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# Preventive effect of transcutaneous acupoint electrical stimulation on emergence agitation after general anesthesia in pediatric patients undergoing tonsillectomy

## A randomized clinical trial

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**Abstract**

**Background:** The aim of this study was to evaluate the preventive effect of transcutaneous acupoint electrical stimulation (TEAS) on emergence agitation after general anesthesia in pediatric patients undergoing tonsillectomy.

**Methods:** This prospective, randomized, controlled trial was conducted between January 2025 to May 2025, enrolling 97 pediatric patients undergoing tonsillectomy. Participants were randomly assigned to the control or the TEAS group. Patients received TEAS at Hegu and Neiguan during surgical procedure in group TEAS. Emergence agitation incidence, cerebral oxygen saturation, level of β-EP, NE, E and COR, intraoperative anesthesia consumption, mean arterial pressure and heart rate, pediatric anesthesia emergence delirium score, adverse event and satisfaction level were recorded.

**Results:** In comparison to the control group, the TEAS group exhibited a significant reduction in the incidence of emergence agitation, pediatric anesthesia emergence delirium scores, intraoperative remifentanil consumption, and levels of β-EP, NE, E and COR. Additionally, cerebral oxygen saturation was notably increased in the TEAS group. Post-intubation, mean arterial pressure and heart rate were also significantly lower in the TEAS group compared to the control group. There were no significant differences in adverse events between the 2 groups. Furthermore, patient satisfaction was higher in the TEAS group than in the control group.

**Conclusion:** TEAS may reduce the incidence of emergence agitation in pediatric patients undergoing tonsillectomy, potentially by enhancing cerebral oxygenation and mitigating stress levels.

**Abbreviations:** IL-6 = interleukin-6, NA = number of awakenings, PCA = patient-controlled analgesia, PSD = postoperative sleep disorder, PSQI = Pittsburgh sleep quality index, SE = sleep efficiency, SGB = Stellate ganglion block, SGB-LI = SGB applied with light irradiation, TNF-α = tumor necrosis factor-α, TST = total sleep time, VAS = visual analog scale.

**Keywords:** cerebral oxygen saturation, emergence agitation, tonsillectomy, transcutaneous acupoint electrical stimulation

## 1. Introduction

Emergence agitation is a prevalent complication following general anesthesia in pediatric patients, characterized by a range of symptoms including crying, excitation, thrashing, disorientation, and incoherence.[1,2] This condition poses a significant challenge in pediatric anesthesia due to its potential to increase the risk of self-injury and the inadvertent removal of surgical dressings, intravenous catheters, and drains. Additionally, it often necessitates increased nursing care and the administration of supplemental sedatives or analgesic medications, which carry the risk of inducing respiratory depression.[3] Emergence agitation is particularly common among young patients undergoing tonsillectomy, underscoring the need for preventive strategies in this population.[4,5] While medications such as midazolam, fentanyl, and propofol are employed to prevent or manage

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*This study was approved by the institutional review board of the Hebei Children's Hospital (approval no: 2025-044) and performed in compliance with the Helsinki Declaration. All participant's guardian signed informed consent forms prior to participation in the study.*

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emergence agitation, their use is associated with the risk of respiratory depression.[6,7] Consequently, there is an urgent need to identify effective strategies to prevent agitation during the recovery phase and enhance the quality of the awakening period in pediatric patients.

Transcutaneous acupoint electrical stimulation (TEAS) is a noninvasive therapeutic modality that integrates the principles of traditional Chinese medicine meridian theory with contemporary electrophysiological methodologies.[8] This technique involves the application of low-frequency pulse currents to specific acupoints via electrodes affixed to the skin's surface. TEAS is predominantly employed for pain management, rehabilitation therapy, and the adjunctive regulation of chronic diseases. Its potential benefits are increasingly acknowledged in various perioperative settings, particularly for pediatric patients.[9] Empirical evidence suggests that TEAS facilitates the recovery of consciousness and reduces the duration of recovery following general anesthesia.[10] A systematic review and meta-analysis have demonstrated that patients receiving TEAS exhibit significantly reduced times to eye opening, tracheal extubation, and discharge from the postanesthesia care unit compared to those in control groups who received either no stimulation or sham stimulation.[11] Nonetheless, there is a paucity of studies investigating its efficacy and underlying mechanisms in mitigating agitation during the awakening phase in pediatric populations.

