Short Communication

# Characteristics of Electroencephalogram Arousals of Sleep-disordered Breathing Children at Different Sleep Stages

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## Introduction

Sleep-disordered breathing (SDB) is the most common sleep-related disorder, and it can seriously affect sleep conditions, growth, and neurocognitive function. Recent research even demonstrates that hypertensive patients with SDB are at an increased risk of developing resistant hypertension.[1] SDB includes several different degrees of sleep disorders, primary snoring (PS), upper airway resistance syndrome, and obstructive sleep apnea-hypopnea syndrome (OSAHS).

A number of studies have shown that OSAHS and PS children have similar sleep structures.[2] Currently, studies on microsleep architecture on electroencephalogram (EEG) arousals in SDB children have attracted more and more attention. Thus, it is worth to compare the difference in EEG arousals between children with PS and children with OSAHS.

## Methods

### Patients

One-hundred and nineteen children, including 100 boys and 19 girls, aged 4–13 years (mean age: 6.8 ± 2.0 years), who suspected suffering from SDB were considered as the experimental group; 30 children, including 24 boys and 6 girls, aged 4–13 years (mean age: 5.8 ± 2.9 years), with vocal nodules, who did not have sleep-related disorders were considered as the control group. They all completed full-night polysomnography (PSG) (Compumedics E-series, Melbourne, Australia) at the Medical Sleep Center of Guangzhou Women and Children's Medical Center from December 2014 to December 2015. According to the American Academy of Sleep Medicine (AASM) criteria, an apnea-hypopnea index (AHI) ≥5 or an obstructive apnea index (OAI) ≥1 together with an lowest arterial oxygen saturation ($LSaO_2$) <92% was diagnosis of OSAHS; an OAI <1 and an $LSaO_2$ >0.92 with total arousal index (ARtotI) <11 was that of PS.

Fifty-three children were diagnosed as OSAHS and 66 children were diagnosed as PS. In this study, the "SDB children" refers to those with OSAHS or PS. No statistically significant difference was observed among the three groups in age, gender, and body mass index for age. This study has been approved by the Medical Ethics Committee of Guangzhou Women and Children's Medical Center. Written informed consent was obtained from one or both parents.

### Parameters

Respiratory parameters and EEG arousals were evaluated using the AASM criteria. EEG arousals were subclassified as follows: total arousal, the sum of all arousals divided by total sleep time; limb arousal, a sudden increase in EEG frequency following spontaneous limb movement in the absence of an apneic event or crescendo snoring; respiratory

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arousal, a sudden increase in EEG frequency within three breaths after termination of a respiratory apneic event; and spontaneous arousal, a sudden increase in EEG frequency in the absence of an obvious precipitating event. Indices for each arousal type were calculated by summing the numbers of each particular arousal and dividing these sums by hours of total sleep time: ARtotI = total arousals/total sleep time, respiratory arousal index (RAI) = respiratory arousals/total sleep time, limb arousal index (LAI) = limb arousals/total sleep time, and spontaneous arousal index (SAI) = spontaneous arousals/total sleep time.

### Statistical analysis

Statistical analysis was performed using the SPSS version 19.0 software package (IBM, USA). All sample distributions were tested for normality. All clinical parameters were summarized using descriptive statistics and presented as mean ± standard deviation (SD) or as median ($P_{25}$, $P_{75}$). Differences between groups were analyzed using Mann-Whitney *U*-test or Wilcoxon's signed-rank test, if the data were not normally distributed, using Student's *t*-test otherwise. The Kruskal-Wallis test was used if multiple independent samples did not show normal distributions because Mann-Whitney *U*-test can be employed to explore the statistical significance of differences among multiple independent samples only if the distributions are normal. The use of repeat hypotheses expanded the Type I error $\alpha$, according to the formula: Corrected $\alpha = 2\alpha/(n\ [n-1])$, where $\alpha = 0.05$ and $n$ is the number of tested groups. We had three groups, and thus corrected $\alpha = 0.017$. Upon pairwise comparison, $P < 0.017$ was considered statistically significant.

## Results

From the Table 1, we found that the EEG arousals indices were significantly different between SDB and control groups ($P < 0.017$). There was a significant difference in ARtotI between PS and OSAHS ($P < 0.001$) and between PS and controls ($P < 0.001$). Children with PS had a higher LAI than those with OSAHS ($P = 0.002$) or control children ($P < 0.001$). In addition, the RAI was higher in OSAHS children than in the other two groups, with statistical significance (both $P < 0.001$). Then, we focused on EEG arousals in SDB children and considered rapid eye movement (REM) and non-REM (NREM) sleep separately. Wilcoxon's test was used to compare the differences between RARtotI and NARtotI, RRAI and NRAI, RLA and NLAI, and RSAI and NSAI. The results showed that both OSAHS and PS children had higher EEG arousals in their NREM sleep stage. From Figure 1, we found that EEG arousals' indices were much higher in NREM sleep stage of SDB patients.

