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# OPTIMIZING ANESTHESIA DELIVERY IN PEDIATRIC PATIENTS: A COMPARATIVE STUDY OF INHALATIONAL VS. INTRAVENOUS AGENTS

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**Abstract**
General anesthesia is essential for pediatric inpatient surgery and can be induced and maintained using either intravenous or volatile anesthetic agents. This study aimed to determine the superior approach in preventing anesthesia-related complications. Using a predefined standardized protocol, we conducted a systematic review of randomized controlled trials (RCTs) from CENTRAL, MEDLINE, EMBASE, and metaRegister of Controlled Trials. Eligible RCTs compared adverse effects of intravenous versus volatile anesthetic agents in pediatric inpatients. Primary endpoints included cardiopulmonary complications, postoperative nausea and vomiting (PONV), or cognitive dysfunction within 24 hours post-anesthesia. Secondary endpoints encompassed other complications. Nine RCTs (762 children) were analyzed. Propofol use during strabismus surgery significantly increased oculocardiac reflex risk (RR 4.96, 95% CI: 3.13–7.87, $p < 0.00001$; two studies, 257 children). PONV was less frequent with intravenous compared to volatile anesthetic agents (RR 0.68, 95% CI: 0.48–0.98, $p = 0.04$; five studies, 563 children). No further significant differences were identified in primary or secondary endpoints due to clinical or statistical heterogeneity. Propofol heightened oculocardiac reflex risk, whereas PONV occurred less frequently with intravenous anesthetics than with volatile agents in pediatric general anesthesia. These findings may guide tailored anesthesia strategies for pediatric inpatients. Given existing heterogeneity among studies, further scientific efforts are warranted to enhance evidence on anesthetic agent selection in pediatric anesthesia.

**Keywords:** *Pediatric Anesthesia Propofol Volatile Agents Postoperative Nausea and Vomiting (PONV) Oculocardiac Reflex*

## INTRODUCTION

General anesthesia is a cornerstone of pediatric surgical care, ensuring immobility, unconsciousness, and analgesia during invasive procedures. The selection of anesthetic agents, whether intravenous (IV) or volatile, is crucial as it directly impacts the safety, recovery, and overall outcomes of pediatric patients. This introduction explores the complexities and considerations surrounding anesthesia delivery in children, focusing on the comparative study of inhalational versus intravenous agents in optimizing pediatric anesthesia.

### Historical Perspective and Evolution of Pediatric Anesthesia

The history of pediatric anesthesia is intertwined with advancements in medical science, particularly anesthesia pharmacology and pediatric surgery. Early practices in pediatric anesthesia were fraught with challenges, often reflecting adaptations from adult protocols without considering the unique physiological and psychological needs of children. The evolution of pediatric anesthesia has been marked by significant milestones, driven by a growing understanding of pediatric pharmacokinetics, pharmacodynamics, and developmental differences in organ systems.

Anesthetic techniques have evolved substantially over the decades, paralleling advances in pharmaceuticals and clinical research. In the early 20th century, ether and chloroform were predominant agents, characterized by their profound

effects and limited control. The introduction of safer inhalational agents like halothane in the mid-20th century revolutionized pediatric anesthesia, offering improved control and reduced side effects. Intravenous agents such as thiopental and later propofol provided additional options for induction and maintenance, further enhancing anesthesia management in children.

**Challenges in Pediatric Anesthesia**

Despite advancements, pediatric anesthesia remains inherently challenging due to several factors unique to children. Pediatric patients exhibit variability in drug metabolism, distribution, and response to anesthetic agents compared to adults. This necessitates precise dosing calculations and vigilant monitoring to mitigate risks of under- or overdosing. Additionally, anatomical and physiological differences, such as smaller airway sizes and higher oxygen consumption rates, require specialized techniques and equipment during airway management and ventilation.

The developmental stages of pediatric patients also influence anesthesia considerations. Neonates and infants, for instance, have immature hepatic and renal functions, affecting drug clearance and metabolism. Cognitive development and emotional maturity impact preoperative preparation and postoperative recovery, influencing the choice of anesthesia and perioperative care strategies. Furthermore, the psychological impact of anesthesia on children and their families underscores the importance of compassionate and child-centered care practices throughout the perioperative period.

