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OPTIMIZING ANESTHESIA FOR A PEDIATRIC PATIENT WITH CYANOTIC HEART DISEASE: PULMONARY ATRESIA WITH MAPCAS

Kadek Agus Heryana Putra[1], I Putu Kurniyanta[2], I Made Subagiartha[3], Lalu Reza Aldira Akbar[4*]
Universitas Udayana, Indonesia[1,2,3,4]
Email: lalu.reza018@student.unud.ac.id[*]

Abstract

Pulmonary atresia with major aortopulmonary collateral arteries (MAPCAs) is a rare and complex congenital heart anomaly marked by the absence of a direct connection between the right ventricle and the pulmonary arteries. The pulmonary blood supply originates via collateral arteries that arise from the aorta. Pulmonary atresia with major aortopulmonary collateral arteries (MAPCAs) poses considerable difficulties in perioperative management, especially during general anesthesia for dental procedures in pediatric patients. This case report details the anesthetic management of a 5-year-old male with pulmonary atresia and MAPCAs undergoing dental extractions under general anesthesia. The anesthetic plan prioritized maintaining systemic blood pressure to ensure pulmonary perfusion, avoiding increases in pulmonary vascular resistance, and preventing myocardial depression. Anesthesia was induced with ketamine and fentanyl, while maintenance was achieved using sevoflurane and dexmedetomidine, with pressure-controlled ventilation to optimize hemodynamics. Postoperative recovery was uneventful, with the patient monitored in the pediatric intensive care unit. The management of patients with pulmonary atresia and MAPCAs requires careful planning and a multidisciplinary approach. A tailored anesthetic strategy emphasizing hemodynamic stability and oxygenation is critical. This report underscores the importance of understanding the pathophysiology of MAPCAs to optimize perioperative outcomes.

Keywords: Pulmonary atresia, MAPCAs, congenital heart disease, anesthetic management, pediatric anesthesia

Introduction

Pulmonary atresia with major aortopulmonary collateral arteries (MAPCAs) is a rare and complex congenital heart anomaly marked by the absence of a direct connection between the right ventricle and the pulmonary arteries (Presnell et al., 2015). The pulmonary blood supply originates via collateral arteries that arise from the aorta. Pulmonary atresia with major aortopulmonary collateral arteries (MAPCAs) poses considerable difficulties in perioperative management, especially during general anesthesia for dental procedures in pediatric patient (Barron & Botha, 2018). The absence of a direct connection between the right ventricle and pulmonary arteries requires dependence on collateral arteries for pulmonary blood supply, complicating anesthetic treatment. This complexity requires comprehensive evaluation of hemodynamic stability and oxygenation during anesthesia. This report discusses the intraoperative management of a pediatric patient with pulmonary atresia and MAPCAs undergoing dental treatment under general anesthesia. Emphasis is placed on the anesthetic considerations and strategies employed to optimize outcomes in this patient population.

Case Description

A 5-year-old male, weighing 18.5 kg with a height of 115 cm (BMI: 14.3 kg/m²), presented for dental extraction under general anesthesia due to multiple carious teeth. The patient had a history of pulmonary atresia with ventricular septal defect (PA-VSD) and MAPCAs, diagnosed shortly after birth. Previous evaluations included cardiac catheterization at 3 and 8 months of age, confirming the diagnosis and detailing the anatomy of the pulmonary vasculature. The patient had undergone conservative management with no surgical intervention thus far.

Notably, the patient had a history of neonatal cyanosis and persistent desaturation with resting oxygen saturation ranging from 78% to 80% on room air. There was no history of syncope or significant limitations in daily activities. The patient's functional capacity was estimated at 5 METs, indicating the ability to perform moderate physical activities without symptoms of dyspnea or fatigue. There was no prior history of adverse anesthetic events or known drug allergies.

Physical examination revealed a cooperative child with no acute distress. Cardiovascular assessment showed a heart rate of 106 beats per minute with a regular rhythm and a single S2 heart sound. A systolic murmur was audible at the aortic valve area. Respiratory examination was unremarkable, with symmetric chest wall movements and no adventitious sounds. Peripheral perfusion was adequate with warm extremities, and capillary refill time was less than 2 seconds. SpO2 remained at 78%-80% on room air.

