### ORIGINAL ARTICLE

## The Efficacy of Intraoperative EEG to Predict the Occurrence of Emergence Agitation in the Postanesthetic Room After Sevoflurane Anesthesia in Children

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**Purpose:** Emergence agitation (EA) is common after sevoflurane anestbesia, but there are no definite predictors. This study investigated whether intraoperative electroencephalography (EEG) can indicate the occurrence of EA in children.

Design: A prospective predictive study design was used.

Methods: EEG-derived parameters (spectral edge frequency 95, beta, alpba, theta, and delta power) were measured at 1.0 minimum alveolar concentration (MAC) and 0.3 MAC of end-tidal sevoflurane (EtSEVO) in 29 patients. EA was evaluated using an EA score (EAS) in the postanesthetic care unit on arrival (EAS 0) and at 15 and 30 minutes after arrival (EAS 15 and EAS 30). The correlation between EEG-derived parameters and EAS was analyzed using Spearman correlation, and receiver-operating characteristic curve analysis was used to measure the predictability. Findings: EA occurred in 11 patients. The alpha power at 1.0 MAC of

EtSEVO was correlated with EAS 15 and EAS 30. The theta/alpha ratio at 0.3 MAC of EtSEVO was correlated with EAS 30. The area under the receiver-operating characteristic curve of percentage of alpha bands at 0.3 MAC of EtSEVO and the occurrence of EA was 0.672.

**Conclusions:** *Children showing high-alpha powers and low theta powers* (= low theta/alpha ratio) during emergence from sevoflurane anesthesia are at high risk of EA in the postanesthetic care unit.

**Keywords:** pediatrics, emergence agitation, EEG, general anesthesia. © 2016 by American Society of PeriAnesthesia Nurses

Conflict of interest: None to report.

**SEVOFLURANE IS ONE OF** the most commonly used anesthetic agents. Its low blood/gas coefficient, nonpungency, and nonairway irritating properties make it the anesthetic agent of choice for rapid induction and emergence in infants and children. However, emergence agitation (EA) or emergence delirium, defined as an "acute and transient confusional state," is one of the most common side effects in children after sevoflurane anesthesia with <sup>1,2</sup> or without surgery<sup>3,4</sup> EA or emergence delirium was used synonymously in the literature. The reports of incidence of EA are varied from 10% to 50%, to as high as 80%.<sup>1-4</sup>

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EA itself is self-limited and does not show severe sequelae; but it might cause difficulties in managing patients during the postanesthesia care unit (PACU) stay, as well as startle the parents. There are many studies on the prevention of EA.<sup>2,4-8</sup> In addition, several risk factors of EA such as preschool age, preoperative temperament and anxiety degree,<sup>8</sup> sevoflurane,<sup>9,10</sup> or surgical procedures<sup>1,11,12</sup> are suggested. However, there is no definitive intraoperative predictive factor for EA.

Several studies report the abnormal findings of electroencephalography (EEG) in children during delirious status.<sup>13-15</sup> These findings suggested that the patients with EA show different EEG patterns during general anesthesia. There was also one study that reported postoperative EA was associated with an increase in the portion of slow EEG rhythm at the lowest BIS value during the induction of anesthesia in children.<sup>16</sup>

Therefore, EEG findings might have a correlation to the occurrence of EA in children. We investigated whether intraoperative EEG changes during sevoflurane anesthesia are related to the occurrence or degree of EA in children.

#### Methods

#### Study Purpose

The purpose of this study was to evaluate the efficacy of changes of intraoperative EEG to predict the occurrence of EA in PACU after sevoflurane anesthesia in children aged from 1 to 6 years (n = 29).

#### Study Design and Procedures

This prospective predictive study was approved by the Institutional Review Board of Seoul National University Hospital (H-1202-094-399; Apr 12, 2012, Seoul, Korea) and registered at cris.nih.go. kr (KCT0000652).

After obtaining informed consent from parents or guardians whose children were scheduled for strabismus surgery, we recruited 31 patients aged from 1 to 6 years. They were classified as American Society of Anesthesiologists physical status I or II. Patients with an abnormal airway, reactive airway disease such as asthma, or a history of upper respiratory tract infection in the preceding 4 weeks, mental retardation, attention-deficit hyperactivity disorder, previous abnormalities in EEG, or cerebral palsy were excluded.

#### Study Variables and Data Collection

The patients did not receive premedication. On arrival to the operating room, the patients were monitored with electrocardiography, pulse oximetry (SpO<sub>2</sub>), noninvasive arterial blood pressure, end-tidal CO<sub>2</sub>, end-tidal sevoflurane concentration (EtSEVO), and single-channel EEG-derived parameters monitor (not raw EEG; Solar 8000, GE, Milwaukee, WI) by pediatric anesthesiologists. All data from the patient monitor were recorded and stored in a personal computer.

Anesthesia was induced with 6 mg/kg of sodium thiopental and 0.02 mg/kg of atropine. After loss of consciousness, the patients were ventilated with inspired 8.0 vol% of sevoflurane in 6 L/min of oxygen via a pediatric circle system. The patients were fully relaxed with 0.6 mg/kg of rocuronium and appropriate size of laryngeal mask airway was inserted after confirming the muscle relaxation with neuromuscular blockade monitoring. The anesthesia was maintained around 1.0 MAC (one minimum alveolar concentration; 2.0 to 2.5 vol% of sevoflurane according to patients' age<sup>17</sup>) in approximately 50% oxygen in air with a total inflow of 2.5 L/min. The patients were ventilated with appropriate respiratory rate and tidal volume to keep 35 to 40 mm Hg of endtidal CO<sub>2</sub>. The concentration of sevoflurane was maintained at 1.0 MAC during surgery and adjusted by patient's blood pressure or heart rate. At the end of surgery, the concentration of sevoflurane was reduced and maintained 0.3 MAC (MAC awake; 0.5 to 0.7 vol% of sevoflurane) for 5 minutes before turning the vaporizer off. If the patient could respond to verbal comment, laryngeal mask airway was removed after reversal of neuromuscular blockade confirmed by sustained head lift (>5 seconds). After the patient was transferred to the PACU, he/she was fully awakened. In the PACU, electrocardiography, NIBP, SpO2, and the respiratory rate were monitored.

EA was evaluated, using the EA score (EAS; Table 1),<sup>18</sup> when the patient first arrived in the PACU (EAS 0), 15 minutes (EAS 15), and 30 minutes after arrival (EAS 30) because EA usually lasts around 30 minutes.<sup>1</sup> EA was identified when the

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