Therefore, the present study aims to investigate the effects of preventive effect of TEAS on emergence agitation after general anesthesia in pediatric patients undergoing tonsillectomy, which may provide reference for clinical applications.

## 2. Materials and methods

This prospective study received approval from the Ethics Committee of Hebei Children's Hospital (Approval No: 2025-044) as well as adheres to the principles outlined in the Helsinki Declaration. All procedures were conducted in accordance with these ethical guidelines. Written informed consent was obtained from each participant's guardian prior to randomization. The eligibility of participants was rigorously assessed by both the study coordinator and the study physician to ensure the inclusion of appropriate candidates.

### 2.1. Participants

A prospective research trial was conducted from January 2025 to May 2025, enrolling participants undergoing tonsillectomy from Hebei Children's Hospital.

The inclusion criteria were as follows:

(1) Gender not limited, age range between 5 and 12 years old, ASA grading standard I-II;
(2) No communication barriers, able to cooperate with research;

The exclusion criteria were as follows:

(1) Suffering from mental illness, epilepsy, or intellectual disability;
(2) Inflammation, ulcers, scars, or damage around the target acupoint;
(3) Previously implanted electrophysiological devices such as defibrillators and pacemakers in the body;
(4) Antiemetics, analgesics and sedatives were used for 3 days before surgery;
(5) Change of surgical procedure or failure to perform surgery due to various reasons.

### 2.2. Sample size estimation, randomization and blinding

The sample size calculation was performed utilizing G*Power software (version 3.1.9, University of Düsseldorf, Germany). The primary aim of this study was to assess the incidence of emergence agitation between 2 cohorts of pediatric patients. Based on preliminary experimental data, it was advised that each cohort consist of 41 subjects to attain 80% statistical power with a 2-tailed alpha level of 5%.[12] However, accounting for the anticipated high dropout rate, a minimum of 45 participants per cohort was deemed necessary.

Furthermore, all participants underwent initial evaluation and were subsequently randomized into 2 groups using the random number table method: the control group and the TEAS group. Both participants and their guardians were blinded to the group assignments. Furthermore, the physicians administering the TEAS interventions, as well as those responsible for the evaluation and analysis of the participants, were kept unaware of the group allocations.

### 2.3. Study design and intervention

***2.3.1. General anesthesia.*** All patients underwent tonsillectomy under general anesthesia. In the operating room, continuous monitoring was conducted using an electrocardiogram, invasive blood pressure, and peripheral pulse oximetry. General anesthesia was induced with sufentanil (0.3–0.5 μg/kg), midazolam (0.05–0.1 mg/kg), etomidate (0.3 mg/kg), and cisatracurium (0.1 mg/kg). Two minutes after cisatracurium was given, a reinforced catheter was placed. Ventilation settings included a frequency of 20 to 23 breaths per minute, an inspiratory-to-expiratory ratio of 1.0:1.5, 100% inhaled oxygen concentration, 2 L/minute oxygen flow, and $ETCO_2$ levels kept between 35 and 45 mm Hg. Propofol was infused at 4 to 6 mg/kg/hour, and remifentanil at 0.2 to 0.4 μg/kg/minute. The BIS value was kept between 40 and 60 during surgery. After surgery, patients were moved to the postanesthesia care unit (PACU) for further monitoring.

***2.3.2. TEAS intervention.*** Based on the principles of traditional Chinese medicine and the study conducted by Kabalak,[12] the acupuncture points selected were bilateral Hegu (LI4, situated on the dorsal aspect of the hand between the first and second metacarpal bones, at the midpoint of the second metacarpal radius) and Neiguan (PC6, located on the palmar side of the forearm, 2 inches proximal to the wrist). In the TEAS group, patients received TEAS using disperse-dense waves at a frequency of 2/100 Hz on acupoints LI4 and PC6 bilaterally with an intensity of 8 to 10 mA according to Professor Li research plan[13] and our preliminary experimental results, commencing immediately upon induction of anesthesia and continuing until the conclusion of the surgical procedure. The intensity was set to the maximum current tolerable by the patient. In the control group (Group C), electrodes were similarly positioned on the aforementioned acupoints prior to anesthesia induction, but no electrical current was administered.

