Clinical effects of sevoflurane anesthesia induction with a portable inhalational anesthetic circuit in pediatric patients

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A b s t r a c t

Introduction: Pediatric anesthesia induction with sevoflurane usually needs a special vaporizer and gas source, which limits its use to the operating room (OR). Many children feel anxious and cry when entering the OR because of being separated from their parents, which impairs anesthesia safety and their physical and mental health. In this study, we used a portable circuit to perform sevoflurane anesthesia induction outside the OR, assessed its effects and compared them with those of ketamine anesthesia in pediatric patients.
Material and methods: One hundred children had anesthesia induced with either sevoflurane (sevoflurane group) through the portable inhalational anesthetic circuit, or ketamine by intramuscular injection (ketamine group), then were transferred to the OR. Peak inspired concentration (Cp) and steady state concentration (Cs) of sevoflurane were measured. Heart rate (HR) and saturation of peripheral oxygen (SpO_2) were monitored. Time for anesthesia induction, awakening, leaving the OR and duration of the operation were recorded. The patients' reaction during anesthesia was also analyzed.
Results: The Cp and Cs of sevoflurane were correlated with bodyweight. Compared with the ketamine group, the sevoflurane group showed shorter time for anesthesia induction (28 ±7 s vs. 195 ±34 s, $p < 0.0001$), awakening (11.2 ±3.6 s vs. 63.5 ±6.7 s, $p < 0.0001$) and leaving the OR (20.5 ±5.6 s vs. 43.4 ±10.6, $p < 0.0001$), less noncooperation during anesthesia induction (10% vs. 80%, $p < 0.0001$), lower HR (130 ±16 beats/min vs. 143 ±19 beats/min, $p = 0.0004$) and higher SpO_2 (98.9 ±0.9% vs. 96.1 ±2.5%, $p < 0.0001$) on arrival at the OR.
Conclusions: Pediatric anesthesia induction by sevoflurane with the portable inhalational anesthetic circuit is convenient, safe and effective outside the OR.

Key words: anesthesia, sevoflurane, pediatric surgery.

Introduction

Since the emergence of the new inhalational anesthetic agent sevoflurane, the inhalational method of anesthesia induction has become a general trend of pediatric anesthesia which has been accepted and used by a lot of anesthesiologists [1–3], and sevoflurane has been more and more widely applied in pediatric anesthesia induction outside the operating room (OR) [4–6]. Because sevoflurane anesthesia induction needs an anesthesia machine with a special sevoflurane vaporizer and

gas source, it is usually performed in the OR. However, lots of children feel anxious and cry when they are separated from their parents while still conscious. The secretions of the children due to the crying will cause great harm for anesthesia, which should be avoided by the anesthesiologists [7, 8]. We have developed a portable inhalational anesthetic circuit, which allows the inhalational anesthesia induction to be performed outside the OR (patent number: 201020516793.X). In the current study, we evaluated the effects of sevoflurane anesthesia induction with the portable circuit, and compared them with those of intramuscular ketamine anesthesia induction in pediatric patients, with reference to the research of Sungur Ulke *et al.* [9].

Material and methods

Procedures

After obtaining approval from our institutional research ethics committee (number: 2012-SR-077, approval date: May 28, 2012) and informed consent from the parents of the participates, we randomly assigned 100 children (64 male, 36 female) undergoing squint correction, ASA I or II, 1–6 years of age and 8–26 kg body weight, to the sevoflurane induction group (sevoflurane group) or the ketamine induction group (ketamine group) (50 patients/group). Randomization was performed immediately before anesthesia induction by drawing prepared numbers from closed envelopes.

All participants were fasted routinely before the elective surgery without administration of preoperative medication. The day before the operation, all of the children and their parents underwent the routine preoperative interview and had full communication with the anesthesiologists, who let the children get familiar with the anesthesia mask until they could accept the anesthesia mask being put lightly on their face as a "game", and let the children and parents practice deep breathing together. Before anesthesia, all the patients stayed in the waiting room outside the OR accompanied by their parents.

The anesthetic induction for the sevoflurane group was performed through the portable inhalational anesthetic induction circuit as shown in Figure 1. In detail, the pediatric face mask (with a volume of about 80 ml) was lightly pressed around the mouth and nose of the patient, while trying to avoid leakage of the gas. The oxygen flow rate was set at 4 l/min. According to the preliminary experiments using the sequential method, the effective dose of sevoflurane which inhibited the body movement of 50% of children during the venous puncture (ED50) was 0.16 ml/kg. Then 0.2 ml/kg of the liquid sevoflurane (Shanghai Hengrui Medicine Co., Ltd) was injected through the anesthetic

injection port into the portable inhalational anesthetic induction circuit. The patients were told to breathe deeply as trained the previous day together with their parents. A multi-function monitor (Type ULT, Datex-Engstrom) was used to monitor the sevoflurane concentration. When the patients showed conscious indifference, the mask was fastened, and pressurized oxygen was used to assist breathing. After the patients lost consciousness, the venepuncture was performed. Once the intravenous access was established, the patients were immediately transferred to the OR for general anesthesia with tracheal intubation. For the patients in the ketamine group, intramuscular injection of ketamine (5 mg/kg) was given for anesthesia induction. After the loss of consciousness, the patients in the ketamine group were transferred to the OR for venous puncture and endotracheal intubation anesthesia.

