

DOI: 10.25237/revchilanestv55n5-10

The recovery of total intravenous anesthesia vs inhalational anesthesia in opioid free pediatric tonsillectomy

Recuperación de la anestesia intravenosa total frente a la anestesia inhalatoria en la amigdalectomía pediátrica sin opioides

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Funding source: The authors received no specific funding for this work.

Conflicts of interest: The authors declare that they have no competing interests.

Fecha de recepción: 21 de noviembre de 2025 / Fecha de aceptación: 12 de abril de 2026

ABSTRACT

Background: Ambulatory pediatric tonsillectomy requires anesthetic techniques that enable rapid, smooth emergence and early discharge with minimal postoperative adverse events. Although total intravenous anesthesia (TIVA) and inhalational anesthesia are commonly used, their relative effects on fast-track recovery within an opioid-free regimen remain inadequately characterized. **Objective:** To compare opioid-free TIVA using propofol with inhalational anesthesia using sevoflurane regarding emergence profile and fast-track recovery in ambulatory pediatric tonsillectomy. **Methods:** This prospective randomized study enrolled 120 ASA I children aged 3-10 years with Mallampati class I-II undergoing ambulatory tonsillectomy. Participants were randomized into two equal groups: propofol-based TIVA via a manually programmed infusion (Group P, n = 60) or sevoflurane inhalational anesthesia (Group S, n = 60). All patients received a standardized opioid-free analgesic protocol. Recovery outcomes were assessed using White's Fast-Track Score, along with postoperative pain, postoperative nausea and vomiting (PONV), and time to discharge. **Results:** Baseline demographics and intraoperative physiological parameters were comparable between groups ($p > 0.05$). Group P showed superior recovery outcomes, including higher consciousness scores (1.9 ± 0.3 vs 1.67 ± 0.48 ; $p = 0.002$), improved PONV-related recovery (1.88 ± 0.32 vs 1.23 ± 0.43 ; $p < 0.001$; indicating less PONV), higher postoperative pain scores as reported (1.97 ± 0.18 vs 1.82 ± 0.39 ; $p = 0.008$), higher total Fast-Track discharge scores (13.48 ± 0.62 vs 12.55 ± 0.62 ; $p < 0.001$), and shorter discharge times (16.3 ± 1.51 min vs 20.25 ± 1.11 min; $p < 0.001$). Physical activity, hemodynamic stability, respiratory stability, and oxygen saturation did not differ significantly between groups. **Conclusion:** In opioid-free ambulatory pediatric tonsillectomy, propofol-based TIVA was associated with smoother emergence, faster fast-track recovery, reduced PONV, and earlier discharge compared with sevoflurane inhalational anesthesia, without compromising cardiorespiratory stability.

Keywords: Pediatric tonsillectomy, total intravenous anesthesia, opioid-free anesthesia, fast-track recover.

RESUMEN

Antecedentes: La amigdalectomía pediátrica ambulatoria requiere técnicas anestésicas que permitan una emersión rápida y suave, así como el alta temprana, con mínimos eventos adversos posoperatorios. Aunque la anestesia intravenosa total (TIVA) y la anestesia inhalatoria se utilizan con frecuencia, sus efectos relativos sobre la recuperación acelerada dentro de un régimen sin opioides siguen estando insuficientemente caracterizados. **Objetivo:** Comparar la TIVA sin opioides basada en propofol con la anestesia inhalatoria basada en sevoflurano en relación con el perfil de emersión y la recuperación acelerada en la amigdalectomía pediátrica ambulatoria. **Métodos:** Este estudio prospectivo y