### 2.4. Sample collection and detection

At 0 minutes prior to injection (T1), immediately following tracheal intubation (T2), and upon completion of surgery (T3), cerebral oxygen saturation (rSO2) was monitored using the cerebral oxygen saturation detector (Covidine II, USA). Two electrodes were positioned on the left and right forehead, 4 cm above the eyebrow arch. rSO2 saturation levels were recorded at T1, T2, and T3.

Concurrently, at these time points, 2-mL blood samples were collected to determine serum concentrations of β-Endorphin (β-EP), norepinephrine (NE), epinephrine (E), and cortisol (COR).

Mean arterial pressure (MAP) and heart rate (HR) were measured at the following time points: upon entering the operating room (Ta), prior to the induction of anesthesia (Tb), following the induction of anesthesia (Tc), immediately post-intubation

(Td), immediately prior to surgery (Te), immediately following surgery (Tf), prior to extubation (Tg), and immediately post-extubation (Th). Additionally, the consumption of anesthetics, specifically propofol and remifentanil, during the surgical procedure was documented. Adverse events, such as nausea and vomiting, as well as the satisfaction levels of patient guardians, were also recorded. The satisfaction levels was evaluated by 7-point Likert scale ranging from "very dissatisfied" to "very satisfied."

### 2.5. Level of emergence agitation

The level of emergence agitation was assessed using the pediatric anesthesia emergence delirium (PAED) scale after extubation, 10 minute after extubation, and before leaving the PACU as outlined in the study by Sikich.[14] The PAED scale comprises specific evaluation criteria: the ability to communicate with medical staff through eye contact; the purposefulness of behavior; unconscious awareness of the surrounding environment; lack of quietness; and the degree of inconsolable sadness. For the first 3 criteria, a score of "4" indicates complete absence, "3" indicates minimal presence, "2" indicates a moderate presence, "1" indicates a substantial presence, and "0" indicates extreme presence. Conversely, for the last 2 criteria, a score of "0" denotes complete absence, "1" indicates minimal presence, "2" indicates a moderate presence, "3" indicates a substantial presence, and "4" indicates extreme presence. The cumulative score from these 5 criteria reflects the level of agitation during the patient's recovery period, with a PAED score of ≥10 points defined as emergence agitation.

### 2.6. Statistical analyses:

The data are presented as the group mean ± standard deviation of the mean. To compare the baseline characteristics of the participants across different groups, a one-factor analysis of variance (ANOVA) was used for continuous variables, while a Pearson chi-square test was employed for categorical variables. To assess the significance of within-group changes before (i.e., baseline) versus after the intervention, a paired *t*-test or Wilcoxon signed-rank test (if the data did not pass a normality test) was conducted. The relative change (%) resulting from the intervention compared with the baseline was examined through a one-factor ANOVA to ascertain any disparities in the alterations across the various groups. A significance level of $P < .05$ was considered statistically significant. The statistical analyses of all experimental data were conducted using SPSS 25.0 software (SPSS, Inc., Chicago).

## 3. Results

### 3.1. Demographic characters of participants

The **flow diagram of study participants** participants illustrates the selection process for the study subjects. Initially, 133 individuals were assessed for eligibility and provided informed consent. Of these, 21 individuals were excluded due to either not meeting the exclusion criteria or declining to participate. During the intervention period, 2 participants were unable to accept the intervention because of inability to tolerate the intervention. Furthermore, during the follow-up period, 8 participants withdrew from the study for various reasons. During the analysis phase, blood samples from 5 patients were found to be contaminated and, therefore, could not be analyzed. Consequently, the final sample size consisted of 97 participants, allocated as follows: the control group (n = 48) and the TEAS group (n = 49).

Table 1 displays the baseline characteristics of the 2 study groups. Statistical analysis indicated no significant differences in these characteristics between the groups.