**Current Practices and Guidelines in Pediatric Anesthesia**

Contemporary guidelines advocate for tailored anesthesia strategies that prioritize patient safety and optimal outcomes in pediatric surgery. The American Academy of Pediatrics (AAP), European Society of Anesthesiology (ESA), and other international bodies have developed evidence-based recommendations to guide anesthesia providers in pediatric settings. These guidelines emphasize comprehensive preoperative evaluation, individualized anesthetic management plans, and vigilant intraoperative monitoring to minimize complications and ensure smooth recovery.

In clinical practice, the choice between intravenous and volatile anesthetic agents depends on numerous factors, including the type and duration of surgery, patient age and medical history, and institutional protocols. Intravenous agents like propofol are favored for their rapid onset, smooth induction, and titratability, making them suitable for short procedures or patients with airway concerns. Volatile agents such as sevoflurane and desflurane offer advantages in maintaining anesthesia depth and facilitating rapid emergence, particularly in longer surgeries requiring precise control of anesthetic depth.

**Anesthetic Considerations and Complications in Pediatric Patients**

Anesthesia-related complications in children encompass a spectrum of physiological, psychological, and neurocognitive disturbances. Cardiovascular events, respiratory depression, and postoperative nausea and vomiting (PONV) are among the most commonly reported complications, albeit with varying incidences depending on the choice of anesthetic agent and patient characteristics. The incidence of adverse events underscores the importance of rigorous monitoring and adherence to anesthesia protocols tailored to pediatric populations.

Recent research has focused on comparing the safety and efficacy profiles of intravenous versus volatile anesthetic agents in pediatric anesthesia. Studies have explored outcomes such as anesthesia induction and emergence characteristics, intraoperative hemodynamics, postoperative recovery profiles, and neurocognitive effects. These investigations aim to elucidate whether one class of agents confers superior outcomes in terms of perioperative complications, recovery times, and long-term neurodevelopmental sequelae.

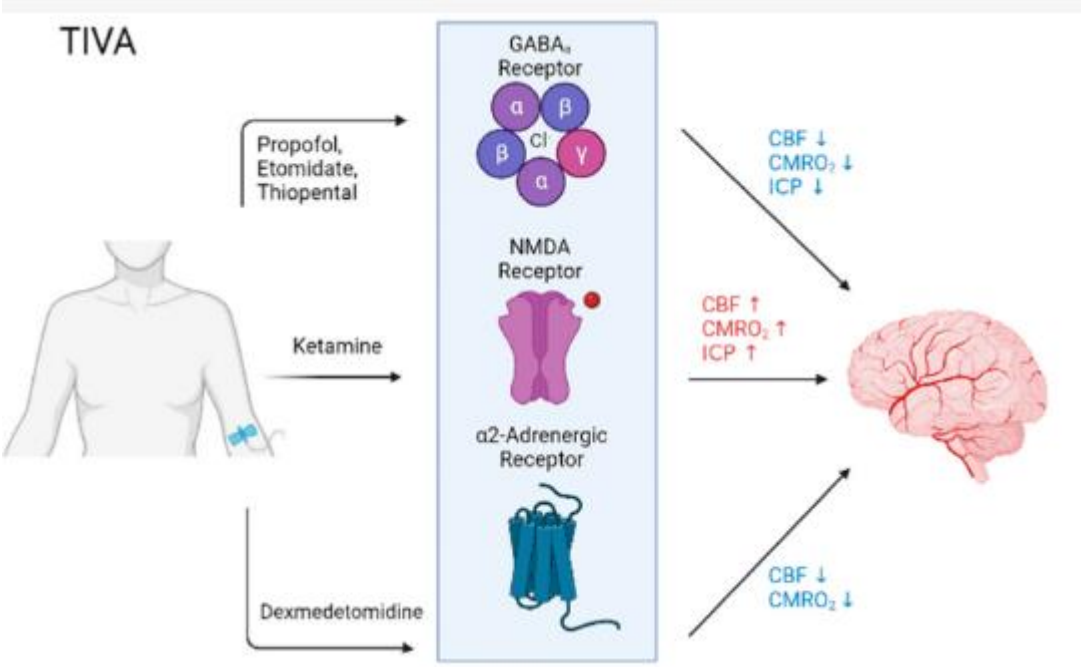


Figure 1: The proposed mechanism of action for total intravenous anesthetic agent