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ISSN: 0719-6792



aleatorizado incluyó a 120 niños ASA I, de 3 a 10 años, con clase Mallampati I-II, sometidos a amigdalectomía ambulatoria. Los participantes fueron aleatorizados en dos grupos: TIVA basada en propofol mediante infusión programada manualmente (Grupo P, $n = 60$) o anestesia inhalatoria con sevoflurano (Grupo S, $n = 60$). Todos los pacientes recibieron un protocolo analgésico estandarizado sin opioides. Los resultados de recuperación se evaluaron mediante la puntuación Fast-Track de White, junto con el dolor posoperatorio, las náuseas y vómitos posoperatorios (NVPO) y el tiempo hasta el alta. **Resultados:** Las características demográficas basales y los parámetros fisiológicos intraoperatorios fueron comparables entre los grupos ($p > 0,05$). El Grupo P mostró resultados de recuperación superiores, incluyendo mayores puntuaciones de conciencia ($1,9 \pm 0,3$ frente a $1,67 \pm 0,48$; $p = 0,002$), mejor recuperación relacionada con las NVPO ($1,88 \pm 0,32$ frente a $1,23 \pm 0,43$; $p < 0,001$; indicando menos NVPO), mejores puntuaciones de dolor posoperatorio según lo reportado ($1,97 \pm 0,18$ frente a $1,82 \pm 0,39$; $p = 0,008$), mayores puntuaciones totales de alta Fast-Track ($13,48 \pm 0,62$ frente a $12,55 \pm 0,62$; $p < 0,001$) y tiempos de alta más cortos ($16,3 \pm 1,51$ min frente a $20,25 \pm 1,11$ min; $p < 0,001$). La actividad física, la estabilidad hemodinámica, la estabilidad respiratoria y la saturación de oxígeno no difirieron significativamente entre los grupos. **Conclusión:** En la amigdalectomía pediátrica ambulatoria sin opioides, la TIVA basada en propofol se asoció con una emersión más suave, una recuperación acelerada más rápida, menor incidencia de NVPO y alta más temprana en comparación con la anestesia inhalatoria con sevoflurano, sin comprometer la estabilidad cardiorrespiratoria.

Palabras clave: Amigdalectomía pediátrica, anestesia intravenosa total, anestesia sin opioides, recuperación acelerada.

Introductions

Ambulatory surgery is increasingly favored because it lowers costs, improves provider efficiency, and enhances patient convenience; accordingly, nearly two-thirds of surgical procedures in North America are performed in ambulatory settings[1]. Children are often appropriate candidates for day-case procedures because postoperative supervision is typically available and major comorbidities are less common. Nevertheless, pediatric patients are physiologically distinct from adults and may be more susceptible to hypoxia, acidosis, hypercarbia, and anesthetic agent-induced myocardial depression, which necessitates anesthetic regimens that support rapid, clear-headed recovery while minimizing pain, nausea, vomiting, prolonged hospital stay, and other adverse events without compromising safety[2].

Tonsillectomy illustrates the clinical relevance of these considerations, as it is among the most common pediatric operations in the United States, exceeding half a million procedures in 2006, and is now predominantly performed as an ambulatory procedure, with fewer than 3% managed as inpatient cases[3]. Because discharge timing is closely linked to early recovery quality, anesthetic technique and drug selection can materially influence postoperative complications and delay discharge[4]. General anesthesia may be maintained using intravenous or inhalational techniques. Propofol-based total intravenous anesthesia (TIVA) has been associated with lower rates of PONV, laryngospasm, and emergence delirium, although it may be limited by injection pain and the risk of awareness[5]. Propofol is widely used for induction and maintenance and is characterized by rapid recovery and limited accumulation even with prolonged infusion[6],[7]. In contrast, inhalational agents are widely used for their effectiveness and ease of delivery[8], and sevoflurane is commonly selected because of its favorable recovery profile[9]. In addition, avoiding perioperative opioids may reduce opioid-related adverse effects such as PONV, respiratory depression, and ileus, supporting greater use of nonopioid adjuncts and multimodal analgesia (MMA) to enable opioid-free anesthesia (OFA) and opioid-sparing strategies[10,11]. Recovery scoring systems provide standardized, objective assessment during the post-anesthesia period[12], and fast-tracking applies discharge criteria in the operating room to allow

eligible patients to bypass Phase I recovery and proceed directly to Phase II[13].

Despite the availability of these approaches, a key gap persists in pediatric ambulatory tonsillectomy: evidence remains insufficiently consistent on how maintenance technique (propofol-based TIVA versus sevoflurane-based inhalational anesthesia), particularly within opioid-sparing/OFA pathways, translates into objectively measured recovery quality and fast-track discharge readiness using standardized scoring systems[4]-[13].

Therefore, the aim of the present study is to compare intravenous and inhalational maintenance strategies in pediatric ambulatory tonsillectomy, focusing on postoperative recovery profiles, opioid-related adverse events (including PONV and respiratory complications), and discharge readiness assessed by validated recovery and fast-tracking scores.

Patients and Methods

Study design and setting

This investigation was conducted as a prospective, randomized controlled trial at El-Nile Specialized Hospital, Edfu, Egypt, and enrolled children scheduled for ambulatory tonsillectomy during the predefined study period.

Participants

Eligible participants were children aged 3–10 years with no comorbidities, classified as ASA I, and with Mallampati class I or II, who were planned for ambulatory tonsillectomy. To minimize operator-related variability, all procedures were performed by the same surgeon.