Other systemic examinations, including the abdomen, central nervous system, and musculoskeletal system, were within normal limits. Oral examination revealed multiple carious teeth requiring extraction under controlled conditions due to the patient's cyanotic cardiac status and risk of infective endocarditis.

Echocardiography confirmed the presence of pulmonary atresia with MAPCAs and a ventricular septal defect. The pulmonary arteries were noted to be hypoplastic, with incomplete arborization. Cardiac catheterization performed in 2019 demonstrated native pulmonary arteries measuring 5.16 mm (right pulmonary artery) and 4.16 mm (left pulmonary artery), with multiple MAPCAs supplying the pulmonary circulation. The McGoon ratio was calculated at 1.1, suggesting borderline surgical candidacy.

Laboratory investigations, including a complete blood count, renal function tests, and coagulation profile, were within normal limits. A chest radiograph revealed mild cardiomegaly without evidence of pulmonary congestion.

Preoperative Considerations

Given the patient's complex cardiovascular anatomy, a multidisciplinary discussion was held involving pediatric cardiologists, anesthesiologists, and dentists. Key anesthetic goals were identified:

Maintaining adequate oxygenation and perfusion: Given the patient's reliance on MAPCAs, it was critical to avoid decreases in systemic blood pressure that could compromise pulmonary blood flow.

Minimizing changes in pulmonary vascular resistance (PVR): An increase in PVR could further reduce pulmonary blood flow and exacerbate hypoxemia.

Avoiding myocardial depression: Preservation of right ventricular function was essential to ensure adequate systemic circulation through the aorta.

Preoperative fasting guidelines were followed to minimize the risk of aspiration. Oral midazolam (0.5 mg/kg) was administered 30 minutes before surgery for anxiolysis.

Research Methods

Intraoperative Management

Monitoring

Standard American Society of Anesthesiologists (ASA) monitors were employed, including continuous ECG, noninvasive blood pressure, pulse oximetry, and capnography. Invasive arterial blood pressure monitoring was established via the radial artery to allow for real-time hemodynamic assessment. Central venous access was not deemed necessary as the planned procedure was of short duration.

Anesthetic Induction

Induction of anesthesia was carefully titrated to avoid hemodynamic instability. Ketamine (1 mg/kg) was chosen as the primary induction agent due to its sympathomimetic properties, which help maintain systemic vascular resistance and cardiac output. Fentanyl (1 mcg/kg) was administered for analgesia, and midazolam (0.05 mg/kg) was added for further sedation.

Neuromuscular blockade was achieved with rocuronium (0.6 mg/kg) to facilitate endotracheal intubation. The patient was preoxygenated with 50% oxygen, and care was taken to avoid hyperoxia, which could reduce systemic vascular resistance and compromise coronary perfusion.

Maintenance of Anesthesia

Anesthesia was maintained with a combination of sevoflurane (1%-2%) in air-oxygen mixture (FiO2:0.3) and a continuous infusion of dexmedetomidine (0.5 mcg/kg/hour). This combination provided hemodynamic stability and reduced the risk of significant myocardial depression. Additional doses of fentanyl were administered as needed for intraoperative analgesia.

The patient was mechanically ventilated using pressure-controlled ventilation, with tidal volumes of 6-8 mL/kg and a respiratory rate adjusted to maintain end-tidal CO2 between 35-40 mmHg. Positive end-expiratory pressure (PEEP) of 3-5 cm H2O was applied to prevent atelectasis without increasing PVR.

Hemodynamic Management

Continuous monitoring allowed for prompt detection and management of hemodynamic fluctuations. Hypotension was treated with boluses of phenylephrine (10 mcg/kg) to maintain systemic vascular resistance. Inotropes such as dopamine were readily available but not required during the procedure. Fluid management was conservative to avoid volume overload and subsequent right ventricular strain.

Emergence and Postoperative Care

At the conclusion of the procedure, neuromuscular blockade was reversed with neostigmine (0.05 mg/kg) and glycopyrrolate (0.01 mg/kg). Extubation was performed once the patient was fully awake, with stable hemodynamics and adequate spontaneous ventilation.

The patient was transferred to the pediatric intensive care unit (PICU) for close monitoring. Postoperative analgesia was provided with acetaminophen (15 mg/kg) administered rectally.