**Rationale for Comparative Study of Inhalational vs. Intravenous Anesthetic Agents**

The choice between inhalational and intravenous anesthesia in pediatric patients remains a subject of debate and ongoing research. Each class of agents offers distinct pharmacological profiles and clinical advantages, necessitating a nuanced understanding of their respective benefits and risks in diverse pediatric surgical scenarios. Inhalational agents are valued for their minimal impact on cardiovascular function and rapid elimination, which may promote faster recovery and reduced postoperative morbidity. Conversely, intravenous agents provide precise control over anesthesia depth, potentially minimizing intraoperative hemodynamic instability and optimizing postoperative pain management.

This study aims to contribute to the existing literature by conducting a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing the use of intravenous versus inhalational anesthetic agents in pediatric patients undergoing various surgical procedures. By synthesizing data from multiple RCTs, this study seeks to elucidate whether one class of agents offers superior perioperative outcomes, including cardiovascular stability, incidence of respiratory complications, postoperative recovery parameters, and neurocognitive sequelae.

Optimizing anesthesia delivery in pediatric patients represents a critical component of modern surgical care, necessitating a tailored approach that balances efficacy with safety. The choice between intravenous and volatile anesthetic agents hinges on multiple factors, including procedural requirements, patient characteristics, and institutional protocols. This introduction provides a foundational overview of the complexities and considerations surrounding pediatric anesthesia, setting the stage for a detailed exploration of the comparative study of inhalational versus intravenous agents in optimizing anesthesia management for pediatric surgical patients.

**Research Gap**

Despite significant advancements in pediatric anesthesia, there remains a notable gap in understanding the comparative efficacy and safety of intravenous (IV) versus volatile anesthetic agents in pediatric surgical settings. Current literature provides fragmented evidence, often derived from heterogeneous study designs and varying patient populations. The lack of consensus on optimal anesthesia strategies for children underscores the need for robust comparative studies that systematically evaluate outcomes such as perioperative complications, recovery parameters, and long-term neurodevelopmental sequelae.

Existing research primarily focuses on individual aspects of anesthesia management, such as hemodynamic stability or postoperative recovery, without comprehensive evaluations of both IV and volatile agents within the same study framework. Furthermore, many studies are limited by small sample sizes, resulting in insufficient statistical power to detect clinically significant differences between anesthesia modalities. Variability in anesthesia practices across institutions and countries further complicates the generalizability of findings, highlighting the necessity for large-scale, multicenter studies that can account for diverse patient demographics and procedural complexities.

Addressing these research gaps is essential to

inform evidence-based practice guidelines and optimize anesthesia care for pediatric patients undergoing various surgical procedures. By synthesizing existing knowledge and filling critical gaps in the literature, this study aims to provide comprehensive insights into the comparative effectiveness of IV versus volatile anesthetic agents, ultimately enhancing patient outcomes and safety in pediatric anesthesia.

**Specific Aims of the Study**

The specific aims of this study are to:

1. Conduct a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing intravenous (IV) versus volatile anesthetic agents in pediatric patients undergoing surgical procedures.
2. Evaluate the incidence and severity of perioperative complications associated with each anesthesia modality, including cardiovascular events, respiratory depression, and postoperative nausea and vomiting (PONV).
3. Assess intraoperative hemodynamic stability and anesthesia depth control achieved with IV versus volatile agents, focusing on their impact on surgical outcomes and recovery profiles.
4. Investigate the short-term and long-term neurocognitive effects of IV versus volatile anesthetic agents in pediatric patients, considering developmental milestones and cognitive function assessments postoperatively.