Randomization, allocation, and blinding

A total of 120 participants were randomly allocated in a 1:1 ratio to one of two groups (60 per group) using a computer-generated sequence. Allocation concealment was maintained using sealed, opaque envelopes. Group P received propofol-based total intravenous anesthesia (TIVA), whereas

Group S received sevoflurane-based inhalational anesthesia. Postoperative outcome assessment was performed by personnel blinded to group assignment.

Preoperative preparation and monitoring

All children were fasted for 6 hours prior to surgery. Weight was recorded on admission, and intravenous access was secured before induction. Standard ASA monitoring was applied throughout, including non-invasive blood pressure, electrocardiography, pulse oximetry, capnography, and temperature monitoring.

Anesthetic management

For induction, Group P received intravenous propofol (3-5 mg/kg), while Group S underwent inhalational induction with sevoflurane (1%-8%) in oxygen via face mask. Endotracheal intubation was performed without neuromuscular blockade using age-appropriate tube sizes. Anesthesia was maintained in Group P using a manually programmed propofol infusion based on the Kataria pediatric model: 15 mg/kg/h for the first 15 minutes, 13 mg/kg/h for the next 15 minutes, 11 mg/kg/h for the subsequent 30-60 minutes, 10 mg/kg/h for 1-2 hours, and 9 mg/kg/h thereafter. In Group S, sevoflurane was administered at 2%-8%, titrated to maintain an expired concentration of 1.5%-3%. Mechanical ventilation was delivered using volume-controlled ventilation with an N₂O:O₂ mixture of 60:40, fresh gas flow of 1.5 L/min, and end-tidal CO₂ (ETCO₂) maintained within the normal pediatric range.

Postoperative management

All participants received a standardized opioid-free multimodal analgesia regimen. Paracetamol suppositories (500 mg adjusted according to weight) were administered, hydration was optimized, and opioids were avoided intraoperatively and postoperatively. Emergence was initiated by discontinuing the anesthetic agent and providing 100% oxygen prior to extubation, with gentle suctioning of the surgical field performed before awakening.

Outcomes

The primary outcome was postoperative recovery profile assessed using White's Fast-Track Score (14-point version) upon arrival to the post-anesthesia care unit (PACU) and at discharge. Secondary outcomes included level of consciousness, physical activity, hemodynamic stability, respiratory stability, oxygen saturation (SpO₂), postoperative nausea and vomiting (PONV), postoperative pain score, total discharge score, time to discharge (minutes), and intraoperative safety parameters (heart rate, blood pressure, respiratory rate, ETCO₂, temperature, and SpO₂).

Sample size calculation

Sample size estimation was performed using G*Power 3.1.9.2 (University of Kiel, Germany) to detect a 10% between-group difference in recovery time (mean 40.1 ± 6.1

minutes), assuming $\alpha = 0.05$ and 80% power. The required minimum was 53 patients per arm; to account for potential dropout, 60 participants were included in each group (total n = 120).

Statistical analysis

Statistical analyses were conducted using SPSS version 26 (IBM, Chicago, IL, USA). Data distribution was evaluated using Shapiro-Wilk testing and histogram inspection. Normally distributed continuous variables were summarized as mean ± standard deviation and compared using the unpaired Student's t-test. Non-normally distributed variables were presented as median (interquartile range) and analyzed using the Mann-Whitney U test. Categorical variables were expressed as number (%) and compared using the Chi-square test or Fisher's exact test, as appropriate. Statistical significance was set at $p < 0.05$.

Results

Baseline characteristics were well balanced between the randomized groups. Age ($P = 0.782$), sex distribution ($P = 0.507$), weight ($P = 0.729$), Mallampati class ($P = 0.668$), and duration of surgery ($P = 0.733$) were not significantly different between Group P and Group S, confirming comparability at enrollment (Table 1).

Intraoperative safety parameters were comparable between groups. Mean heart rate, respiratory rate, systolic and diastolic blood pressure, temperature, and oxygen saturation (SpO₂) did not differ significantly, indicating that both anesthetic maintenance techniques were similarly safe under the study protocol. At discharge, analysis of White's Fast-Track Score components using mean ± SD showed no significant differences between groups in physical activity ($P = 1.000$), hemodynamic stability ($P = 0.700$), respiratory stability ($P = 0.700$), or SpO₂ ($P = 0.052$). However, Group P demonstrated significantly better level of consciousness ($P = 0.002$), lower PONV burden ($P < 0.001$), lower postoperative pain ($P = 0.008$), and a higher total discharge score ($P < 0.001$) compared with Group S (Table 2).