## Discussion

Yue *et al*.[3] observed that EEG arousals fragment sleep and affect sleep quality, causing daytime sleepiness, restlessness, inattention, poor school performance, and development of aggressive personality traits. A greater EEG arousal frequency is associated with increased physical fatigue in SDB children, contributing significantly to emotional fatigue. SDB children exhibit more EEG arousal, sleep fragmentation, sleep deprivation, daytime

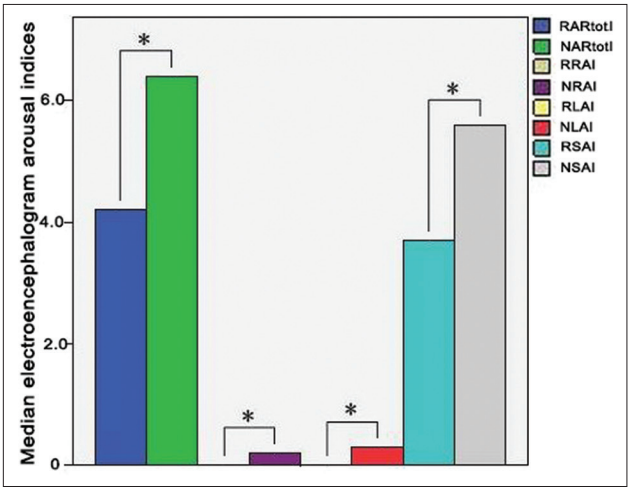


**Figure 1:** Electroencephalogram arousal indices between nonrapid eye movement and rapid eye movement sleep in children with SDB ($n = 119$). RARtotI: Rapid eye movement total arousal index; NARtotI: Nonrapid eye movement total arousal index; RRAI: Rapid eye movement respiratory arousal index; NRAI: Nonrapid eye movement respiratory arousal index; RLAI: Rapid eye movement limb arousal index; NLAI: Nonrapid eye movement limb arousal index; RSAI: Rapid eye movement spontaneous arousal index; NSAI: Nonrapid eye movement spontaneous arousal index; SDB: Sleep-disordered breathing, in this study, the SDB includes obstructive sleep apnea-hypopnea syndrome and primary snoring.

**Table 1: Electroencephalogram arousal indices in obstructive sleep apnea–hypopnea syndrome group, primary snoring group, and control group**

| Variables | OSAHS ($n = 53$) | PS ($n = 66$) | Control ($n = 30$) | $Z$* | $P$* | $Z$† | $P$† | $Z$‡ | $P$‡ | $Z$§ | $P$§ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ARtotI | 17.4 (14.7, 20.6) | 10.5 (10.1, 10.9) | 7.7 (7.0, 8.1) | −9.36 | <0.001 | −5.91 | <0.001 | −7.54 | <0.001 | 116.4 | <0.001 |
| RAI | 0.8 (0.5, 1.9) | 0.2 (0.1, 0.5) | 0.3 (0.1, 0.6) | −5.48 | <0.001 | −0.87 | 0.387 | −3.82 | <0.001 | 32.7 | <0.001 |
| LAI | 0.2 (0.1, 0.6) | 0.5 (0.2, 1.4) | 0.1 (0.1, 0.2) | −2.80 | 0.002 | −3.99 | <0.001 | −2.21 | 0.027 | 19.3 | <0.001 |
| SAI | 16.2 (13.4, 18.9) | 9.0 (7.4, 9.8) | 6.8 (5.9, 7.6) | −9.05 | <0.001 | −4.52 | <0.001 | −7.54 | <0.001 | 106.5 | <0.001 |

Data were presented with median ($P_{25}$, $P_{75}$). The Kruskal-Wallis test was used to compare data from multiple independent samples, and Mann-Whitney *U*-test for pairwise comparisons. *Comparisons between three independent groups; comparing among three groups, $P<0.017$ was considered statistically significant, upon pairwise comparison, $P<0.05$ was considered statistically significant; †Comparisons between the OSAHS and PS groups; ‡Comparisons between the PS group and controls; §Comparisons between the OSAHS group and controls. ARtotI: Total arousal index; RAI: Respiratory arousal index; LAI: Limb arousal index; SAI: Spontaneous arousal index; OSAHS: Obstructive sleep apnea-hypopnea syndrome; PS: Primary snoring.

sleepiness, and attention-deficit disorders than that of children without SDB.

Many workers have recognized the significance of EEG arousals in SDB children: the RAI is higher in OASHS than PS children, and as an indicator of EEG arousal, it can effectively reflect the extent of sleep fragmentation associated with various grades of illness. Brockmann *et al*.[4] showed that SDB children exhibited more EEG arousal, sleep fragmentation, sleep deprivation, daytime sleepiness, hyperactivation, and attention-deficit disorders than did children without SDB. In addition, we found that the LAI is higher in children with PS which explains that frequent nocturnal limb movements induce arousal that can destabilize sleep, creating daytime inattention, and hyperactivity. In our study, this is a small but statistically significant increase in PS versus OSAHS. This may command our attention: if a child snores at night, and the PSG report does not identify a serious condition, the structure of microsleep is nonetheless changing.

We are not sure whether the LAI can serve as an indicator additional to the RAI, reflecting the extent of sleep fragmentation associated with changes in the severity of illness. Meanwhile, whether the higher LAI is a hint of PS or not should be justified by further research, and more evidence are required.

We found that the EEG arousal indices occurred higher EEG arousals during NREM sleep. Changes in hormone secretion patterns during NREM sleep can affect neurocognitive function. Liu *et al*.[5] reported that, in children with severe OSAHS, the AHI is higher during NREM sleep, and NREM and REM sleep are distinguished by the extent of decline in upper airway expansionary force. In NERM sleep, the force decline is more marked, causing the AHI to rise and the EEG arousal threshold to fall, thus explaining why EEG arousals are more prevalent during NREM sleep.

In our study, we found that children with SDB have higher EEG arousals than controls, and it may explain their poor performances. There are many therapies for children with OSAHS, which suggests that children with PS may also need appropriately treating. In addition, we should pay more attention to NREM sleep stage.


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## Conflicts of interest

There are no conflicts of interest.

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