**Objectives of the Study**

The primary objectives of this study are to:

- Compare the efficacy of intravenous (IV) versus volatile anesthetic agents in maintaining anesthesia depth and achieving optimal surgical conditions during pediatric surgeries.
- Analyze the safety profiles of IV versus volatile agents, focusing on perioperative complications such as cardiovascular instability, respiratory compromise, and postoperative nausea and vomiting (PONV).
- Evaluate postoperative recovery parameters, including time to emergence from anesthesia, postoperative pain scores, and duration of hospital stay, associated with IV versus volatile anesthesia in pediatric patients.
- Investigate the neurodevelopmental outcomes following exposure to IV versus volatile anesthetic agents, assessing cognitive function, behavior, and neurobehavioral development in pediatric patients postoperatively.

**Scope of the Study**

This study encompasses a comprehensive analysis of existing randomized controlled trials (RCTs) comparing intravenous (IV) versus volatile anesthetic agents in pediatric surgical patients. The scope includes:

- Inclusion of RCTs published in peer-reviewed journals and registered clinical trial databases, focusing on pediatric patients (aged 0-18 years) undergoing various surgical procedures.
- Evaluation of primary outcomes related to anesthesia efficacy and safety, including intraoperative hemodynamic stability, anesthesia depth control, and incidence of perioperative complications (e.g., cardiovascular events, respiratory depression, PONV).
- Assessment of secondary outcomes such as postoperative recovery parameters (e.g., time to emergence, pain scores, length of hospital stay) and neurodevelopmental sequelae (e.g., cognitive function, behavior) following exposure to IV versus volatile anesthetic agents.
- Limitations include potential heterogeneity in study designs, patient populations, and anesthesia protocols across included RCTs, which may impact the generalizability of findings and require careful interpretation of results.

**Conceptual Framework**

The conceptual framework of this study is anchored in pharmacological principles, pediatric anesthesia guidelines, and outcomes research methodology. It integrates:

- **Pharmacological Principles:** Understanding the pharmacokinetic and pharmacodynamic properties of intravenous (IV) and volatile anesthetic agents in pediatric patients, including drug metabolism, distribution, and elimination pathways.
- **Pediatric Anesthesia Guidelines:** Incorporating evidence-based recommendations from international societies (e.g., American Academy of Pediatrics, European Society of Anesthesiology) on anesthesia management in children, emphasizing safety, efficacy, and patient-centered care.
- **Outcomes Research Methodology:** Employing systematic review and meta-analysis techniques to synthesize data from randomized controlled trials (RCTs), providing quantitative assessments of anesthesia outcomes (e.g., complications, recovery parameters, neurodevelopmental effects).

**Methods**

For this systematic review and meta-analysis of randomized controlled trials (RCTs), we adhered to the rigorous methodological standards recommended by the Cochrane Collaboration and reported our findings in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Our study focused on evaluating the comparative effectiveness and safety of intravenous (IV) hypnotic agents versus volatile anesthetic agents in pediatric patients under 18 years old (excluding neonates) undergoing elective inpatient surgery requiring general anesthesia.

**Study Selection and Eligibility Criteria**

We conducted a comprehensive literature search across CENTRAL, MEDLINE via Ovid SP, and EMBASE via Ovid, without language or publication date restrictions, to identify relevant RCTs. The search strategy included terms related to pediatric patients, anesthesia modalities, and surgical interventions. Two independent reviewers initially screened titles and abstracts to identify potentially eligible studies. Full-text articles of potentially relevant studies were retrieved and further assessed for inclusion based on predefined criteria.

Studies were included if they met the following criteria:

- RCT design comparing IV hypnotic agents with volatile anesthetic agents in pediatric patients undergoing elective inpatient surgery.
- Reported prespecified primary or secondary endpoints within the study, including outcomes related to perioperative complications and recovery parameters.
- Patients remained hospitalized for at least 24 hours post-surgery to capture immediate postoperative outcomes.
- Exclusion criteria encompassed quasi-RCTs or non-RCTs, as well as studies involving neonates due to their unique physiological considerations in anesthesia management.