### 3.2. Cerebral oxygen saturation

Throughout the observation, the rSO2 of the 2 groups fluctuated within the normal range. As shown in Table 2, compared with $T_1$, the values of rSO2 on 2 sides increased in 2 groups at

**Table 1**

**Characteristics of the study participants.**

| Characteristics | Control group (n = 48) | TEAS group (n = 49) | *P*-value |
|---|---|---|---|
| Age (year) | 7.25 ± 2.41 | 8.42 ± 2.02 | .475 |
| Gender | | | |
| Male ([n] %) | 22 (45.83%) | 24 (48.98%) | .691 |
| Female ([n] %) | 26 (54.817%) | 25 (51.02%) | |
| BMI (kg/m$^2$) | 15.34 ± 1.87 | 15.85 ± 1.93 | .492 |
| ASA grade | | | |
| I | 35 | 39 | .363 |
| II | 13 | 10 | |
| Operation time (mins) | 35.05 ± 5.33 | 36.14 ± 6.42 | .564 |
| Anesthesia time (mins) | 52.65 ± 8.12 | 54.56 ± 10.04 | .549 |

ASA = American society of anesthesiologists, BMI = body mass index.

**Table 2**

**Comparison of cerebral oxygen saturation between 2 groups (χ±s).**

| Time | Side | Control group (n = 48) | TEAS group (n = 49) | *P*-value |
|---|---|---|---|---|
| $T_1$ | Left | 57.35 ± 3.01 | 56.87 ± 3.17 | .359 |
| | Right | 57.14 ± 2.98 | 57.30 ± 3.26 | .562 |
| $T_2$ | Left | 64.98 ± 5.13* | 73.48 ± 6.42*,# | .011 |
| | Right | 65.15 ± 5.34* | 75.12 ± 6.85*,# | .023 |
| $T_3$ | Left | 75.39 ± 6.57* | 84.34 ± 7.98*,# | .021 |
| | Right | 75.96 ± 7.02* | 84.95 ± 8.03*,# | .018 |

$T_1$ = 0 minutes prior to injection, $T_2$ = immediately following tracheal intubation, $T_3$ = upon completion of surgery.
Compared with $T_1$, *$P < .05$; Compared with group C, #$P < .05$.

$T_{2-3}$, the values of rSO2 on 2 sides increased in group TEAS at $T_{2-3}$ compared with group C ($P$ <.05).

### 3.3. β-EP, NE, E and COR levels

As shown in Figure 1, there was no significant difference in level of β-EP, NE, E and COR between 2 groups at $T_1$ ($P$ >.05). Compared with the baseline at $T_1$, the level of β-EP, NE, NE, E and COR in both 2 groups were significantly increased at $T_{2-3}$ ($P$ <.05). The level of β-EP, NE, NE, E and COR in group TEAS at $T_{2-3}$ were significantly decreased compared with group control, and the difference was statistically significant ($P$ <.05).

### 3.4. Level of intraoperative and postoperative indicators

The PAED scores immediately after extubation and 10 minute after extubation and the incidence of emergence agitation were significantly lower in the TEAS group than in the group Control. The PAED scores before leaving the PACU did not differ between the groups. The intraoperative consumption of remifentanil was significantly lower in the TEAS group than in the control group. There was no significant difference between the groups in terms of the intraoperative consumption of propofol. No significant difference between the 2 groups was observed in terms of the incidence of postoperative adverse reactions. Parental satisfaction was significantly higher in the TEAS group than in the control group. Results are detailed in Table 3.

As shown in Figure 2, the MAP and HR at Td were significantly lower in the TEAS group than in the control group. There was no significant difference in the MAP and HR between the groups at other time points.

## 4. Discussion

During the emergence phase from pediatric general anesthesia, agitation is one of the common postoperative adverse complications characterized by a dissociation between consciousness and behavior. This condition is evidenced by a lack of responsiveness to comforting measures, crying, limb flailing, incoherent speech, moaning, and disorientation. In severe instances, it can result in the inadvertent removal of tracheal tubes, infusion lines, urinary catheters, drainage tubes, and other critical medical apparatus, thereby elevating perioperative risks and potentially inflicting significant physical and psychological harm on the child. Therefore, it is necessary to explore effective intervention measures for agitation during the awakening period of pediatric patients. Our findings indicate that TAES at the Hegu and Neiguan acupoints exerts a preventive effect on emergence agitation following general anesthesia in children undergoing tonsillectomy. Furthermore, TAES contributes to the enhancing cerebral oxygenation, maintaining hemodynamic stability and mitigating the stress response, as well as reducing postoperative adverse events.

