, dedicated surface electrodes were applied, and the electrodes were connected to a Huatuo SDZ-III electronic acupuncture stimulator. Both active-treatment groups received a 2/100-Hz dense-disperse waveform. Stimulation intensity was individually adjusted to produce visible mild local muscle contraction while remaining tolerable to the patient. Stimulation was initiated at induction of anesthesia and continued until the end of surgery.
Because several acupoints specified in the original registered protocol were difficult to access continuously without interfering with the neurosurgical field, patient positioning, skin preparation, or sterile draping, the protocol was simplified during implementation while retaining the principal acupoints intended to represent each combination.
In the EAA group, TEAS was applied at Lingtai (GV10), Shendao (GV11), bilateral Neiguan (PC6), and bilateral Shenmen (HT7). GV10 is located on the posterior midline in the depression below the spinous process of the sixth thoracic vertebra, and GV11 on the posterior midline in the depression below the spinous process of the fifth thoracic vertebra. PC6 is located on the anterior aspect of the forearm, 2 cun proximal to the palmar wrist crease, between the tendons of palmaris longus and flexor carpi radialis. HT7 is located at the ulnar end of the palmar wrist crease, on the radial side of the flexor carpi ulnaris tendon.
In the EAB group, TEAS was applied bilaterally at Neiguan (PC6), Ximen (PC4), Daling (PC7), and Shenmen (HT7). PC4 is located on the anterior aspect of the forearm, 5 cun proximal to the palmar wrist crease, between the tendons of palmaris longus and flexor carpi radialis. PC7 is located at the palmar wrist crease between the tendons of palmaris longus and flexor carpi radialis. The locations of PC6 and HT7 were identical to those used in the EAA group.
In the control group, identical electrodes were placed over the prespecified acupoints and connected to the stimulator, but no effective electrical stimulation was delivered. All other aspects of perioperative management were standardized across groups.

### 2.4 Anesthesia Protocol

On arrival in the operating room, peripheral venous access was established and noninvasive blood pressure, 12-lead electrocardiography, pulse oximetry, bispectral index (BIS), and body temperature were monitored routinely. A radial arterial catheter was placed under local anesthesia, and central venous access was established when clinically indicated. Anesthesia was induced with midazolam 0.1 mg/kg, sufentanil 0.5 μg/kg, etomidate 0.3 mg/kg, and rocuronium 0.6 mg/kg. After tracheal intubation, mechanical ventilation was instituted with a tidal volume of 8-10 mL/kg and respiratory rate of 12-15 breaths/min; ventilatory settings were adjusted to maintain end-tidal carbon dioxide at 35-45 mmHg. Anesthesia was maintained with sevoflurane at 0.7-1.0 minimum alveolar concentration, propofol at 4-6 mg·kg⁻¹·h⁻¹, and remifentanil at 0.1-0.2 μg·kg⁻¹·min⁻¹, with additional neuromuscular blockade administered as required. BIS was maintained between 40 and 60. Vasoactive drugs and other measures were used to maintain intraoperative hemodynamic variables within ±20% of baseline, and acid-base or electrolyte abnormalities were corrected according to blood-gas analysis.

### 2.5 ECG Acquisition and Electrophysiological Measurements

Standard 12-lead electrocardiograms were obtained before induction of anesthesia (T0), after completion of the principal lesion-related surgical step (T1), at the end of surgery (T2), and 24 h postoperatively (T3). All ECGs were analyzed by investigators blinded to group allocation. Lead V5 was used consistently for measurement of the QT interval, QRS duration, and Tp-e interval. The QT interval was defined from the onset of the QRS complex to the end of the T wave; Tp-e was defined from the peak to the end of the T wave. QTc was corrected for heart rate using Bazett's formula ($QTc = QT/\sqrt{RR}$, with QT and RR expressed in seconds). Tp-e/QT was calculated as the ratio of Tp-e to QT, and iCEB was calculated as QT/QRS.