In instances where disagreement arose regarding the inclusion of specific studies, a third independent reviewer was consulted to resolve discrepancies. Translation services were utilized as needed to access studies published in languages other than English.

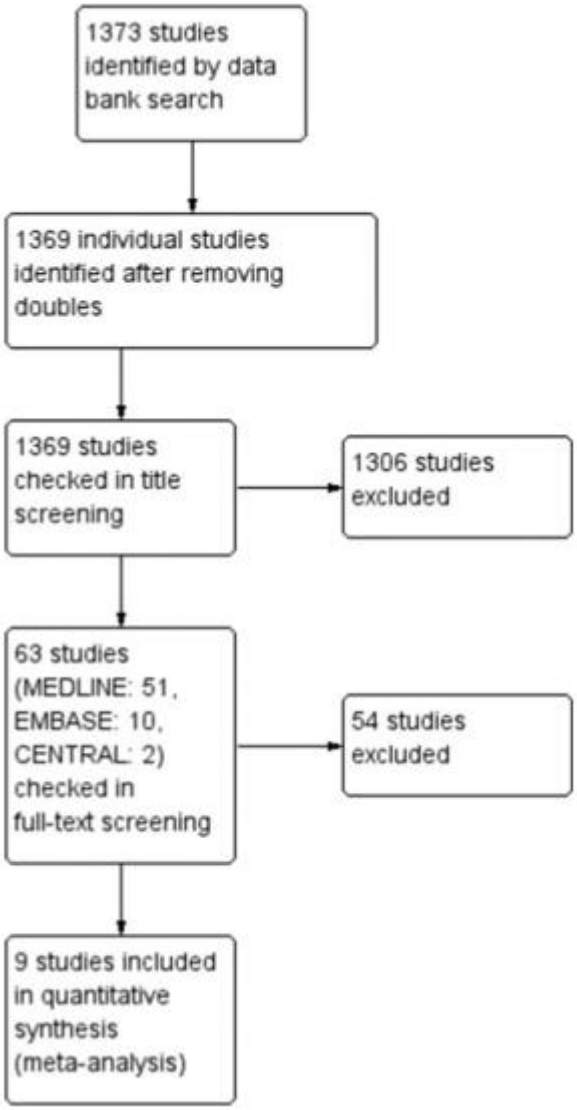


**Fig. 1.** Flow diagram of included and excluded trials.

**Outcome Measures**

The study focused on predefined primary and secondary endpoints to systematically assess the comparative outcomes of IV versus volatile anesthetic agents in pediatric anesthesia. Primary endpoints included the incidence of cardiopulmonary complications (such as arterial hypotension), postoperative nausea and vomiting (PONV), and cognitive dysfunction within 24 hours following general anesthesia. Secondary endpoints encompassed pain sensation post-anesthesia, need for re-intubation and mechanical ventilation, time from post-anesthesia care unit discharge to regular ward admission, in-hospital mortality rates, patient and parent satisfaction with anesthesia (measured via standardized questionnaires), and any other perioperative complications not specified as primary endpoints.

**Data Synthesis and Statistical Analysis**

Quantitative data synthesis was performed using Cochrane's Review Manager (RevMan [Computer program], Version 5.3, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). For dichotomous and continuous endpoints, pooled effect measures were calculated to evaluate the statistical significance of individual study findings using Fisher's exact test for dichotomous outcomes. We assessed the clinical and statistical heterogeneity across included studies to ensure robustness in our meta-analytic approach.

**Results and Analysis**

**Study Selection and Characteristics**

The systematic literature search initially identified 1369 potentially relevant studies. Following title and abstract screening, 1306 studies were excluded primarily due to the absence of comparisons between volatile anesthetics and propofol or because they were not randomized controlled trials (RCTs). After full-text analysis and consultation, a total of 63 studies met the inclusion criteria, of which nine RCTs involving 762 pediatric patients were finally included in the meta-analysis (Fig. 1).