Emergence agitation is a prevalent postoperative complication observed in pediatric patients undergoing tonsillectomy. This condition is characterized by confusion, restlessness, and inconsolable crying, which can complicate recovery and increase the risk of injury or other adverse outcomes. Various strategies have been explored to mitigate the incidence and severity of Emergence agitation in children. Therefore, a large number of studies have explored the prevention and treatment of emergence agitation during the recovery period after tonsillectomy in children. For instance, a study investigating the effects of intraoperative dexmedetomidine infusion in pediatric patients undergoing tonsillectomy found that it provided satisfactory

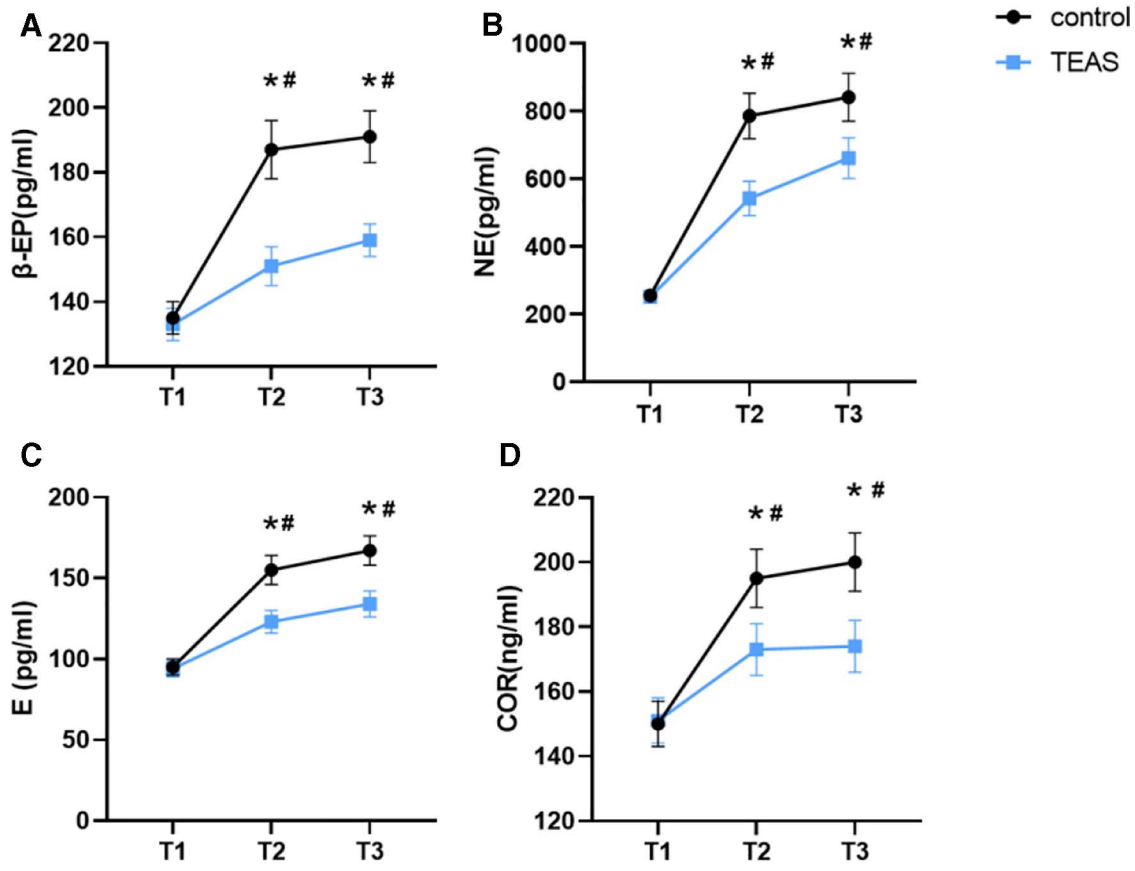


**Figure 1.** Expression level of β-EP (A), NE (B), E (C) and COR (D) at different timepoints between 2 groups. Compared with Control group, *$P$<.05, Compared with T1, #$P$<.05. β-EP = β-endorphin, COR = cortisol, E = epinephrine, NE = norepinephrine.