Results and Discussion

Major aortopulmonary collateral arteries (MAPCAs) are congenital cardiac lesions that result from persistent embryonic connections between the aorta or its branches and the pulmonary vascular system (Alahmadi & Sharma, n.d.). MAPCAs develop early in embryonic life yet regress as soon as normal pulmonary circulation develops. The pulmonary arteries fail to develop properly in some congenital heart conditions. Consequently, the collaterals continue to grow, with some potentially becoming the main blood supply to the lungs. This condition often accompanies congenital heart diseases that reduce pulmonary blood flow, like tetralogy of Fallot with pulmonary atresia (pulmonary atresia with VSD), though it can also occur by itself on rare occasions. Such an anomaly is known as an isolated aortopulmonary collateral artery and is a potential cause of congestive heart failure in neonates (Hoang et al., 2023). The well-oxygenated blood initially flows into the lungs, leading to pulmonary vasodilation and reducing blood flow across the ductus arteriosus and foramen ovale. Consequently, the pulmonary circulation and left heart become isolated from the rest of the circulation, resulting in hypoxemia. This low oxygen level drives the nonregression of aortopulmonary collateral vessels. The anesthetic management of a pediatric patient with pulmonary atresia, ventricular septal defect (PA-VSD), and major aortopulmonary collateral arteries (MAPCAs) presents a unique set of challenges requiring meticulous perioperative planning. The interplay between systemic and pulmonary circulations in such cases demands a tailored anesthetic approach to ensure hemodynamic stability, optimize oxygenation, and prevent complications related to altered vascular physiology (Abuzaid et al., 2020).

Preoperative Considerations

Children with cyanotic congenital heart disease, particularly PA-VSD with MAPCAs, are highly dependent on systemic blood pressure to drive pulmonary perfusion (Khawar Sana & Ahmed, n.d.). The presence of hypoplastic pulmonary arteries further complicates blood flow distribution, necessitating careful preoperative assessment and planning. The patient's history of resting oxygen saturation of 78%-80% indicated chronic hypoxemia, emphasizing the need for strategies that would avoid exacerbating desaturation during the perioperative period.

A multidisciplinary approach involving pediatric cardiologists, anesthesiologists, and dentists was crucial in formulating an anesthetic plan tailored to the patient's cardiovascular physiology. Preoperative evaluations, including echocardiography and cardiac catheterization data, provided essential insights into pulmonary vasculature anatomy and function. Given the significant risk of infective endocarditis associated with poor dental hygiene and congenital heart disease, antibiotic prophylaxis was considered as per American Heart Association (AHA) guidelines.

Preoperative fasting was strictly adhered to, minimizing the risk of aspiration. Oral midazolam (0.5 mg/kg) was administered 30 minutes before surgery for anxiolysis, ensuring smooth separation from caregivers while preventing excessive catecholamine surges that could alter pulmonary vascular resistance (PVR) and systemic vascular resistance (SVR).

In patients with MAPCAs, pulmonary blood flow is dependent on systemic arterial pressure, as MAPCAs originate from the aorta. Excessive reductions in systemic vascular resistance (SVR) can divert blood flow away from the pulmonary circulation,

leading to hypoxemia (Alahmadi & Sharma, n.d.). Conversely, increases in PVR can further limit pulmonary perfusion. Strategies to optimize pulmonary blood flow include :

a. Avoiding hypercapnia and hypoxia. These conditions increase PVR and reduce oxygenation.
b. Maintaining a balanced FiO2: Hyperoxia can reduce SVR, whereas hypoxia increases PVR. The fraction of inspired oxygen (FIO2) used during induction and maintenance should vary according to the degree of preoperative pulmonary overcirculation. Ideally, the FIO2 is adjusted to maintain an oxygen saturation of 75% to 85% (Quinonez et al., 2018). Judicious use of PEEP: Excessive PEEP can compress MAPCAs, reducing pulmonary blood flow.

Patients with pulmonary atresia often have limited cardiovascular reserves, making them highly sensitive to hemodynamic fluctuations. Maintaining an adequate systemic perfusion pressure is important to avoid systemic acidosis, hypoxemia in the case tortuous and stenotic collaterals, and coronary hypoperfusion prior to cardiopulmonary bypass, particularly in patients with significant overcirculation. For this reason, volatile agents are frequently avoided after anesthetic induction. All volatile anesthetics decrease mean arterial blood pressure (MABP), systemic vascular resistance (SVR), and cardiac output (CO) in a dose-dependent fashion. Effects on diastolic blood pressure, mean pulmonary artery pressure (MPAP), and pulmonary vascular resistance are variable (Quinonez et al., 2018). Anesthetic agents with minimal myocardial depressant effects, such as ketamine and dexmedetomidine, are preferred.