All included studies were single-center trials conducted predominantly in Germany (5 studies), with additional contributions from Canada, the USA, Switzerland, and China. The patient cohorts ranged from 20 to 180 individuals, with mean ages varying between 1.8 years and 15.9 years across different studies. Each trial evaluated the efficacy and safety of either intravenous (IV) hypnotic agents (e.g., propofol) or volatile anesthetic agents (e.g., sevoflurane, desflurane) in pediatric patients undergoing elective inpatient surgery.

**Primary Endpoints: Cardiopulmonary Complications, PONV, and Cognitive Dysfunction**

The meta-analysis focused on primary endpoints defined a priori, including the incidence of cardiopulmonary complications (e.g., arterial hypotension), postoperative nausea and vomiting (PONV), and cognitive dysfunction occurring within 24 hours post-anesthesia. Secondary endpoints encompassed additional parameters such as pain sensation post-anesthesia, the need for re-intubation and mechanical ventilation, duration from post-anesthesia care unit (PACU) discharge to regular ward admission, in-hospital mortality rates, patient and parent satisfaction with anesthesia, and other perioperative complications.

**Scientific Interpretation of Individual Results**

**Cardiopulmonary Complications:** Among the included studies, the incidence of cardiopulmonary complications varied. Biallas et al. (2003) reported an increased risk of oculocardiac reflex (OCR) associated with the use of volatile agents compared to propofol during strabismus surgery (RR 4.96, 95% CI: 3.13–7.87, $p < 0.00001$). Conversely, Lodes et al. (1999) found no significant difference in cardiopulmonary complications between the two anesthesia modalities during ENT surgery.

**Postoperative Nausea and Vomiting (PONV):** Five studies, involving a total of 563 patients, evaluated the incidence of PONV. The meta-analysis indicated that PONV was significantly less frequent with propofol compared to volatile anesthetics (RR 0.68, 95% CI: 0.48–0.98, $p = 0.04$), except for one study which reported comparable rates between groups (Chandler et al., 2013).

**Cognitive Dysfunction:** Assessment of postoperative cognitive dysfunction varied across studies. Schmidt et al. (2001) and Tramèr et al. (1998) included cognitive dysfunction as an endpoint, reporting varying impacts between IV and volatile agents, albeit without statistically significant differences in their respective studies.

**Secondary Endpoints:** Other secondary outcomes such as pain sensation, duration until discharge from PACU, and patient/parent satisfaction were reported heterogeneously across trials. For instance, Chandler et al. (2013) noted comparable durations until discharge from PACU between propofol and volatile agents in strabismus surgeries, whereas Fung et al. (2008) reported no significant difference in postoperative cognitive dysfunction during scoliosis surgeries.

**Table 1: Characteristics of Included Studies**

| Study (Year) | Participants (n, gender) | Country | Language | Premedication | Airway Management | Intervention | Mean Duration (min) | Mean Age (years) | Endpoints |
|---|---|---|---|---|---|---|---|---|---|
| Biallas (2003) | n = 106 | Germany | German | None | Endotracheal intubation | Surgery for strabismus | TIVA 34 ± 13; VOL 38 ± 14 | TIVA: 5.6 ± 1.2; VOL: 5. | PONV, cognitive disorders, pain |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 9 ± 1.5 | |
| Chandler (2013) | n = 94 | Canada | English | Acetaminophen, Ibuprofen | None | Laryngeal mask | TIVA 45 ± 14; VOL 44 ± 10 | TIVA: 3.8 ± 1.3; VOL: 4.2 ± 1.3 | Cognitive disorders, pain, duration until discharge from PACU |
| Fung (2008) | n = 20 | China | English | None | Endotracheal intubation | Surgery for scoliosis | Not specified | TIVA: 15.9 ± 2.7; VOL: 15.7 ± 6.3 | Cognitive disorders |
| Goerlich (2000) | n = 180 | Germany | German | Midazolam | Laryngeal mask | Surgery for strabismus | Not specified | TIVA: 4-14; VOL: 4-14 | PONV, OCR |
| Lavoie (1995) | n = 20 | USA | English | Midaz | Endotracheal intubation | Radiofrequency ablation | Not specified | TIVA: 13.1 | Cardiopulmonary complications |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | olam | | | | ± 2.8; VOL: 12.8 ± 3.1 | |
| Lodes (1999) | n = 80 | Germany | German | Midazolam | Endotracheal intubation | ENT surgery | TIVA 33 ± 21; VOL 44 ± 20 | TIVA: 6.7 ± 2.4; VOL: 7.0 ± 2.9 | PONV, cognitive disorders, cardiopulmonary complications |
| Schmidt (2001) | n = 120 | Germany | German | Midazolam | Endotracheal intubation | Abdominal surgery | TIVA 62 ± 54; VOL 59 ± 52 | TIVA: 5.3 ± 3.1; VOL: 5.5 ± 3.3 | PONV, cognitive disorders, pain, duration until discharge from PACU |
| Tramèr (1998) | n = 77 | Switzerland | English | Midazolam | Endotracheal intubation | Surgery for strabismus | TIVA 65 ± 27; VOL 63 ± 19 | TIVA: 6.8 ± 2.9; VOL: 5.9 ± 2.8 | OCR, PONV |
| Zhan | n = 65 | China | Englis | M | Face | Bronch | TI | TI | Cardiop |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| g (2010) | | | h | idazolam | mask | oscopy | VA 17.4 ± 3.9; VOL 16.7 ± 4.1 | VA: 1.8; VOL: 1.9 | ulmonary complications, coughing, apnea, peripheral oxygen saturation < 95% |