### 2.6 Arrhythmia Assessment

Arrhythmia occurrence was a secondary outcome. Continuous intraoperative ECG monitoring was supplemented by the 12-lead ECGs obtained at T0-T3. Arrhythmias observed during the study period were recorded by type and included sinus bradycardia, premature atrial complexes, premature ventricular complexes, supraventricular tachycardia, atrial fibrillation, ventricular tachycardia, and other clinically significant rhythm disturbances.

### 2.7 Sample-Size Estimation

Sample size was estimated according to the original study protocol. With a two-sided $\alpha$ of 0.05 and statistical power ($1-\beta$) of 0.80, at least 16 patients were required per group. Allowing for approximately 20% attrition, loss to follow-up, or protocol deviation, the planned sample size was 20 patients per group, for a total of 60 participants.

### 2.8 Statistical Analysis

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). A complete-case analysis was conducted among participants who completed the prespecified intervention and had complete ECG data from T0 through T3. Normally distributed continuous variables are presented as mean ± standard deviation and were compared among groups using one-way analysis of variance. Non-normally distributed variables are presented as median (interquartile range) and were analyzed using the Kruskal-Wallis H test. Categorical variables are presented as number (percentage) and were compared using the chi-square test or Fisher's exact test, as appropriate. Repeated-measures analysis of variance was used for QTc, Tp-e, Tp-e/QT, and iCEB to evaluate the overall group effect, time effect, and group-by-time interaction. When a significant interaction was detected, simple-effects analyses were performed, with Bonferroni adjustment for pairwise comparisons. All tests were two-sided, and $P<0.05$ was considered statistically significant.

## 3 RESULTS

### 3.1 Participant Flow and Analysis Population

A total of 60 patients were enrolled and randomized, with 20 assigned to each group. During the study, 2 patients in the control group, 4 in the EAA group, and 4 in the EAB group did not complete the study because of factors including surgical positioning that precluded sustained TEAS, prolonged surgery, failure to complete the intervention according to protocol, or incomplete ECG data. Ultimately, 50 patients had complete T0-T3 data and were included in the complete-case analysis: 18 in the control group, 16 in the EAA group, and 16 in the EAB group. The final number analyzed in each group met the prespecified minimum sample size of 16 patients per group.

### 3.2 Baseline Characteristics

Age, sex distribution, ASA physical status, and type of surgery did not differ significantly among the three groups (all $P>0.05$). Surgical duration, anesthesia duration, and baseline heart rate (HR), systolic blood pressure (SBP), and mean arterial pressure (MAP) before anesthesia induction were also comparable across groups (all $P>0.05$), with no evident between-group imbalance in baseline characteristics (Table 1).

**Table 1** Baseline Characteristics of the Three Groups

| Variable | Control (n=18) | EAA (n=16) | EAB (n=16) | Statistic | P value |
|---|---|---|---|---|---|
| Age, years | 47.00 ± 10.38 | 52.44 ± 16.45 | 50.31 ± 12.62 | F=0.729 | 0.488 |
| Male/female, n | 8/10 | 12/4 | 7/9 | - | 0.157 |
| ASA physical status II/III, n | 1/17 | 2/14 | 3/13 | - | 0.493 |
| Tumor surgery/other surgery, n | 13/5 | 12/4 | 13/3 | - | 0.917 |

| | | | | | |
|---|---|---|---|---|---|
| Surgical duration, min | 255.28 ± 90.31 | 222.94 ± 108.23 | 255.19 ± 100.47 | F=0.573 | 0.568 |
| Anesthesia duration, min | 324.33 ± 92.30 | 286.25 ± 122.25 | 319.56 ± 115.97 | F=0.583 | 0.562 |
| Baseline HR, beats/min | 77.83 ± 16.28 | 76.00 ± 9.95 | 76.75 ± 11.38 | F=0.086 | 0.918 |
| Baseline SBP, mmHg | 124.61 ± 14.28 | 132.69 ± 17.35 | 128.25 ± 19.25 | F=0.960 | 0.390 |
| Baseline MAP, mmHg | 91.11 ± 7.57 | 97.69 ± 11.04 | 96.13 ± 14.17 | F=1.642 | 0.205 |

Note: Values are presented as mean ± SD for continuous variables and as counts for categorical variables. Continuous variables were compared using one-way analysis of variance; categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. ASA, American Society of Anesthesiologists; HR, heart rate; SBP, systolic blood pressure; MAP, mean arterial pressure.

