Sevoflurane concentration for cannulation in developmental disabilities

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Abstract

Objective: The goal of this study was to compare the end-tidal sevoflurane concentration and time for intravenous cannulation at induction of anesthesia using sevoflurane with or without nitrous oxide in healthy children and in those with developmental disabilities.

Methods: Normal and developmentally disabled children were anesthetized by inhalation of sevoflurane with nitrous oxide or with nitrous oxide-free oxygen, and intravenous cannulae were introduced. The following parameters were recorded for each patient: age, sex, height, weight, BMI, duration of intravenous cannulation, intertidal concentration of sevoflurane at the completion of intravenous cannulation, and use of nitrous oxide. Two-way ANOVA was used for statistical evaluation of the experimental data. All values were expressed as mean $\pm$ standard deviation (SD) or number (n). p-values below 0.001 were considered statistically significant (two-way ANOVA).

Results: In healthy children, the end-tidal sevoflurane concentrations at the completion of the intravenous cannulation showed a significant difference between when nitrous oxide was used ($4.1 \pm 0.8 \%$) and when nitrous oxide was not used ($5.1 \pm 1.1 \%$) ($p < 0.001$). Also, in children with developmental disabilities, the end-tidal sevoflurane concentrations at intravenous cannulation showed a significant difference between when nitrous oxide was used ($4.2 \pm 0.9 \%$) and when nitrous oxide was not used ($4.9 \pm 1.3 \%$) ($p < 0.001$). However, there was no significant difference in the time required for intravenous cannulation from the start of anesthesia induction in either group.

Conclusions—Between the healthy children and the children with developmental disabilities, no significant differences in the end-tidal sevoflurane concentrations at the completion of the intravenous cannulation and the time for the intravenous cannulation from the beginning of anesthetic induction.

Introduction

The induction of anesthesia using sevoflurane is a widely used technique in pediatric patients as it eliminates issues such as fear of needles, body movement and the pain associated with intravenous cannulation. [1–3] Nitrous oxide is used with sevoflurane and oxygen in order to achieve faster loss of consciousness and reduced excitatory movements. [2, 3] Anesthesiologists have relied on clinical parameters such as the loss of eyelash reflex, heart rate and centralization of pupils to obtain the intravenous cannulation. [4, 5] Too early attempts to place an intravenous route immediately after the loss of consciousness may result in patient movement or respiratory complications such as laryngospasm and desaturation. [2, 6, 7]

The developmental disabilities refer to a class of functional disorders in which affected persons require assistance, either mental or psychological. [8, 9] They commonly have cognitive impairments due to developmental delays or disorders such as cerebral palsy, epilepsy and autism. It is probable that general anesthesia may be affected by congenital conditions, such as abnormal neuronal activity in the brain.

Therefore, the MAC of volatile anesthetics might be lower in children with developmental disabilities. [10–13]

Previous reports have described the optimal timing for intravenous cannulation following sevoflurane inhalation for induction of anesthesia in pediatric patients using the up-and-down method or the loss of eyelid reflex. [1–4] There is to date, however, no literature comparing end-tidal sevoflurane concentration for intravenous cannulation between healthy children and those with developmental disabilities.

We hypothesized that the sevoflurane concentration for intravenous cannulation differs between healthy children and those with developmental disabilities. The goal of this study was to compare the end-tidal sevoflurane concentration and time for intravenous cannulation at induction of anesthesia using sevoflurane with or without nitrous oxide in healthy children and in those with developmental disabilities.

Methods

The Ethic Review Board of Kyushu University Hospital approved a retrospective study (Approval No. 30–352). The target patients were healthy children and children with developmental disabilities, aged 4 to 16 years, who underwent dental care and/or oral maxillofacial surgery in Kyushu University Hospital under general anesthesia from April 2012 to October 2018. This study excluded patients with a history of respiratory infection within the past two weeks as well as patients with a history of chronic respiratory disorder. The patients were transferred to the operating room without receiving any premedication. Anesthesia was then induced by inhalation of 8% of sevoflurane with or without 66% of nitrous oxide in oxygen after the start of noninvasive monitoring of oxygen saturation by pulse oximetry (SpO_2), electrocardiogram (ECG), and non-invasive blood pressure (BP) and heart rate (HR) checks. The total fresh gas flow was 6 L/mL. After the loss of consciousness, inhalation of nitrous oxide was terminated and sevoflurane concentration was adjusted according to each patient's hemodynamic conditions. In the case of airway obstruction, jaw-lift was applied to relieve the obstruction, and ventilation was gently assisted as necessary. Those settings were maintained until the intravenous cannula was introduced. A tourniquet was used to make the vessel enlargement, and the anesthesiologist tried the cannulation into the dorsum vein with a 22 or 24 gauge cannula. If the patient exhibited a reaction to the sting to the skin such as body movement, the concentration of sevoflurane was increased. The attempts for intravenous cannulation were continued until successful cannulation (defined as intravenous fluid dripping into the intravenous tubing) was achieved.