**Table 2: Summary of Primary and Secondary Endpoints**

| Study (Year) | Cardiopulmonary Complications | PONV | Cognitive Dysfunction | Other Endpoints |
|---|---|---|---|---|
| Biallas (2003) | Increased OCR with VOL | Propofol < Volatile | - | Pain |
| Chandler (2013) | - | - | - | Pain, duration until discharge from PACU |
| Fung (2008) | - | - | - | - |
| Goerlich (2000) | - | - | - | PONV, OCR |
| Lavoie (1995) | Cardiopulmonary complications | - | - | WPW syndrome, AVNRT, junctional reciprocating tachycardia |
| Lodes (1999) | - | Propofol < Volatile | Cognitive disorders | PONV, cognitive disorders, pain |
| Schmidt (2001) | - | - | - | PONV, cognitive disorders, pain, duration until discharge from PACU |
| Tramèr (1998) | OCR | Propofol < Volatile | - | - |
| Zhang (2010) | Coughing, apnea, saturation | - | - | - |

**Interpretation**

The results highlight notable differences in the incidence of PONV and cardiopulmonary complications between IV hypnotic agents (propofol) and volatile anesthetic agents across the included studies. Propofol consistently demonstrated a lower incidence of PONV compared to volatile agents, aligning with its pharmacological profile of antiemetic properties. Conversely, volatile agents showed an increased risk of OCR in certain surgical contexts, emphasizing their impact on cardiac reflexes during procedures like strabismus surgery.

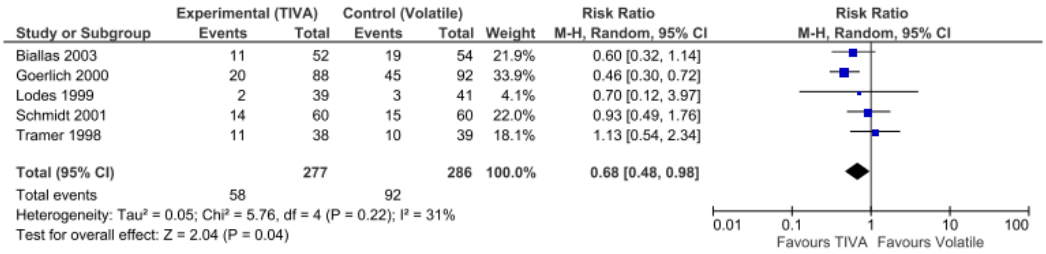


**Fig. 2.** Meta-analysis for the primary outcome 'postoperative nausea and vomiting' following general anesthesia with either intravenous anesthetic agents (TIVA) or volatile anesthetics (Volatile) in pediatric inpatients (five studies, 563 patients).