Group P had a significantly higher level of consciousness score ($P = 0.002$), better PONV score ($P < 0.001$), better postoperative pain score ($P = 0.008$), and higher total discharge score ($P < 0.001$), while physical activity ($P = 1.000$), hemodynamic stability ($P = 0.698$), respiratory stability ($P = 0.698$), and SpO₂ ($P = 0.052$) were not significantly different between groups (Table 3).

Discussion

The present study compared recovery after propofol-based total intravenous anesthesia (TIVA) versus sevoflurane-based inhalational anesthesia in ambulatory pediatric opioid-free tonsillectomy, focusing on emergence smoothness, recovery quality, and discharge readiness. TIVA yielded a more favorable recovery profile on the Fast Tracking Score, with earlier attainment of discharge criteria and higher early recovery scores, consistent with propofol's predictable pharmacokinetics and titratability. In

Table 1. Demographic data and surgery duration of the studied groups

Variable	Group P (n=60)	Group S (n=60)	P value
Age (years), Mean $\pm$ SD	7.00 $\pm$ 2.27	7.12 $\pm$ 2.33	0.782
Age (years), Range	3–10	3–10	-
Sex, Male n (%)	24 (40%)	27 (45%)	0.507
Sex, Female n (%)	36 (60%)	33 (55%)	-
Weight (kg), Mean $\pm$ SD	24.36 $\pm$ 6.75	24.82 $\pm$ 7.70	0.729
Weight (kg), Range	14-37	14-48	-
ASA physical status, I n (%)	60 (100%)	60 (100%)	-
ASA physical status, II n (%)	0 (0%)	0 (0%)	-
Mallampati score, I n (%)	44 (73.33%)	42 (70%)	0.668
Mallampati score, II n (%)	16 (26.67%)	18 (30%)	—
Duration of surgery (min), Mean $\pm$ SD	24.00 $\pm$ 5.19	23.68 $\pm$ 4.96	0.733
Duration of surgery (min), Range	15-1	15-30	-

ASA: American Society of Anaesthesiologists; SD: standard deviation; P values compare Group P vs Group S; "—": indicates not applicable within the subcategory.

Table 2. Fast-tracking score components at discharge (Mean $\pm$ SD)

Parameter	Group P (n = 60)	Group S (n = 60)	P value
Level of consciousness score	1.90 $\pm$ 0.30	1.67 $\pm$ 0.48	0.002*
Physical activity score	1.95 $\pm$ 0.22	1.95 $\pm$ 0.22	1.000
Hemodynamic stability score	1.93 $\pm$ 0.25	1.95 $\pm$ 0.22	0.700
Respiratory stability score	1.95 $\pm$ 0.22	1.93 $\pm$ 0.25	0.700
SpO ₂ score	1.90 $\pm$ 0.30	1.98 $\pm$ 0.13	0.052
PONV score	1.88 $\pm$ 0.32	1.23 $\pm$ 0.43	< 0.001*
Postoperative pain score	1.97 $\pm$ 0.18	1.82 $\pm$ 0.39	0.008*
Total discharge score	13.48 $\pm$ 0.62	12.55 $\pm$ 0.62	< 0.001*

PONV: postoperative nausea and vomiting; SpO₂: peripheral oxygen saturation; SD: standard deviation; *Statistically significant (P < 0.05). Higher scores indicate better recovery/discharge readiness per White's Fast-Track scoring.

Table 3. Fast-tracking score components at discharge (Median and IQR)

Parameter	Group P (n = 60)	Group S (n = 60)	P value
Level of consciousness score, Median (IQR)	2 (2-2)	2 (1-2)	0.002*
Physical activity score, Median (IQR)	2 (2-2)	2 (2-2)	1.000
Hemodynamic stability score, Median (IQR)	2 (2-2)	2 (2-2)	0.698
Respiratory stability score, Median (IQR)	2 (2-2)	2 (2-2)	0.698
SpO ₂ score, Median (IQR)	2 (2-2)	2 (2-2)	0.052
PONV score, Median (IQR)	2 (2-2)	1 (1-1)	< 0.001*
Postoperative pain score, Median (IQR)	2 (2-2)	2 (2-2)	0.008*
Total discharge score, Median (IQR)	14 (13-14)	12 (12-13)	< 0.001*

IQR: interquartile range; PONV: postoperative nausea and vomiting; SpO₂: peripheral oxygen saturation; *Statistically significant (P < 0.05). Higher scores indicate better recovery/discharge readiness.

contrast, sevoflurane despite its established role in pediatric anesthesia has been associated with higher emergence agitation and PONV, which can delay functional recovery; the opioid-free

protocol in our study minimized confounding from opioid-related adverse effects, allowing clearer attribution of differences to the maintenance technique. The shorter discharge time in

the TIVA group (≈ 4 minutes) is aligned with these superior fast-track outcomes and may be operationally relevant in high-turn-over ambulatory tonsillectomy lists.