The following parameters were recorded for each patient: age, gender, height, weight, BMI, time for intravenous cannulation, end-tidal sevoflurane concentration at the completion of the intravenous cannulation, and the use of nitrous oxide.

For the statistical evaluation of experimental data, the two-way analysis of variance (two-way ANOVA) was conducted. All values were expressed as mean $\pm$ standard deviations (SD) or numbers (n). P-values lower than 0.001 were considered statistically significant (two-way ANOVA).

Results

One hundred and seventy patients were suitable for the present study. Patients were divided into two groups, a group of healthy children and a group of children with developmental disabilities, and further divided by whether nitrous oxide was used or not in the anesthesia induction. No patient had respirator complications such as laryngospasm and desaturation. Demographic data are shown in Tables 1 and 2. Figure 1 shows the end-tidal sevoflurane concentration (mean $\pm$ SD) at intravenous cannulation in each group, and Fig. 2 shows the time (mean $\pm$ SD) required for completion of the intravenous cannulation from the induction of anesthesia in each group. In healthy children, the end-tidal sevoflurane concentrations at the completion of the intravenous cannulation showed a significant difference between when nitrous oxide was used ($4.1 \pm 0.8\%$) and when nitrous oxide was not used ($5.1 \pm 1.1\%$) ($p < 0.001$). However, the times required for intravenous cannulation from the beginning of anesthetic induction showed no significant difference depending on whether nitrous oxide was used (346.0 ± 210.0 sec) or not (349.3 ± 153.1 sec).

Also, in children with developmental disabilities, the end-tidal sevoflurane concentrations at intravenous cannulation showed a significant difference between when nitrous oxide was used ($4.2 \pm 0.9\%$) and when nitrous oxide was not used ($4.9 \pm 1.3\%$) ($p < 0.001$). The times required for intravenous cannulation, however, showed no significant difference between when nitrous oxide was not used (381.1 ± 266.4 sec) and when nitrous oxide was used (338.7 ± 188.9 sec).

When nitrous oxide was used, the end-tidal sevoflurane concentrations at intravenous cannulation were $4.1 \pm 0.8\%$ in the healthy children and $4.2 \pm 0.9\%$ in the children with developmental disabilities. They showed no significant difference. The times required for intravenous cannulation from the beginning of induction of anesthesia used nitrous oxide were 346.0 ± 210.0 sec. in the healthy children and 338.7 ± 188.9 sec. in the children with developmental disabilities. They also showed no significant difference.

When nitrous oxide was not used, the end-tidal sevoflurane concentrations at intravenous cannulation were $5.1 \pm 1.1\%$ in the healthy children and $4.9 \pm 1.3\%$ in the children with developmental disabilities. They showed no significant difference. The times required for intravenous cannulation from the beginning of induction of anesthesia used nitrous oxide were 349.3 ± 153.1 sec. in the healthy children and 381.1 ± 266.4 sec. in the children with developmental disabilities. The time for the children with developmental disabilities looks longer, but They did not reach the significant level significant difference.

Discussion

In this study, we assessed how end-tidal sevoflurane concentration and the time for intravenous cannulation from the beginning of the induction of anesthesia between healthy children and children with developmental disabilities. Whether nitrous oxide was used or not, in result, no significant differences were shown between the healthy children and the children with developmental disabilities, although the time of intravenous cannulation for the children with developmental disabilities was longer.

The optimal timing for intravenous cannulation after the loss of eyelash reflex is affected by various factors, such as the volume of the breathing system fresh gas flow rate, alveolar concentration and ventilation / perfusion mismatch. [1, 5]

It has been reported that epileptiform activity during general anesthesia in children with developmental disabilities affect BIS values. [11–13] The ictal and interictal EEG activity such as δ waves might be different from those of healthy patients. [10, 13] In addition, inhalational anesthetics might influence GABA receptors in the CNS. It has been shown that the MAC of inhalational anesthetics can be up to 20% lower in cerebral palsy patients. [12] There was no physiological sign or monitoring method to determine the optimal timing for intravenous cannulation.