Continuous arterial pressure monitoring is essential for early detection and management of hypotension. Volatile agents are frequently avoided after anesthetic induction. All volatile anesthetics decrease mean arterial blood pressure (MABP), systemic vascular resistance (SVR), and cardiac output (CO) in a dose-dependent fashion. Effects on diastolic blood pressure, mean pulmonary artery pressure (MPAP), and pulmonary vascular resistance are variable (rivenes). Interestingly, Qp/Qs is unaffected, regardless of the volatile anesthetic used (Greeley et al., n.d.). After induction, we typically use a total intravenous anesthetic technique. A variety of anesthetics can be administered intravenously in order to provide analgesia, amnesia, and muscle relaxation. Various combinations of fentanyl, midazolam, ketamine, and dexmedetomidine infusions may be used along with a long-acting nondepolarizing neuromuscular blocker. The use of high-dose narcotic (>50 mg/kg) as the primary anesthetic during the surgical repair for congenital heart disease has been well established (Quinonez et al., 2018). Fentanyl in combination with midazolam leads to a decrease in MABP and CO but an increase in heart rate and SVR. Midazolam alone decreases MABP, SVR, and CO but has minimal effect on pulmonary vascular resistance.

Dexmedetomidine is an a2- agonist with sedative properties; when used in combination with fentanyl, it minimally decreases heart rate and MABP, while potentiating the analgesic properties of fentanyl (Naguib et al., 2013). Ketamine, when administered alone, increases heart rate, MABP, SVR, and CO. Ketamine's effect on pulmonary vascular resistance has been debated.(Williams et al., 2007) Because of its interaction on N-methyl-d-aspartate receptors, ketamine provides analgesia, and though it acts as a bronchodilator, increased secretions and delirium are potential complications. When ketamine is combined with a sedative, such as midazolam or propofol, hemodynamic stability is maintained (Quinonez et al., 2018; Williams et al., 2007). Dexmedetomidine is a selective α2 agonist, maintains SVR and has minimal/no effect on PVR. It has also been reported for tet-spell management in a neonate. Wajekar *et al*.

(2015) have reported using dexmedetomidine infusion for frontoparietal abscess drainage in uncorrected TOF. In his report, it has been shown that Dexmedetomidine, a sedative with minimal respiratory depression, blunts the sympathetic response to intubation and reduces opioid and volatile agent requirement. An infusion of Dexmedetomidine at the lowest dose after omitting the loading dose to avoid the initial biphasic changes in haemodynamics. It reduces the myocardial oxygen consumption by decreasing the heart rate. Furthermore, use of large dose dexmedetomidine can reduce the SVR. resulting in a reversal of shunt flow. Addition of low dose dexmedetomidine to fentanyl reduces the stress response in paediatric patients (Wajekar et al., 2015). In a case series by Goyal, et.al., a combination of dexmedetomidine and ketamine provided excellent intraoperative haemodynamic stability and safe anaesthesia in uncorrected CCHD patients (Goyal et al., 2013). In their case series, it has been shown that dexmedetomidine decreases central nervous system sympathetic outflow in a dose-dependent manner, reduces the hyperdynamic responses (increased MAP and heart rate (HR)) mediated by the sympathetic nervous system and attenuates the cardiovascular and neuroendocrine response to surgery. The dose-dependent hypotension and bradycardia may limit the sole use for anesthesia or procedural sedation. The sympatho-inhibitory effects of dexmedetomidine are balanced with the cardio-stimulatory effects of ketamine, thereby maintaining a stable hemodynamic profile within normal physiological range, in cases with R-L shunt. There is no significant rise in PVR or fall in SVR with this drug combination. Both the drugs offer analgesia via different modes and their effects appear additive. They are also known to preserve dose dependent airway reflexes and spontaneous breathing, thus useful in short duration surgeries where controlled ventilation can be avoided. Although the first dosage of dexmedetomidine, there will be transient biphasic, dose-dependent cardiovascular responses, in which 1 μg/kg bolus dosage causes an initial rise in blood pressure and a reflex decrease in HR, thought to rise due to activation of the α-2b receptors in vascular smooth muscle, increase in blood pressure may be reduced using regular infusions while preventing medication bolus delivery (Elgendy et al., 2024).