All patients in the study were monitored routinely after they arrived at the OR, and were given midazolam 0.01 mg/kg, propofol 1.5 mg/kg, fentanyl 4 µg/kg, vecuronium 0.1 mg/kg and atropine 0.01 mg/kg. After endotracheal intubation, mechanical ventilation was provided by the anesthesia machine (S/5 Aespir; Datex-Ohmeda, Madison, WI). Propofol (6–8 mg/kg × h) and remifentanil (0.1–0.2 µg/kg × min) were given to maintain anesthesia and discontinued at the end of surgery.

Measurements

The anesthesia induction time (from medication to loss of consciousness of the patients), operation time, awakening time (from drug withdrawal to extubation), and leaving the OR time (from extubation to the patient's leaving the OR) were recorded. The heart rate (HR) and saturation of peripheral oxygen (SpO$_2$) before the anesthesia induction, when the patients arrived at the OR, and at the end of the surgery were measured.
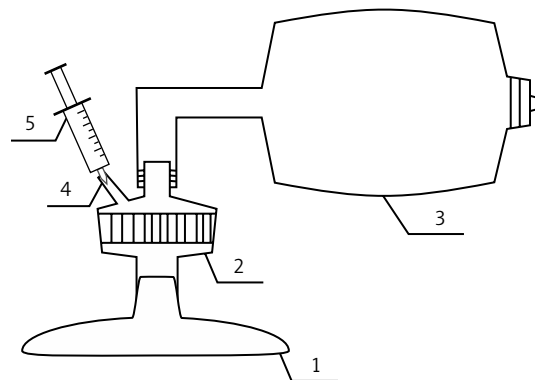
Figure 1. The main components of the portable inhalational anesthetic induction circuit include an anesthetic mask (1), a respiratory filter (2), a breathing bag (3), an anesthetic injection port (4), and a standard syringe with scale (5)

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Table I. Age (years), sex (F/M), weight (kg), anesthesia induction time (s), operation time (min), awakening time (min), leaving the operation room time (min), and incidence of crying of the children receiving sevoflurane or ketamine anesthesia induction

Parameter	Sevoflurane ($n = 50$)	Ketamine ($n = 50$)	Value of p
Age	3.6 (1.6)	3.4 (1.8)	0.558
Sex	17/33	19/31	0.677
Weight	15.8 (4.2)	16.7 (5.5)	0.360
Anesthesia induction time	28 (7)	195 (34)	< 0.0001
Operation time	40.4 (7.6)	38.6 (6.4)	0.203
Awakening time	11.2 (3.6)	63.5 (6.7)	< 0.0001
Leaving the operating room time	20.5 (5.6)	43.4 (10.6)	< 0.0001
Incidence of crying during anesthesia induction	5 (10)	40 (80)	< 0.0001

Values are mean (SD) or number (proportion).

The peak concentration of inspired sevoflurane (Cp) was recorded. The concentrations of the inspired and expired sevoflurane were measured. When 3 minimums of the $Gap_{ins-exp}$ ($Gap_{ins-exp}$ means the gap between inspired and expired sevoflurane concentration of each respiration) were reached, the average of the 3 inspired sevoflurane concentrations at that time was calculated as the steady-state concentration of inspired sevoflurane (Cs), which was the comparably stable concentration of the inspired sevoflurane. The time to reach steady-state concentration of inspired sevoflurane was also recorded. The Funk reaction score of the patients during the venepuncture was evaluated as previously reported [10], in brief: 1 for fight without success; 2 for fight with success; 3 for minor resistance; 4 for no reaction. The cases of crying during anesthetic induction were recorded. And satisfaction evaluation for the anesthesia induction method was performed in the parents of the children (two choices for the satisfaction evaluation: satisfied or unsatisfied).

The number of the cases with adverse reaction such as nausea, vomiting and laryngospasm was also calculated.