**3.3 Perioperative Cardiac Electrophysiological Indices**

***3.3.1 QTc***

The overall QTc level did not differ significantly among groups (P=0.529). QTc varied significantly across time points (P=0.010), and the temporal pattern differed among groups, as indicated by a significant group-by-time interaction (P=0.040). QTc did not differ among groups at T0 (P=0.969). Descriptively, QTc increased from baseline at T1 and T2 in the control group, whereas the corresponding changes were smaller in the EAA and EAB groups (Table 2).

**Table 2** Perioperative QTc Values in the Three Groups (ms, Mean ± SD)

| Group | n | T0 | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Control | 18 | 430.53 ± 29.00 | 450.92 ± 30.69[a] | 448.72 ± 26.21[a] | 439.81 ± 31.52[a] |
| EAA | 16 | 428.65 ± 27.89 | 431.53 ± 28.40 | 437.39 ± 27.90 | 444.50 ± 32.20[a] |
| EAB | 16 | 430.46 ± 11.74 | 433.37 ± 23.89 | 429.67 ± 21.12 | 446.77 ± 17.46[a] |

Note: T0, before anesthesia induction; T1, after completion of the principal lesion-related surgical step; T2, end of surgery; T3, 24 h postoperatively. [a]P<0.05 vs T0 within the same group; [b]P<0.05 vs control at the same time point; [c]P<0.05 vs EAA at the same time point.

***3.3.2 Tp-e***

The overall Tp-e level differed significantly among groups (P=0.002), varied significantly across time points (P<0.001), and showed a significant group-by-time interaction (P=0.020). Baseline Tp-e did not differ significantly among groups (P=0.098). Descriptively, Tp-e increased from baseline at T1 and T2 in both the control and EAA groups, whereas values in the EAB group showed comparatively limited fluctuation across time points (Table 3).

**Table 3** Perioperative Tp-e Values in the Three Groups (ms, Mean ± SD)

| Group | n | T0 | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Control | 18 | 81.56 ± 9.51 | 93.17 ± 15.04[a] | 90.72 ± 12.97[a] | 90.22 ± 14.88 |
| EAA | 16 | 75.00 ± 12.38 | 90.19 ± 22.52[a] | 90.75 ± 20.89[a] | 75.81 ± 12.31[b] |
| EAB | 16 | 74.25 ± 10.10 | 74.94 ± 9.99[b] | 75.75 ± 10.02[bc] | 75.50 ± 10.34[ab] |

Note: T0, before anesthesia induction; T1, after completion of the principal lesion-related surgical step; T2, end of surgery; T3, 24 h postoperatively. [a]P<0.05 vs T0 within the same group; [b]P<0.05 vs control at the same time point; [c]P<0.05 vs EAA at the same time point.

***3.3.3 Tp-e/QT***

No significant overall group effect (P=0.072), time effect (P=0.366), or group-by-time interaction (P=0.057) was observed for Tp-e/QT. Baseline Tp-e/QT was also comparable among groups (P=0.653) (Table 4).

**Table 4** Perioperative Tp-e/QT Ratios in the Three Groups (Mean ± SD)

| Group | n | T0 | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Control | 18 | 0.206 ± 0.031 | 0.216 ± 0.033 | 0.214 ± 0.030 | 0.224 ± 0.045 |
| EAA | 16 | 0.198 ± 0.036 | 0.216 ± 0.047 | 0.217 ± 0.039 | 0.192 ± 0.033 |
| EAB | 16 | 0.198 ± 0.027 | 0.191 ± 0.026 | 0.192 ± 0.029 | 0.192 ± 0.028 |

Note: T0, before anesthesia induction; T1, after completion of the principal lesion-related surgical step; T2, end of surgery; T3, 24 h postoperatively.

***3.3.4 iCEB***

The overall iCEB level did not differ significantly among groups (P=0.138). A significant time effect was observed (P=0.029), whereas the group-by-time interaction was not significant (P=0.373). Baseline iCEB did not differ among groups (P=0.100) (Table 5).