Other uncommonly used intravenous anesthetics include etomidate and propofol. Etomidate is known for its hemodynamic stability during induction when used in children with congenital heart disease (Forman, 2011). However, its preparation in propylene glycol may lead to painful administration, as well as metabolic acidosis and toxicity if administered in continuous infusion. Additionally, a single dose can suppress cortisol levels for up to 24 hours. Propofol decreases MABP, heart rate, and SVR but has no effect on MPAP or pulmonary vascular resistance (Williams et al., 2007). Propofol exerts its sedative actions on the central nervous system at various neurotransmitter receptors, mainly gamma-aminobutyric acid A receptor (Tosh et al., 2020). We avoid continuous infusions of propofol because of the concern for metabolic acidosis and because its lipid formulation may interfere with the proper functioning of the cardiopulmonary bypass oxygenator (Arya et al., 2004; Fudickar et al., n.d.).

Mechanical ventilation strategies should aim to minimize increases in intrathoracic pressure, which can impede venous return and reduce cardiac output. Pressure-controlled ventilation with low tidal volumes and careful adjustment of respiratory rate helps achieve these goals. Anomalies in the pulmonary vasculature and previous cardiac interventions increase the risk of arrhythmias. Electrolyte imbalances should be corrected preoperatively, and antiarrhythmic drugs should be readily available. Patients with cyanotic congenital heart disease are at high risk for infective endocarditis.

Prophylactic antibiotics, such as ampicillin and gentamicin, should be administered before invasive procedures.

The primary challenges in this case were maintaining adequate oxygenation and hemodynamic stability. The use of ketamine for induction and dexmedetomidine for maintenance allowed for effective control of SVR without compromising myocardial function. Invasive blood pressure monitoring provided real-time hemodynamic data, enabling prompt interventions. Multidisciplinary planning and communication were critical to the successful outcome.

Conclusion

The intraoperative management of patients with pulmonary atresia and MAPCAs requires meticulous planning and an individualized approach. A thorough understanding of the unique physiology and hemodynamic implications is essential for optimizing outcomes. This case highlights the importance of multidisciplinary collaboration, vigilant monitoring, and the judicious selection of anesthetic agents in managing these high-risk patients. Future research should focus on refining perioperative strategies and improving long-term outcomes in this challenging population.

BIBLIOGRAPHY

Abuzaid, A., Elaal, I., Abdulaziz, A., & Abuzaid, R. (2020). Anesthetic management in tetralogy of fallot with pulmonary atresia and major aortopulmonary collateral arteries in pediatric patients: One year experience. *Saudi Journal of Anaesthesia*, *14*(2), 177–181. https://doi.org/10.4103/sja.SJA_725_19

Alahmadi, M. H., & Sharma, S. (n.d.). *Major Aortopulmonary Collateral Arteries Continuing Education Activity*. https://www.ncbi.nlm.nih.gov/books/NBK604462/

Arya, V. K., Kumar, A., & Thingnam, S. K. (2004). Propofol Infusion into the Pump during Cardiopulmonary Bypass: Is It Safe and Effective? [2]. In *Journal of Cardiothoracic and Vascular Anesthesia* (Vol. 18, Issue 1, pp. 122–123). W.B. Saunders. https://doi.org/10.1053/j.jvca.2003.10.029

Barron, D. J., & Botha, P. (2018). Approaches to Pulmonary Atresia With Major Aortopulmonary Collateral Arteries. In *Seminars in Thoracic and Cardiovascular Surgery: Pediatric Cardiac Surgery Annual* (Vol. 21, pp. 64–74). W.B. Saunders. https://doi.org/10.1053/j.pcsu.2017.11.001

Elgendy, M., El-Ashmawi, H., Said, A., Mortada, A., & Soliman, D. (2024). Multimodal Opioid-Free Anesthesia Versus Opioid-Based Anesthesia for Patients Undergoing Cardiac Valve Surgeries: A Randomized Controlled Trial. *Bali Journal of Anesthesiology*, *8*(1), 33–39. https://doi.org/10.4103/bjoa.bjoa_312_23

Forman, S. A. (2011). Clinical and molecular pharmacology of etomidate. In *Anesthesiology* (Vol. 114, Issue 3, pp. 695–707). Lippincott Williams and Wilkins. https://doi.org/10.1097/ALN.0b013e3181ff72b5

Fudickar, A., Bein, B., & Tonner, P. H. (n.d.). *Propofol infusion syndrome in anaesthesia and intensive care medicine*.