**Table 3**

**Comparison of intraoperative and postoperative indicators between 2 groups.**

| Characteristics | Control group (n = 48) | TEAS group (n = 49) | *P*-value |
|---|---|---|---|
| PAED scores | | | |
| After extubation | 11 (2–18) | 8 (2–16) | <.001 |
| Ten min after extubation | 10 (2–17) | 7 (2–16) | <.001 |
| Before leaving the PACU | 6 (2–14) | 4 (1–14) | <.001 |
| Incidence of emergence agitation | 10 (20.83%) | 4 (8.16%) | <.001 |
| Propofol consumption (mg) | 95.2 ± 5.3 | 93.2 ± 5.1 | .674 |
| Remifentanil consumption (μg) | 366.4 ± 10.4 | 303.5 ± 8.1 | .013 |
| Nausea and vomiting | 2 (4.17%) | 2 (4.08%) | .692 |
| Satisfaction level | 4 (3–6) | 6 (4–7) | <.001 |

PACU = postanesthesia care unit, PAED = pediatric anesthesia emergence delirium.

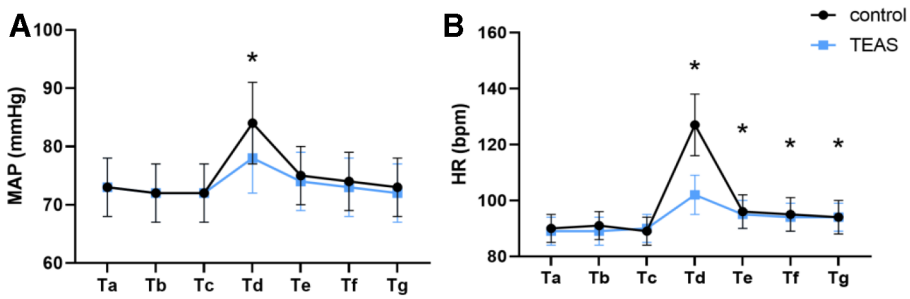


**Figure 2.** Expression level of MAP (A), and HR (B) at different timepoints between 2 groups. Compared with Control group, *$P$<.05. HR = heart rate, MAP = mean arterial pressure.

intraoperative conditions without adverse hemodynamic effects, although it did not significantly lower the incidence of EA.[15] Beyond pharmacological interventions, nondrug strategies have also been explored. For example, repeated maternal voice orientation has been shown to effectively reduce the incidence and severity of emergence agitation in pediatric patients undergoing tonsillectomy and adenoidectomy. This approach leverages the calming effect of a familiar voice to ease the child's transition from anesthesia to wakefulness, thereby improving postoperative outcomes.[16] while emergence agitation remains a significant challenge in pediatric tonsillectomy, interventions such as dexmedetomidine administration and maternal voice orientation offer promising strategies to mitigate its impact. Continued research and clinical trials are essential to refine these approaches and develop comprehensive protocols for managing emergence agitation in pediatric surgical settings.

The phenomenon of emergence agitation in pediatric patients during the awakening period can be attributed to various factors, including residual anesthetic agents, postoperative pain, and external stimuli.[1] Notably, there is a significant association between emergence agitation and cerebral oxygen metabolism disorders. Insufficient cerebral oxygen supply, as seen in conditions such as hypotension and anemia, or an increased metabolic demand, as observed in hypercapnia during surgery, can result in cerebral tissue hypoxia.[17] Under hypoxic conditions, ATP synthesis in brain cells is reduced, leading to lactate accumulation, which may cause abnormal neuronal excitability and cognitive dysfunction, thereby heightening the risk of emergence agitation. This may be due to disrupted brain oxygen metabolism, resulting in glutamate accumulation and the functional inhibition of the gamma-aminobutyric acid (GABA) system, which causes excessive excitation of the central nervous system. Furthermore, if postoperative brain oxygen metabolites, such as lactate and free radicals, are not promptly cleared, they may exacerbate postoperative brain edema or inflammatory responses, thereby prolonging the recovery of neurological function.[18] An increase in perioperative stress response levels directly causes agitation during awakening due to neuroendocrine system activation affecting the central nervous system. Research shows that monitoring indicators like COR and NE can alert to high agitation risk. Reducing stress response levels in patients can significantly decrease agitation during awakening.[19]