**3.4 Perioperative Arrhythmias**

During the study observation period, arrhythmias were recorded in 3 patients in the control group, including 2 cases of sinus bradycardia and 1 case of occasional premature ventricular complexes. One patient in the EAA group experienced premature ventricular complexes. No arrhythmias were recorded in the EAB group.

**Table 5** Perioperative iCEB Values in the Three Groups (Mean ± SD)

| Group | n | T0 | T1 | T2 | T3 |
|---|---|---|---|---|---|
| Control | 18 | 4.52 ± 0.73 | 4.66 ± 0.70 | 4.53 ± 0.53 | 4.61 ± 0.64 |
| EAA | 16 | 4.13 ± 0.55 | 4.40 ± 0.65 | 4.42 ± 0.62 | 4.20 ± 0.49 |
| EAB | 16 | 4.16 ± 0.36 | 4.29 ± 0.37 | 4.37 ± 0.44 | 4.31 ± 0.39 |

Note: T0, before anesthesia induction; T1, after completion of the principal lesion-related surgical step; T2, end of surgery; T3, 24 h postoperatively.

## 4 DISCUSSION

In this randomized study of patients undergoing neurosurgery, perioperative cardiac electrophysiological indices followed different temporal patterns across TEAS acupoint combinations. QTc varied over time and demonstrated a significant group-by-time interaction; descriptively, QTc increased after the principal lesion-related surgical step and at the end of surgery in the control group, whereas changes at the corresponding time points were smaller in both TEAS groups. Tp-e showed significant overall group, time, and interaction effects, with comparatively limited fluctuations in the EAB group. By contrast, Tp-e/QT showed no significant group, time, or interaction effect, and iCEB differed over time but not by group or group-by-time interaction. Arrhythmias were observed in 3, 1, and 0 patients in the control, EAA, and EAB groups, respectively.

The significant group-by-time interaction for QTc indicates that QTc evolved differently across the three groups. In the control group, QTc increased relative to baseline after the principal lesion-related surgical step and at the end of surgery, while the magnitude of change was smaller in the two TEAS groups. Previous work has shown that general anesthesia and surgical stress can be accompanied by perioperative QTc prolongation. Using continuous high-fidelity 12-lead ECG monitoring, Duma et al. demonstrated significant intraoperative QTc prolongation, with QTc exceeding 500 ms in a subset of surgical patients [16]. More recently, TEAS was reported to attenuate carbon dioxide pneumoperitoneum-related abnormalities in ventricular repolarization during laparoscopic cholecystectomy [20]. The direction of our findings is broadly consistent with those observations and suggests that TEAS may be associated with smaller early perioperative QTc fluctuations. However, given the modest sample size and the absence of statistically significant between-group differences at every time point, these data do not establish that TEAS prevents perioperative QTc prolongation.

Most neurosurgical TEAS studies have focused on anesthetic consumption, stress responses, hemodynamic stability, and postoperative recovery. Bai et al. reported lower catecholamine and cortisol concentrations and attenuated hemodynamic fluctuations during emergence after supratentorial craniotomy [9], while Wang et al. observed reduced remifentanil requirements and improvements in selected perioperative physiological measures during intracranial aneurysm clipping [5]. Systematic reviews have also suggested potential benefits of TEAS for postoperative pain and global recovery quality [17-18], and a meta-analysis reported attenuation of extubation-related stress responses after noncardiac surgery [19]. The clinical scope of perioperative TEAS continues to expand [21]. By extending the outcome set to QTc, Tp-e, Tp-e/QT, and iCEB, the present study provides exploratory clinical evidence regarding possible cardiac electrophysiological effects of TEAS in neurosurgical patients.