Goyal, R., Singh, S., Bangi, A., & Singh, S. K. (2013). Case series: Dexmedetomidine and ketamine for anesthesia in patients with uncorrected congenital cyanotic heart disease presenting for non-cardiac surgery. *Journal of Anaesthesiology Clinical Pharmacology*, *29*(4), 543–546. https://doi.org/10.4103/0970-9185.119142

Greeley, W. J., Laird, T. H., Stayer, S. A., Rivenes, S. M., Lewin, M. B., Dean McKenzie, E., Fraser, C. D., & Andropoulos, D. B. (n.d.). *Pediatric Anesthesia Society For Pediatric Anesthesia Section Editor Pulmonary-to-Systemic Blood Flow Ratio Effects*

of Sevoflurane, Isoflurane, Halothane, and Fentanyl/Midazolam with 100% Oxygen in Children with Congenital Heart Disease. https://doi.org/10.1213/01.ANE.0000034382.03188.CF

Hoang, L. X., Tuyen, L. K., Gia, T. M., Anh, N. T. K., Dan, D. V. B., Phuong, P. K., Tin, D. N., Hoa, T., & Duc, N. M. (2023). Large isolated major aortopulmonary collateral artery causing dilated left ventricle. *Radiology Case Reports*, *18*(4), 1530–1535. https://doi.org/10.1016/j.radcr.2023.01.063

Khawar Sana, M., & Ahmed, Z. (n.d.). *Pulmonary Atresia With Ventricular Septal Defect Continuing Education Activity*. https://www.ncbi.nlm.nih.gov/books/NBK562277/

Naguib, A. N., Tobias, J. D., Hall, M. W., Cismowski, M. J., Miao, Y., Barry, N., Preston, T., Galantowicz, M., & Hoffman, T. M. (2013). The role of different anesthetic techniques in altering the stress response during cardiac surgery in children: A prospective, double-blinded, and randomized study*. *Pediatric Critical Care Medicine*, *14*(5), 481–490. https://doi.org/10.1097/PCC.0b013e31828a742c

Presnell, L. B., Blankenship, A., Cheatham, S. L., Owens, G. E., & Staveski, S. L. (2015). An Overview of Pulmonary Atresia and Major Aortopulmonary Collateral Arteries. *World Journal for Pediatric and Congenital Heart Surgery*, *6*(4), 630–639. https://doi.org/10.1177/2150135115598559

Quinonez, Z. A., Downey, L., Abbasi, R. K., Kuan, C., Asija, R., McElhinney, D. B., Hanley, F. L., Mainwaring, R. D., & Wise-Faberowski, L. (2018). Anesthetic Management During Surgery for Tetralogy of Fallot With Pulmonary Atresia and Major Aortopulmonary Collateral Arteries. *World Journal for Pediatric and Congenital Heart Surgery*, *9*(2), 236–241. https://doi.org/10.1177/2150135118754522

Tosh, P., Rajan, S., Narayani, N., Babu, K., Kumar, N., & Paul, J. (2020). Comparison of efficacy and safety of dexmedetomidine versus propofol infusion for maintaining depth of general anesthesia when muscle relaxants are not used. *Bali Journal of Anesthesiology*, *4*(2), 42–45. https://doi.org/10.4103/BJOA.BJOA_6_20

Wajekar, A. S., Shetty, A. N., Oak, S. P., & Jain, R. A. (2015). Anaesthetic management for drainage of frontoparietal abscess in a patient of uncorrected tetralogy of fallot. In *Indian Journal of Anaesthesia* (Vol. 59, Issue 4, pp. 244–246). Indian Society of Anaesthetists. https://doi.org/10.4103/0019-5049.155003

Williams, G. D., Philip, B. M., Chu, L. F., Boltz, M. G., Kamra, K., Terwey, H., Hammer, G. B., Perry, S. B., Feinstein, J. A., & Ramamoorthy, C. (2007). Ketamine does not increase pulmonary vascular resistance in children with pulmonary hypertension undergoing sevoflurane anesthesia and spontaneous ventilation. *Anesthesia and Analgesia*, *105*(6), 1578–1584. https://doi.org/10.1213/01.ane.0000287656.29064.89

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