TEAS has been explored in various clinical settings for its potential benefits in managing postoperative symptoms and enhancing recovery. One area of interest is its application in reducing emergence agitation, a common postoperative complication characterized by confusion, disorientation, and restlessness upon waking from anesthesia.[9] The Neiguan and Hegu acupoints are often targeted in TEAS treatments due to their traditional associations with calming and analgesic effects. A study investigating the effects of TEAS on postoperative pain in pediatric orthopedic surgery found that TEAS significantly reduced emergence agitation, as well as the consumption of remifentanil and the time to extubation. The study highlighted the safety and efficacy of TEAS in relieving postoperative pain and reducing the need for perioperative analgesia in children, which suggests its potential utility in managing emergence agitation.[9] Another study focused on the use of TEAS in preventing postoperative nausea and vomiting in high-risk patients undergoing laparoscopic gynecological surgery. The study demonstrated that TEAS, when combined with dexamethasone and palonosetron, effectively reduced the incidence of PONV and improved patient satisfaction. Although the primary focus was not on emergence agitation, the reduction in PONV and associated discomfort could indirectly contribute to a calmer emergence from anesthesia.[20] Overall, Although studies have shown that TEAS can improve the incidence of nausea and vomiting after tonsillectomy in children,[12] its effects on agitation during the recovery period and potential mechanisms of action are still unknown, further research is needed to fully understand its mechanisms and optimize its use in clinical practice.

Cerebral oxygen metabolism can reflect the matching relationship between oxygen supply and oxygen consumption in the whole brain, and the state of cerebral circulation more accurately. It is considered to be an important basis for early

detection of cerebral ischemia and hypoxia. Previous study have shown that there is a close relationship between emergence agitation or delirium and cerebral oxygen metabolism disorder during operation.[21] The levels of β-EP, NE, E, and COR rise significantly under stress, correlating with pain and anxiety. NE and E increase rapidly during surgical or traumatic stress, aligning with pain scores, while COR levels rise during cardiovascular events or surgeries, indicating stress duration and intensity. These biomarkers reflect patient stress levels in the perioperative period. Our research findings indicate that TEAS can significantly decrease intraoperative rSO2 and reduce postoperative PAED scores. This suggests that TEAS may lower the incidence of emergence agitation following tonsillectomy by decreasing cerebral oxygen metabolism. Furthermore, we observed a reduction in the dosage of remifentanil required in the TEAS group, along with a decreased incidence of nausea and vomiting. Additionally, levels of stress-related hormones, such as β-EP, NE, NE, E and COR, were reduced in pediatric patients during surgery, and hemodynamic stability was enhanced immediately after extubation. These findings indicate that TEAS can maintain stable stress level and circulatory dynamics.

The present study is subject to several limitations. Firstly, our investigation is restricted to the acupoint stimulation of Hegu and Neiguan, necessitating further research into the coordinated stimulation of additional acupoints. Secondly, the study population comprised patients aged 5 to 12 years. Given that psychological development is age-dependent, variations in psychological development could potentially influence the outcomes. However, due to the limited sample size, we were unable to evaluate the effects across different age groups. Furthermore, the study was conducted as a single-center trial, exclusively involving patients undergoing tonsillectomy, a procedure associated with a high risk of emergence agitation. Consequently, the generalizability of our findings to other surgical procedures and settings is limited. Finally, extending the follow-up time will be more conducive to confirming the advantages of TEAS.

## 5. Conclusion

In conclusion, TEAS treatment could decrease the incidence of emergence agitation for pediatric patients undergoing tonsillectomy and the potential mechanism may be related to improving cerebral hypoxia and alleviating stress level.

## Author contributions

**Conceptualization:** Xin Li, Tong Wu, Qianyi Xing, Wenjuan Bao.
**Data curation:** Xin Li, Tong Wu.
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**Funding acquisition:** Weimin Li.
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**Methodology:** Weimin Li, Qianyi Xing.
**Writing – original draft:** Xin Li.
**Writing – review & editing:** Wenjuan Bao.

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