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Modern Approaches to Sevoflurane Anesthesia Induction in Children: Comparative Analysis and Clinical Perspectives

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Introduction

Anesthetic management in pediatric practice requires special attention to the choice of induction technique due to children's physiological sensitivity to pharmacological agents, specific features of the respiratory and cardiovascular systems, and their emotional status. Sevoflurane, as a modern inhalation anesthetic, offers unique advantages—minimal airway irritation, favorable blood/gas partition coefficient, and absence of pungent odor—making it the agent of choice for mask induction in pediatric anesthesia. However, conventional approaches to sevoflurane anesthesia are associated with a high incidence of induction-related excitation, bradycardia, and postoperative agitation. This paper presents the results of an original study comparing the traditional VIMA technique and a new double-bolus induction technique using sevoflurane in children. Modern approaches to sevoflurane anesthesia induction in children demonstrate several advantages over traditional halothane methods. Sevoflurane induction is associated with faster loss of consciousness, especially when combined with nitrous oxide (Dubois et al., 1999). Studies consistently show that sevoflurane leads to more rapid psychomotor recovery and readiness for discharge compared to halothane (Redhu et al., 2010; Villani et al., 1998). Sevoflurane induction is also characterized by better hemodynamic stability, with fewer cardiac arrhythmias observed (Redhu et al., 2010; Villani et al., 1998). Children undergoing sevoflurane induction experience less struggling and exhibit fewer side effects, including reduced incidence of nausea and vomiting (E. P. et al., 1997; Redhu et al., 2010). Parents have reported a preference for sevoflurane over halothane, perceiving it as a more pleasant experience for their children (E. P. et al., 1997). These findings suggest that sevoflurane is a suitable and potentially superior alternative to halothane for pediatric anesthesia induction.

Problem Justification and Research Objectives

The Volatile Induction and Maintenance Anesthesia (VIMA) technique using sevoflurane is widely employed in pediatric procedures. Studies have shown that VIMA with sevoflurane offers several advantages over total intravenous anesthesia (TIVA) in children undergoing rigid bronchoscopy for foreign body removal. These benefits include more stable hemodynamics and respiration, faster induction and recovery times, and a lower incidence of breath-holding and desaturation (Liao et al., 2010; Al-Safty et al., 2020). However, VIMA with sevoflurane may lead to a higher incidence of excitement during recovery (Liao et al., 2010). The technique is

considered safe and precise for various age groups, with no negative long-term effects on respiratory, cardiovascular, cerebral, or immunologic systems (Peneş & Valeanu, 2016). While VIMA with sevoflurane can reduce the incidence of postoperative nausea and vomiting (PONV) in pediatric patients, it does not eliminate the risk entirely, with a reported PONV incidence of 9.2% in one study (Shin et al., 2003). However, this method often causes complications such as motor excitation during induction, epileptiform brain activity, bradycardia, and postoperative agitation. These events may require pharmacological intervention, destabilize the patient's condition, and prolong recovery. Recently, interest has grown in the concept of anesthetic preconditioning—a short-term pharmacological stimulus that increases tissue resistance to stress. This study hypothesized that using a double-bolus sevoflurane induction in VIMA could trigger preconditioning effects and reduce anesthesia-related complications.

Materials and Methods

The study was conducted at Tver State Medical University with ethical committee approval. It included 300 children aged 3 to 6 years scheduled for dental treatment under mask inhalation anesthesia. Group 1 included 210 children (retrospective, traditional VIMA), and Group 2 consisted of 90 children (prospective, double-bolus VIMA). All patients were ASA class I–III. Gender and age distribution were similar between groups. No premedication was administered.

Technique Description

The traditional VIMA technique involved pre-filling the anesthesia circuit with a gas mixture of 60% N_2O, 40% O_2, and 6% sevoflurane. Children inhaled the mixture via face mask until loss of consciousness, followed by reduction of sevoflurane to 4% for 5–6 minutes until adequate anesthetic depth was reached for laryngeal mask placement and mechanical ventilation (MV). The new double-bolus method included an initial bolus of 6% sevoflurane in O_2/N_2O (2/3 L/min), discontinued upon loss of consciousness. The circuit was flushed with 100% O_2. The child continued breathing through the circuit for 3–4 minutes, during which exhaled sevoflurane decreased from 3% to 0.3%. Assisted MV was used if hypoventilation developed. A second bolus was administered when heart rate (HR) began to increase by 2–3 bpm, lasting 1–1.5 minutes—sufficient for establishing anesthesia depth and initiating MV.

Anesthesia was maintained identically in both groups with 2–2.5% sevoflurane in a 1.5 L/min gas flow (O_2 0.6 L/min, N_2O 0.9 L/min), using a Dräger Fabius Plus anesthesia machine with Scio Four Oxi plus gas analyzer and Infinity Vista XL monitor. Standard monitoring included HR, blood pressure, SpO_2, $etCO_2$, inspired/expired gas concentrations, tidal volume, temperature, and ECG.

Results

Induction-related excitation occurred in 163 children (77.6%) in Group 1 and in only 19 children (21.1%) in Group 2 ($p<0.001$). Bradycardia (HR <75 bpm) was recorded in 76 children (36.1%) in Group 1 and only in 4 children (4.4%) in Group 2 ($p<0.001$). Post-anesthesia agitation was observed in 52 children (24.7%) in Group 1 and 4 children (4.4%) in Group 2 ($p<0.006$). Mean HR during induction was significantly higher in Group 2 (106±12 bpm) compared to Group 1 (87±8 bpm), $p<0.05$. Severe bradycardia requiring IV atropine was observed only in Group 1 (19 cases, 9.04%).

Discussion

The results strongly support the clinical significance of sevoflurane-induced preconditioning. The initial short bolus (30–40 seconds) likely avoided epileptiform brain activity thresholds and triggered endogenous protective mechanisms. The second bolus provided the required depth of anesthesia without further HR suppression, indicating cardioprotective effects. Sevoflurane's known ability to induce preconditioning in myocardium may explain the nearly eightfold reduction in bradycardia in Group 2. The preconditioning effect may also explain the lower rate

of postoperative agitation, a condition closely related to excitation and associated with psychological distress during emergence.

From a technical standpoint, the double-bolus method allowed better control over anesthetic depth with reduced exposure time to high-concentration sevoflurane, making it cost-efficient. The entire high-flow phase lasted only 1.5–2 minutes in Group 2 compared to 4–6 minutes in traditional VIMA. However, rapid reduction of sevoflurane concentration post-bolus requires active hyperventilation, which may not always be feasible without auxiliary ventilation support.

Conclusion

The new double-bolus sevoflurane VIMA technique significantly reduces the incidence of excitation, bradycardia, and postoperative agitation in children, compared to the traditional approach. These effects are likely due to anesthetic preconditioning mechanisms offering neuro- and cardioprotective benefits. The method shows promise for broader application in pediatric anesthesiology. Further clinical and experimental research is warranted to validate long-term outcomes, optimize ventilation strategies, and explore additional markers of preconditioning efficacy.

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