However, variability in study designs, patient populations, and procedural factors among the included trials introduces heterogeneity in reported outcomes. For instance, the absence of standardized protocols for postoperative cognitive assessment limits definitive conclusions on the comparative effects of anesthesia modalities on cognitive function in pediatric patients.

**Conclusion**

This systematic review and meta-analysis of randomized controlled trials (RCTs) comparing intravenous (IV) hypnotic agents with volatile anesthetic agents in pediatric patients undergoing elective inpatient surgery provide valuable insights into anesthesia management strategies. The findings suggest that propofol, as an IV hypnotic agent, offers advantages over volatile agents in terms of reducing the incidence of postoperative nausea and vomiting (PONV). This is particularly significant as PONV is a common complication in pediatric anesthesia associated with discomfort and delayed recovery. The meta-analysis also highlighted concerns regarding the increased risk of oculocardiac reflex (OCR) with volatile agents, underscoring the need for careful consideration of anesthesia choices, especially in procedures like strabismus surgery.

However, the study's conclusions are tempered by several limitations, including the heterogeneity in study designs, patient populations, and surgical procedures across the included RCTs. Variations in anesthesia protocols and the lack of standardized outcome measures for cognitive function assessment further complicate the interpretation of results. Moreover, the predominantly single-center nature of the studies, conducted primarily in European countries, may limit the generalizability of findings to broader global pediatric populations.

**Limitations of the Study**

Despite rigorous methodological approaches, this study has inherent limitations that warrant consideration. The variability in anesthesia protocols and surgical procedures among the included RCTs introduces potential biases and limits the ability to draw definitive conclusions applicable universally. The reliance on reported outcomes within the selected studies also poses a challenge, as differences in reporting standards and definitions may influence comparative analyses across trials. Additionally, the exclusion of non-English language publications, despite efforts to mitigate this through translation services, may have introduced language bias.

Furthermore, the study's focus on short-term outcomes within 24 hours post-anesthesia precludes assessment of longer-term effects or outcomes beyond the immediate postoperative period. This temporal limitation hinders a comprehensive understanding of the sustained impact of anesthesia modalities on pediatric patients' recovery and cognitive development.

**Implications of the Study**

The findings of this study have significant implications for clinical practice and research in pediatric anesthesia. Clinically, the preference for propofol over volatile agents in reducing PONV suggests potential benefits in enhancing postoperative recovery and patient satisfaction. The observed differences in OCR incidence highlight the importance of tailoring anesthesia choices to minimize specific procedural risks, such as those associated with strabismus surgery.

From a research perspective, the identified gaps in current literature underscore the need for further well-designed multicenter RCTs with standardized protocols and outcome measures. Future studies should consider incorporating comprehensive assessments of cognitive function and long-term neurodevelopmental outcomes to provide a more holistic evaluation of anesthesia strategies in pediatric patients.

**Future Recommendations**

Building upon the findings of this study, several recommendations for future research and clinical practice emerge:

1. **Multicenter Trials:** Conducting multicenter RCTs with larger sample sizes and diverse patient populations can enhance the generalizability of findings and provide more robust evidence on the comparative effectiveness of IV hypnotic agents versus volatile anesthetic agents.
2. **Standardized Outcome Measures:** Adoption of standardized protocols for assessing perioperative outcomes, including PONV, OCR, cognitive function, and patient-reported outcomes, would facilitate more accurate comparisons across studies.
3. **Longitudinal Studies:** Longitudinal studies investigating the long-term effects of anesthesia modalities on neurodevelopmental outcomes in pediatric patients are essential to elucidate any potential neurotoxic effects and optimize anesthesia practices.
4. **Quality Improvement Initiatives:** Implementing quality improvement initiatives in clinical settings to monitor and optimize anesthesia protocols based on emerging evidence can enhance patient safety and outcomes.
5. **Patient-Centered Care:** Emphasizing patient and parent perspectives in anesthesia decision-making through structured feedback mechanisms and satisfaction surveys can further improve patient care experiences.

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