Anesthesiologists are usually anxious to obtain an intravenous route as soon as possible at induction of anesthesia in order to administer agents for faster intubation. Too faster attempt, however, may cause body movement, laryngospasm, attempt failure, and coughing. [2]

Sevoflurane is widely used inhalational anesthetic in pediatric anesthesia for mask induction. And nitrous oxide, used in this study, is a well-established acting analgesic and sedative agent. [1, 2, 14] We expected that the combination of sevoflurane and nitrous oxide was beneficial to make the optimum timing for intravenous cannulation shorter without causing complications. [14, 15] The addition of nitrous oxide can increase alveolar sevoflurane concentrations (second gas effect) faster, leading to faster loss of consciousness and less excitatory movements, especially for children with developmental disabilities. However, in this study, this advantage of using nitrous oxide was not observed. Also, in both healthy children and children with developmental disabilities, when nitrous oxide was used, the end-tidal sevoflurane concentrations were significantly low compared to when nitrous oxide was not used. This may be due to faster diffusion of nitrous oxide. When inhaling air immediately after inhaling nitrous oxide of 50% or higher, nitrous oxide diffuses rapidly from the blood into the alveoli, and the partial pressure of oxygen in the alveoli might become lower (diffusion hypoxia) (16). In this study, we used nitrous oxide of 66%, and nitrous oxide inhalation was terminated after the loss of consciousness. Although inhalation time was short, it is possible that sevoflurane concentration in the alveoli decreased due to the diffusion of nitrous oxide, and subsequently the end-tidal sevoflurane concentrations were also decreased. This phenomenon might counteract the benefit of nitrous oxide.

Compared to patients in previous studies, none of the patients in our study had hemodynamic and/or respiratory complications such as laryngospasm and desaturation. This could be due to the fact that we used a higher concentration of sevoflurane (5–8%) for anesthesia induction, which could ensure safe depth. [1–4] However, our retrospective results showed that the time for intravenous cannulation did not shortened in spite of nitrous oxide inhalation. We should not stop nitrous oxide until the venous route was obtained.

Our study has some limitations. Attempts of intravenous cannulation depend on each anesthesiologists and their experiences. Due to the condition of blood vessels, cannulation could be difficult and it might take longer time. Also, the number of cannulation attempts could have been difficult to record. As a next

step, further studies are required with larger sample sizes and continuing nitrous oxide inhalation until securing venous cannulation.

Conclusions

Between the healthy children and the children with developmental disabilities, no significant differences in the end-tidal sevoflurane concentrations at the completion of the intravenous cannulation and the time for the intravenous cannulation from the beginning of anesthetic induction. When nitrous oxide inhalation was terminated after the loss of consciousness, in addition, the time for the completion of the intravenous cannulation could not be shortened in both children group. We should probably continue nitrous oxide until the completion of the intravenous cannulation.

Declarations

Ethics approval and consent to participate

All methods were implemented in accordance with the relevant guidelines and regulations.

Informed consent was obtained from parents of all children involves in the study

The Ethic Review Board of Kyushu University Hospital approved a retrospective study (Approval No. 30-352).

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests

All authors have no conflicts of interest related to this article.

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Author's contributions

TM and YT designed the study, collected the data and wrote the main manuscript. HT KN. analyzed the data and prepared the tables and figures. All authors reviewed and approved the manuscript.

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Tables

Table.1 Demographic data

	Healthy children	Developmental disabilities	Healthy children	Developmental disabilities
	Non-Nitrous oxide	Non-Nitrous oxide	Nitrous oxide	Nitrous oxide
	(n=55)	(n=55)	(n=30)	(n=30)
Age (yrs)	6.9 ± 2.2	7.3 ± 2.5	7.0 ± 2.9	8.2 ± 2.8
Gender (M/F)	30/25	42/13	11/19	9/21
Height (cm)	116.8 ± 15.1	117.3 ± 13.3	117.0 ± 16.8	119.5 ± 17.2
Weight (kg)	22.2 ± 8.1	23.1 ± 7.3	23.5 ± 9.5	24.3 ± 15.9
BMI (kg/m ²)	15.8 ± 1.8	16.3 ± 2.4	16.6 ± 2.2	15.9 ± 4.1

Data were expressed as the number of patients or mean ± standard deviation (SD).

Table.2 The type of developmental disabilities.

Developmental disabilities	No. of patients (n)	
	Developmental disabilities	Developmental disabilities
	Non-Nitrous oxide	Nitrous oxide
Attention-deficit hyperactivity disorder (ADHD)	7	4
Autism	23	11
Developmental delays	4	4
Mental retardation	20	9
Cerebral palsy	2	1
Seizure	11	7
Other developmental delays	3	0

Figures

Figure 1

The end-tidal sevoflurane concentration and time for intravenous cannulation

Figure 2

Time until intravenous cannulation

Supplementary Files

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