Our findings concur with prior comparative evidence. Kumar et al. (2025), demonstrated the feasibility of propofol infusion (6-12 mg/kg/h IV) versus sevoflurane (1.5%-2.5% inhalation) for maintenance in pediatric short procedures[14]. Nanditha Padikkasu (2025) reported superior post-anesthesia discharge scoring with propofol TIVA compared with sevoflurane in a prospective randomized study of 90 fibroadenoma patients[15], and Wong et al. (2023), found better postoperative quality of recovery with propofol TIVA in 90 elective hepatectomy patients[16]. A 2021 study also suggested that propofol TIVA can be effective in pediatric outpatient anesthesia while improving parental satisfaction and reducing recovery-room workload[17]. Similarly, Han et al. (2020), reported higher Quality of Recovery-40 scores and better ambulation with IV propofol than inhaled sevoflurane in hand-assisted laparoscopic nephrectomy donors, although pain scores were not significantly different differences that may reflect adult populations and procedural context[18]. In children undergoing dental surgery, Kocaturk, O. and S. Keles (2018), observed lower emergence delirium and higher parental satisfaction with TIVA, alongside reduced postoperative pain without prolonging extubation or recovery time[19]; Ishii et al. (2016), likewise reported a lower incidence of postoperative delirium with propofol compared with sevoflurane in a double-blind prospective study[20].

Intraoperatively, both techniques were comparably safe in our cohort, with no significant differences in heart rate, respiratory rate, blood pressure, temperature, ETCO_2 , or SO_2 . This aligns with NASR (2025), who found no significant differences in heart rate or SO_2 between propofol and sevoflurane in adults with elevated liver enzymes, although mean arterial pressure was lower with propofol likely reflecting differences in population and baseline hepatic status[21]. Erbatur et al. (2023), similarly reported no significant intraoperative differences in heart rate or mean arterial pressure between propofol- and sevoflurane-based techniques in elective septorhinoplasty under general anesthesia[22].

Several limitations warrant consideration. The single-center design at El-Nile Specialized Hospital may limit external validity, and anesthetist blinding was not feasible, raising the possibility of performance bias in titration and emergence management. The cohort was restricted to relatively healthy children (ASA I; Mallampati I-II; 3-10 years), limiting applicability to higher-risk patients or those with anticipated airway difficulty. Recovery assessment relied primarily on White's Fast-Track Score, which may not capture later outcomes (e.g., at-home behavioral recovery, delayed pain, late PONV) or caregiver-reported endpoints, and measured discharge time can be influenced by organizational factors (e.g., staffing and workflow). Clinically, these data support considering propofol-based TIVA within an opioid-free multimodal analgesia pathway to improve early recovery quality and facilitate earlier discharge in ambulatory pediatric tonsillectomy, while recognizing that safe implementation depends on clinician expertise, appropriate infusion systems, and careful dosing to mitigate risks such as awareness; where resources or familiarity are limited, sevoflurane remains an acceptable, safe alternative guided by local capability.

Conclusion

This study indicates that opioid-free propofol-based total intravenous anesthesia (TIVA) yields superior early recovery outcomes compared with sevoflurane-based inhalational anesthesia in children undergoing ambulatory tonsillectomy. TIVA was associated with higher fast-track discharge scores, better level of consciousness at discharge, lower postoperative pain and PONV, and a shorter time to discharge, while intraoperative hemodynamic and respiratory stability remained comparable between techniques.

Declarations

Ethics approval and consent to participate: The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the appropriate institutional ethics committee. Written informed consent was obtained from the parents or legal guardians of all enrolled children, and assent was obtained from children when applicable.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' contributions: All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by the authors. The first draft of the manuscript was written by the authors, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements: The authors thank the operating room and post-anesthesia care unit staff at El-Nile Specialized Hospital for their support during patient recruitment, perioperative management, and data collection.

Trial registration: Not applicable.

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