Statistical analysis

The SAS 9.1 software was used to analyze the data. The normally distributed data were

Table II. Number of cases with different Funk reaction scores in the children receiving sevoflurane or ketamine anesthesia induction

Score	Sevoflurane ($n = 50$)	Ketamine ($n = 50$)
1	0	0
2	1	0
3	12	7
4	37	43

Values are numbers (p = 0.128).

expressed as mean ± standard deviation (SD) and analyzed by paired Student t test. Repeated measurement data were tested by repeated measurement data analysis of variance. Non-normal distribution data were analyzed using Wilcoxon's ranked sum test. The enumeration data were compared by χ^2 test. The linear regression analysis was performed to evaluate the relationship between the body weight (BW) of patients and the Cp or Cs. Value of $p < 0.05$ was considered statistically significant.

Results

The age, weight, and operation time of the ketamine group and sevoflurane group were not significantly different. The time for anesthesia induction, awakening and leaving the OR of the sevoflurane group was significantly shorter, and the incidence of crying in the sevoflurane group was obviously lower, when compared with the ketamine group ($p < 0.0001$) (Table I). There was no statistically significant difference of the Funk reaction score during venepuncture between the two groups ($p = 0.128$) (Table II).

The maximum deliverable concentration of inspired sevoflurane via this route was approximately 5.4% at the dose of 0.2 ml/kg of the liquid sevoflurane. In the sevoflurane group, the Cp was attained around the second or the third breathing, and the Cs was reached after about 5–7 breaths. The time to reach Cs was 15.4 ±3.2 s. Both the Cp and Cs were positively correlated with the BW of the patients ($Cp = 0.58 + 0.27 \times BW$, $r = 0.91$; $Cs = 0.17 + 0.19 \times BW$, $r = 0.96$).

When arriving at the OR, the HR of the ketamine group was significantly higher than the base value ($p < 0.0001$) and higher than that of the sevoflurane group ($p = 0.0004$). There was no significant difference of the HR and SpO_2 of the two groups at the end of the surgery (Table III).

Table III. Heart rate (HR) (beats/min) and saturation of peripheral oxygen (SpO$_2$) (%) at different time points from the children receiving sevoflurane or ketamine anesthesia induction

Parameter	Sevoflurane ($n = 50$)	Ketamine ($n = 50$)	Value of p
HR before anesthesia induction	125 (14)	127 (15)	0.171
HR when children arrived at operating room	130 (16)	143 (19)	0.0004
HR after operation	128 (14)	132 (18)	0.219
SpO$_2$ before anesthesia induction	98.7 (0.8)	98.6 (0.9)	0.375
SpO$_2$ when children arrived at operating room	98.9 (0.9)	96.1 (2.5)	< 0.0001
SpO$_2$ after operation	99.5 (0.5)	99.5 (0.5)	0.427

Values are means (SD).

The rate of satisfactory degree of anesthesia induction in the sevoflurane group was 96%, while in the ketamine group it was 22% ($p < 0.0001$).

No nausea or vomiting was observed in both groups. One patient in the ketamine group showed mild laryngospasm, but it did not make a significant difference between the two groups ($p > 0.05$).

Discussion

A series of stress reactions, such as crying as the reflection of fear and anxiety of the pediatric patients, usually takes place during anesthesia induction before surgery, especially when the children leave their parents. This may not only affect the stableness of the anesthesia induction and the operation but also cause a change of personality and behavior at different levels, resulting in enormous damage to the physical and mental health of the children [4–7].

At present, in clinical pediatric anesthesia induction, the method of intramuscular injection of ketamine is often used [9]. However, since intramuscular injection itself is also a kind of trauma which can cause the fear and crying of the children, it usually needs the assistance of the parents and medical staff to be achieved. In this study, the incidence of crying was as high as 80% in the ketamine group when the children were receiving an intramuscular injection, but only 10% in the sevoflurane group, which indicated that the sevoflurane induction with the portable inhalational anesthetic induction circuit was more acceptable to the children. This result was consistent with the report from Ogurlu *et al.* that sevoflurane mask induction was easily accepted and succeeded in 96% of the children [11]. In addition, our results showed that the time for anesthesia induction, awakening and leaving the OR in the ketamine group was significantly longer, which may be because the metabolism and clearance of ketamine was relatively slow. Moreover, Schwartz *et al.* reported that the success rate of intravenous placement was obviously increased

after anesthesia induction in the children, and recommended a 2-minute interval following the loss of the lid reflex before attempting intravenous placement in children with sevoflurane induction, which also reduced the incidence of laryngospasm [2].

Although sevoflurane is suitable for pediatric anesthesia induction, it usually needs a special vaporizer and gas source, which limits anesthesia induction with sevoflurane to the OR. In this study, we performed sevoflurane anesthesia induction with a portable circuit, which allowed inhalational anesthetic induction outside the OR with the presence and assistance of the parents, and avoided the fear and crying of the children. This can reduce the factors contributing to the anesthesia risk, such as secretions of the patients, and thus may increase the safety of anesthesia and surgery.

