ISSN No. 3090-3580

CASE REPORT

# Low-Flow Anesthesia Management in Pediatric Laparoscopic Choledochal Cyst Excision and Hepaticojejunostomy: A Case Report

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DOI : 10.24843/xqsck350

## Abstract

Laparoscopic surgery offers significant benefits in pediatric populations but presents anesthetic challenges, especially during prolonged procedures. This case report describes the anesthetic management of an 11-year-old boy who underwent nearly 12 hours of laparoscopic choledochal cyst excision, Roux-en-Y hepaticojejunostomy, and cholecystectomy. Low-flow anesthesia using sevoflurane was administered via a Dräger Perseus A500, enabling precise control of anesthetic delivery, oxygenation, and ventilation. Throughout the procedure, inspired oxygen fraction ($FiO_2$) was maintained above 30%, and end-tidal $CO_2$ ($EtCO_2$) remained stable around 35 mmHg. Volatile agent consumption was reduced, with age-adjusted MAC (xMAC) consistently between 0.85 and 0.90. Intraoperative hemodynamics and postoperative recovery were stable, with no immediate complications. This case highlights the safety, efficiency, and cost-effectiveness of low-flow anesthesia in complex pediatric laparoscopic surgery when guided by advanced monitoring systems and supports its broader adoption in resource-limited healthcare settings.

**Keywords**: Choledochal cyst, Laparoscopic surgery, Low-flow anesthesia; Pediatric anesthesia, Sevoflurane

# Manajemen Anestesi Aliran Rendah pada Eksisi Kista Koledokus Laparoskopi Pediatrik dan Hepatikojejunostomi: Laporan Kasus

## Abstrak

Bedah laparoskopi memberi banyak manfaat pada populasi pediatrik, namun menghadirkan tantangan anestesi, terutama pada prosedur yang berlangsung lama. Laporan kasus ini menggambarkan manajemen anestesi pada anak laki-laki usia 11 tahun yang menjalani operasi laparoskopi selama hampir 12 jam berupa eksisi kista koledokus, hepaticojejunostomy Roux-en-Y, dan kolesistektomi. Anestesi aliran rendah menggunakan sevoflurane diberikan melalui mesin Dräger Perseus A500, yang memungkinkan kontrol presisi terhadap pemberian anestesi, oksigenasi, dan ventilasi. Sepanjang prosedur, fraksi oksigen terinspirasi ($FiO_2$) dijaga di atas 30%, dan end-tidal $CO_2$ ($EtCO_2$) stabil sekitar 35 mmHg. Konsumsi agen volatil berkurang, dengan nilai MAC yang disesuaikan usia (xMAC) konsisten antara 0,85–0,90. Hemodinamik intraoperatif dan pemulihan pascaoperasi stabil tanpa komplikasi. Kasus ini menyoroti keamanan, efisiensi, dan kehematan biaya anestesi aliran rendah pada bedah laparoskopi pediatrik kompleks dengan dukungan pemantauan canggih, serta mendukung penerapannya secara lebih luas di fasilitas dengan sumber daya terbatas.

**Kata kunci**: Anestesi aliran rendah, Anestesi pediatrik, Kista koledokus, Bedah laparoskopi, Sevoflurane

## Introduction

This case is notable for its successful use of low-flow anesthesia during a prolonged pediatric laparoscopic choledochal cyst excision and Roux-en-Y hepaticojejunostomy, an uncommon and technically demanding scenario. Pediatric laparoscopic surgeries are inherently challenging due to altered respiratory mechanics from $CO_2$ insufflation, limited physiological reserves, and heightened sensitivity to anesthetic agents. These factors increase the risk of hypothermia, hemodynamic instability, and potential neurodevelopmental concerns associated with prolonged exposure to general anesthesia. In this case, careful anesthetic planning was essential to maintain

intraoperative stability and ensure patient safety throughout the complex procedure.[1]