The two active protocols produced different temporal patterns for Tp-e. Both incorporated PC6 and HT7; the EAA protocol additionally included GV10 and GV11, whereas the EAB protocol included PC4 and PC7. Tp-e was comparable among groups at baseline, yet the longitudinal pattern differed. Descriptively, Tp-e remained relatively stable in the EAB group, whereas it increased after the principal lesion-related surgical step and at the end of surgery in the EAA group. Previous studies have reported that TEAS using PC6 together with PC4 may improve perioperative heart rate variability and selected biomarkers related to myocardial injury [10], and electroacupuncture protocols incorporating PC6 and PC4 have shown cardioprotective signals in patients undergoing cardiac surgery [11, 22]. A systematic review of acupuncture for premature ventricular complexes also identified PC6, HT7, GV10, and GV11 as commonly used acupoints [24]. Thus, both protocols have some support in the prior literature. Nevertheless, the present findings indicate only that different acupoint combinations may be associated with different Tp-e trajectories; they do not establish the superiority of a specific meridian-based combination.

An additional strength of the corrected dataset is that baseline Tp-e did not differ significantly among groups ($P=0.098$), reducing concern that baseline imbalance alone explains the longitudinal findings. Abnormal Tp-e and Tp-e/QT values have been associated with arrhythmic and other adverse cardiovascular outcomes [14-15], although most supporting evidence derives from populations at elevated cardiovascular risk. In the present study, the group-by-time interaction was significant for Tp-e but not for Tp-e/QT, indicating that the available repolarization markers did not change concordantly. Accordingly, the data are insufficient to conclude that either TEAS protocol consistently improves ventricular repolarization across all measured indices.

iCEB showed only a significant time effect, without a significant overall group effect or group-by-time interaction. iCEB reflects the relationship between ventricular depolarization and repolarization, and its direction of change may differ across arrhythmogenic states; therefore, higher or lower values cannot be interpreted simplistically as greater electrophysiological stability [23]. Our findings suggest that TEAS may influence selected repolarization-related indices such as QTc and Tp-e, while no clear between-group dynamic effect was demonstrated for the broader depolarization-repolarization balance represented by iCEB. The lack of concordance across indices further supports a multidimensional approach to perioperative electrophysiological assessment.

During the observation period, arrhythmias were documented in 3 patients in the control group, 1 in the EAA group, and none in the EAB group. Prior systematic reviews have examined acupuncture as an adjunctive intervention for premature ventricular complexes, atrial fibrillation, and other arrhythmias [12-13, 24], although substantial heterogeneity persists in intervention protocols and methodological quality. A recent randomized trial in thoracoscopic surgery also investigated electroacupuncture in relation to new-onset postoperative supraventricular arrhythmias [25]. In our study, however, only 4 arrhythmic events occurred in total, and continuous 24-h postoperative ambulatory ECG monitoring was not performed. These events are therefore reported descriptively and should not be interpreted as evidence of an antiarrhythmic treatment effect.

This study has several limitations. First, it was a single-center study with a modest sample size. Although 60 patients were randomized, only 50 had complete data and were included in the complete-case analysis; post-randomization noncompletion may therefore have introduced attrition bias. Second, practical constraints related to the neurosurgical field, patient positioning, skin preparation, and sterile draping required simplification of the acupoint combinations specified in the original registration, and the present results apply to the modified protocols actually delivered. Both active groups shared PC6 and HT7, and the number and spatial distribution of acupoints were not identical; consequently, observed differences cannot be attributed exclusively to meridian-specific acupoint effects. Third, continuous postoperative ambulatory ECG monitoring was not performed, limiting detection of transient arrhythmias. Finally, heart rate variability and neurohumoral biomarkers were not measured concurrently, precluding a more direct evaluation of the mechanisms through which TEAS might influence cardiac electrophysiology.

In conclusion, TEAS using different acupoint combinations was associated with distinct perioperative trajectories of QTc and Tp-e in patients undergoing neurosurgery, with comparatively smaller Tp-e fluctuations observed in the EAB group. No consistent between-group dynamic differences were demonstrated for Tp-e/QT or iCEB. Because few arrhythmic events were observed, no efficacy inference regarding arrhythmia prevention is warranted. The electrophysiological effects and clinical relevance of different TEAS acupoint combinations should be examined further in larger studies with standardized interventions and more comprehensive rhythm monitoring.

## COMPETING INTERESTS

The authors declare no conflicts of interest.

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