In the current study, the peak of the inspired sevoflurane concentration could be reached at the second or the third time of breathing, and the steady state of the inspired concentration could be quickly attained (through about 5–7 times of breathing); thus the anesthesia induction takes a very short time. Moreover, the breathing bag of the portable circuit can be used to support or control breathing with the mask, which can avoid the occurrence of anoxia in the children, and this may be the main reason for which the SpO$_2$ of the sevoflurane group was obviously higher than that of the ketamine group.

The HR of the ketamine group was significantly higher than that of the sevoflurane group when the patients arrived at the OR. This may be because ketamine has a central excitatory effect on the cardiovascular system, and sevoflurane has slight inhibitory effects on the myocardium. Previous reports showed that the HR was unchanged or slightly increased after sevoflurane induction even when its concentration was as high as 8%, and no obvious breathlessness, cough or laryngospasm was observed [3]. In addition, Chawathe *et al.* found that, in pediatric anesthesia induction, sevoflurane of 12% was even better than 8% for

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more stableness and convenience, and no cardio-vascular side effect was observed [12].

The application of the portable circuit for sevoflurane anesthesia induction was shown to be safe. No complication was observed in the patients who received sevoflurane induction with the portable circuit. This may mainly be because the amount of inhaled sevoflurane was related to the ventilation volume, which was regulated by the children themselves, and would not be excessive as long as there was no excessive ventilation. The procedure was the same as the standardized induction of inhalation anesthesia through the anesthetic vaporizer.

Sevoflurane anesthesia induction with the portable circuit is convenient, safe and effective, making it advantageous in various occasions such as traumatic examination and arteriovenous puncture in uncooperative children, especially in some places without an anesthesia machine and anesthesia vaporizer, which can give the children anesthesia induction while sparing them the fear and pain.

Moreover, sevoflurane anesthesia induction with the portable anesthetic circuit was also widely accepted by the families of the children, because the parents preferred to accompany the children, try to let them cooperate with the anesthesiologists and witness them "artistically falling asleep" under anesthesia, rather than to see the children crying when they were going to the OR for anesthesia induction.

In conclusion, this study demonstrated that sevoflurane anesthesia induction with the portable inhalational anesthetic circuit is not only convenient for application but also safe and effective for out-of-operating room pediatric anesthesia induction.

Conflict of interest

The authors declare no conflict of interest.

References

1. Lerman J. Inhalation agents in pediatric anaesthesia – an update. Curr Opin Anaesthesiol 2007; 20: 221-6.
2. Schwartz D, Connelly NR, Gutta S, Freeman K, Gibson C. Early intravenous cannulation in children during sevoflurane induction. Paediatr Anaesth 2004; 14: 820-4.
3. Ho KY, Chua WL, Lim SS, Ng AS. A comparison between single- and double-breath vital capacity inhalation induction with 8% sevoflurane in children. Paediatr Anaesth 2004; 14: 457-61.
4. Michel F, Constantin JM. Sevoflurane inside and outside the operating room. Expert Opin Pharmacother 2009; 10: 861-73.
5. Matveevskii AS, Mahmoud M. New airway device for ventilation and monitoring in pediatric patients undergoing MRI study. J Clin Monit Comput 2012; 26: 17-20.
6. Arai YC, Ito H, Kandatsu N, Kurokawa S, Kinugasa S, Komatsu T. Parental presence during induction enhances the effect of oral midazolam on emergence behavior of children undergoing general anesthesia. Acta Anaesthesiol Scand 2007; 51: 858-61.
7. LaRosa-Nash PA, Murphy JM. An approach to pediatric perioperative care. Parent-present induction. Nurs Clin North Am 1997; 32: 183-99.
8. Aydin T, Sahin L, Algin C, et al. Do not mask the mask: use it as a premedicant. Paediatr Anaesth 2008; 18: 107-12.
9. Sungur Ulke Z, Kartal U, Orhan Sungur M, Camci E, Tugrul M. Comparison of sevoflurane and ketamine for anesthetic induction in children with congenital heart disease. Paediatr Anaesth 2008; 18: 715-21.
10. Funk W, Jakob W, Riedl T, Taeger K. Oral preanaesthetic medication for children: double-blind randomized study of a combination of midazolam and ketamine vs midazolam or ketamine alone. Br J Anaesth 2000; 84: 335-40.
11. Ogurlu M, Orhan ME, Bilgin F, Sizlan A, Yanarates O, Yilmaz N. Efficacy of different concentrations of sevoflurane administered through a face mask for magnetic resonance imaging in children. Paediatr Anaesth 2010; 20: 1098-104.
12. Chawathe M, Zatman T, Hall JE, et al. Sevoflurane (12% and 8%) inhalational induction in children. Paediatr Anaesth 2005; 15: 470-5.