Low-flow anesthesia (LFA), defined as fresh

gas flow below 1 L/min, was employed using sevoflurane as the volatile agent and facilitated by the Dräger Perseus A500 workstation. This approach minimized volatile agent consumption, preserved heat and humidity in the respiratory tract and reduced environmental and occupational exposure to waste anesthetic gases. Sevoflurane's pharmacological profile—particularly its low blood-gas partition coefficient and stability in $CO_2$ absorbers—makes it well-suited for such techniques. Importantly, the use of low-flow anesthesia also offered significant pharmacoeconomic advantages, making it highly suitable for resource-conscious healthcare systems such as Indonesia's National Health Insurance program (Badan Penyelenggara Jaminan Sosial or BPJS). This case adds to the limited literature documenting the safe and cost-effective application of low-flow techniques in complex pediatric laparoscopic procedures.[2]

## Case Presentation

An 11-year-old boy was admitted to a tertiary hospital with a confirmed diagnosis of a choledochal cyst type IVa (Todani classification), accompanied by chronic cholecystitis and gallbladder hydrops. He had a long-standing history of episodic colicky abdominal pain beginning at age one, often associated with high-grade fever, which resolved with symptomatic treatment. There was a history of jaundice without pale stools or tea-colored urine. Two weeks before admission the symptoms worsened, prompting further investigation, including MRCP, which revealed significant intra- and extrahepatic bile-duct dilatation consistent with a choledochal cyst and associated biliary anomalies. At admission there were no complaints of abdominal pain, fever, jaundice, or respiratory symptoms. He was scheduled for elective laparoscopic cyst excision with Roux-en-Y hepaticojejunostomy. He had no significant past medical or surgical history, no known drug or food allergies, and normal developmental milestones for age. There was no family history of similar conditions or relevant genetic disorders. Preoperative examination showed a cooperative patient with stable vital signs and no signs of acute illness. Routine laboratory tests (complete blood count, coagulation profile, renal function, liver enzymes) were within acceptable limits for surgery. Chest radiography was normal, and MRCP confirmed the diagnosis.

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Submitted: 10-Jul-2025 Revised: 22-Jul-2025
Accepted: 05-Sep-2025 Published: 01-Dec-2025



On the day of surgery, standard pediatric anesthetic protocols were followed. Premedication included intravenous midazolam and ketamine. Induction used intravenous propofol and fentanyl; neuromuscular blockade was achieved with atracurium. Endotracheal intubation was performed with a cuffed 6.0 ETT, secured at 17 cm at the lips. Tube position was confirmed by auscultation and capnography. Maintenance anesthesia consisted of oxygen and compressed air as carrier gases with low-flow sevoflurane delivered via the Dräger Perseus A500. Inspired and expired sevoflurane concentrations were maintained at approximately 2.1–2.3% and 2.0–2.2%, respectively, corresponding to xMAC ~0.85–0.90 for age (Figure 1). Ventilation parameters included a tidal volume of 280 mL, respiratory rate of 18 breaths/min , and minute ventilation

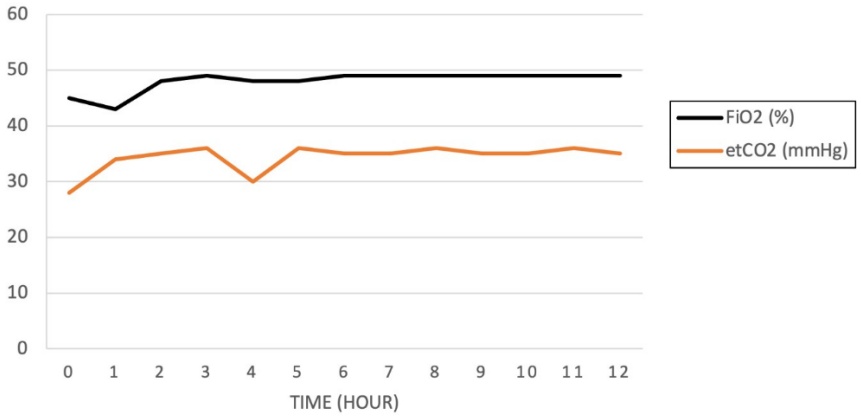


**Figure 1.** Sevoflurane monitoring demonstrates consistent inSev, etSev, and xMAC values, indicating adequate anesthetic depth during surgery.

of 5.1 L/min. Airway pressures were within normal limits (Paw 19 $cmH_2O$; PEEP 5 $cmH_2O$). $EtCO_2$ was stable at ~35 mmHg throughout the procedure. Fraction of inspired oxygen ($FiO_2$) was maintained at 45–48% with minimal fluctuation, indicating effective oxygenation during LFA (Figure 2). Surgery was performed in the supine position using five laparoscopic ports. Pneumoperitoneum was established with $CO_2$ insufflation at 12–13 mmHg. Cystic dilatation of the common bile duct was resected; the distal end was closed using a linear stapler. A Roux limb was constructed by dividing the jejunum 25 cm distal to the ligament of Treitz. Hepaticojejunostomy and jejunojejunostomy were completed with absorbable sutures and staplers. Cholecystectomy was performed, and a subhepatic drain (NGT 16 Fr) was placed before closure. Total operative time was approximately 11 hours 55 minutes.

Intraoperative monitoring documented a blood-pressure range of 82–118/43–65 mmHg and heart rate of 81–120 beats/min. Oxygen saturation remained 98–100%. Total intraoperative crystalloid was 1242 mL. Estimated blood loss was 100 mL and urine output 300 mL; no blood products or colloids were required.

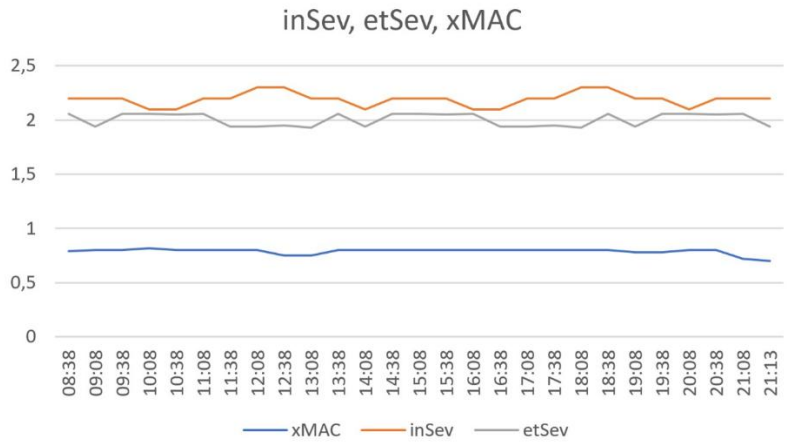


**Figure 2.** Intraoperative trends of $FiO_2$ and $etCO_2$, showing stable oxygenation and ventilation throughout the procedure.

At the end of surgery, the patient was transferred to the Pediatric Intensive Care Unit (PICU) for postoperative monitoring and ventilatory support. Analgesia was provided via epidural bupivacaine 0.125% with morphine 0.3 mg in 8 mL every 10–12 hours, plus scheduled paracetamol and ibuprofen. The postoperative course was uneventful; the patient was hemodynamically stable on PICU arrival.

## Discussion

The application of LFA in pediatric laparoscopic procedures, such as choledochal cyst excision combined with hepaticojejunostomy and cholecystectomy, presents both opportunities and challenges. Modern anesthesia workstations, like the Dräger Perseus A500, support the effective implementation of LFA through advanced features such as the Low Flow Wizard and Econometer. These tools assist clinicians in optimizing fresh gas flow rates to ensure patient safety, minimize anesthetic agent consumption, and reduce costs. In the presented case, low-flow anesthesia was successfully employed using this workstation. Sevoflurane was chosen as the volatile agent due to its rapid onset and stability, making it particularly suitable for low-flow techniques in pediatric patients. Furthermore, the availability of integrated gas analyzers for monitoring inspired oxygen ($FiO_2$), end-tidal carbon dioxide ($EtCO_2$), and agent concentrations enhances the safety and practicality of conducting LFA in modern clinical settings. $EtCO_2$ monitoring is crucial in pediatric patients undergoing LFA, as it provides real-time assessment of ventilation and helps detect respiratory abnormalities. Studies have shown that $EtCO_2$ values remain within acceptable ranges during LFA, indicating its safety and efficacy in maintaining adequate ventilation.[2,3]

One of the primary advantages of low-flow anesthesia is the significant reduction in the consumption of anesthetic gases. A comparative study demonstrated that sevoflurane consumption was significantly lower in the low-flow group (4.17 ± 0.70 mL) compared to the standard-flow group (8.96 ± 1.11 mL), highlighting the efficiency of LFA in reducing anesthetic usage.[4] Studies have reported that with high-flow anesthesia (e.g., 5 L/min), approximately 80–90% of anesthetic agents and gases are wasted. In contrast, low-flow anesthesia minimizes this wastage, leading to considerable cost savings and reduced environmental impact.[5] This is particularly relevant in healthcare systems focused on cost-efficiency, such as Indonesia's BPJS program, without compromising patient safety or anesthetic quality.

While low-flow anesthesia offers significant benefits such as reduced anesthetic gas consumption and improved cost-efficiency, it is not without its challenges. One of the primary concerns is the risk of hypoxia due to rebreathing, particularly when fresh gas flows are reduced. Studies have shown that maintaining a minimum inspired oxygen concentration ($FiO_2$) above 30% is critical to preventing hypoxic episodes during low-flow techniques. For example, research by Baum et al. emphasized that careful monitoring and adjustment of $FiO_2$ are essential in pediatric low-flow anesthesia to ensure patient safety. [5] In the present case, this principle was applied effectively, with $FiO_2$ consistently maintained above 30% throughout the nearly 12-hour procedure. This demonstrates that with appropriate monitoring and vigilance, low-flow anesthesia can be safely implemented even in complex pediatric laparoscopic surgeries.

Additionally, effective ventilation is paramount in laparoscopic surgeries due to the use of $CO_2$ insufflation, which can increase systemic $CO_2$ absorption and elevate end-tidal $CO_2$ ($EtCO_2$) levels. This issue is particularly significant in pediatric patients, who have a higher per-body-weight metabolic rate and increased $CO_2$ absorption. Nevertheless, in the present case,

$EtCO_2$ was successfully maintained around 35 mmHg, demonstrating well-controlled ventilation and gas exchange. These findings underscore that with vigilant intraoperative monitoring, low-flow anesthesia can be safely and effectively applied even in lengthy and complex pediatric laparoscopic surgeries.[6]

Comparatively, standard high-flow anesthesia techniques may offer more straightforward management of gas concentrations and quicker adjustments to changes in patient physiology. However, they come with increased consumption of anesthetic agents and greater environmental impact. Moreover, high-flow techniques may lead to more significant heat and humidity loss from the respiratory tract, which can be detrimental, especially in pediatric patients. [5,7]

This case reinforces the viability of low-flow anesthesia as a safe and efficient technique in prolonged pediatric laparoscopic surgery. Despite the inherent challenges in managing ventilation and oxygenation in children, the combination of modern anesthesia technology and continuous intraoperative monitoring allowed for stable physiological parameters throughout the procedure. The significant reduction in volatile agent use underscores its pharmacoeconomic value, particularly in resource-limited settings. Ultimately, this report supports the broader adoption of low-flow anesthesia in pediatric practice, provided that careful monitoring and appropriate equipment are in place.


## Acknowledgement

Nil.


## Declaration of Patient Consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.


## Financial Support and Sponsorship

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.


## Conflicts of Interest

The authors report no conflict of interest.

## Data Availability Statement

De-identified patient data from this case report will be made available upon reasonable request to the corresponding author following publication, subject to institutional data-sharing policies and ethics approval.

## Author's Contributions

All authors contributed significantly to the conception and design of the study, data collection, analysis, and interpretation of the results. All authors participated in writing and critically revising the manuscript for important intellectual content, approved the final version to be published, and are accountable for all aspects of the research.

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