

CASE REPORT

Transforming Pediatric Thoracotomy: The Critical Role of Thoracic Paravertebral Block in Cyanotic Congenital Heart Disease

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ABSTRACT

Background: *Cyanotic Congenital Heart Disease* (CCHD) encompasses a range of cardiac anomalies that result in low oxygen levels in the blood. This case report explores the use of *Thoracic Paravertebral Block* (TPVB) as an effective anesthetic technique in a pediatric patient with multiple congenital heart defects.

Case Illustration : We report the case of a 46-day-old male pediatric patient diagnosed with CCHD, including pulmonary atresia and *Transposition of the Great Arteries* (TGA) with *Ventricular Septal Defect* (VSD) and *Atrial Septal Defect* (ASD). The patient had previously undergone a right Blalock-Taussig (R-BT) shunt and PDA stenting, during which he experienced *cardiac arrest* but achieved return of spontaneous circulation (ROSC). He was admitted for another operation, thoracotomy and decortication due to trapped pleural effusion and empyema. The intraoperative management included the use of TPVB, which provided effective analgesia and hemodynamic stability throughout the procedure.

Discussion: TPVB has been increasingly recognized as a valuable regional anesthetic technique in pediatric cardiac surgery. Its use can mitigate the hemodynamic fluctuations often seen with general anesthesia alone, especially in patients with compromised cardiovascular status. In this case, TPVB facilitated stable anesthesia, reduced the requirement for systemic opioids, and helped manage recurrent episodes of desaturation and bradycardia.

Conclusion: TPVB is a viable anesthetic option in pediatric patients with CCHD undergoing thoracic surgery. It offers substantial benefits in terms of hemodynamic stability and pain management, contributing to improved perioperative outcomes in this high-risk population.

Keywords: Anesthesia; Cyanotic congenital heart disease; Desaturation; Pediatric; Thoracic paravertebral block.

INTRODUCTION

Appropriate postoperative analgesia after thoracotomies is essential to improve patient outcomes, reduce complication rates, morbidity, hospital costs, and length of stay. Postoperative pain control is a major concern in the care of patients undergoing thoracic surgery, particularly when thoracotomy is required. The pain associated with thoracotomy can be severe, involving multiple nerves emanating from various sources in the chest wall.

The intercostal nerves are paramount in conducting pain stimuli arising from skin and muscle incisions, as well as from rib spreading. The vagus and phrenic nerves also conduct pain stimuli originating in the mediastinal and diaphragmatic pleura. In generating shoulder pain, there is no precise localization of pain pathways, although involvement of the brachial plexus has been theorized. Intercostal nerves are also important for the transition from acute to chronic pain, as they suffer from long-term extrinsic compression by surgical instruments and often become embedded in post-surgical scars. These insults often cause a

change in the pain from nociceptive to neurogenic and neuropathic^{1,2}.

Thoracic Paravertebral Block (TPVB) provides superior postoperative analgesia compared to intercostal nerve blocks, intrapleural analgesia, spinal analgesia with opiates, and intravenous (IV) opioid-based analgesia. Studies have shown that TPVB results in reduced postoperative pain and opioid requirements³. It should be noted that the best medical practice, resulting in the highest quality analgesia, aims to alleviate both surgical and non-surgical pain through a multimodal approach⁴.

In addition, other factors must be considered when comparing regional anesthesia techniques for thoracic surgery and the impact of thoracotomy and general anesthesia on postoperative pulmonary function. These include anesthesia-related factors (mechanical ventilation resulting in high airway pressures, alveolar collapse and recruitment, consequences of one-lung ventilation on right heart function and pulmonary vessels), surgical-related factors (handling of lung parenchyma, and chest wall muscle retraction and resection), pain-related factors

(abdominal muscle contraction, diaphragmatic block), and mixed etiology-related factors (fluid shift, lung stiffness, *cytokine* release)^{5, 6}. All of these factors exert a restrictive pattern on pulmonary function, decreasing vital capacity and functional residual capacity. The risk of pulmonary complications may be reduced by adequate analgesia, sufficient to allow pain-free deep breathing, coughing, and clearing of airway secretions⁷.

CASE ILLUSTRATION

The patient, a 46-day-old male with a history of *pulmonary atresia*, *ventricular septal defect* (VSD), and *lung atelectasis*, was referred from PKU Yogyakarta with a diagnosis of *pulmonary atresia*, VSD, and *patent foramen ovale* (PFO). He was delivered via cesarean section, cried immediately post-delivery, and had a history of repeated desaturation, requiring CPAP support with FiO₂ of 30% and PEEP of 7. *Bilateral bronchopneumonia* was diagnosed on May 17th. On May 24th, he experienced persistent jaundice with a total bilirubin of 12.23, treated with 48 hours of phototherapy. Due to persistent desaturation, he was referred to RS PKU Yogyakarta, where he was managed with oxygen and antibiotics.

An echocardiogram confirmed multiple cardiac defects, leading to a decision for PDA stenting. Following a failed first attempt, successful PDA stenting was performed on June 4th which he experienced *cardiac arrest* but achieved return of spontaneous circulation (ROSC). Subsequent imaging showed worsening pulmonary edema and pleural effusion, leading to the current thoracotomy.

Currently, the patient is receiving therapy with Paracetamol 43 mg every 6 hours, oral Aspilet 15 mg daily, intravenous Meropenem 115 mg every 8 hours (Day 22 of treatment), and intravenous Furosemide 2.5 mg every 6 hours.

Preoperative physical examination showed the patient in generally good condition, with rapid breathing and a heart rate of 144-150 bpm, regular. His respiratory rate was 50-72 breaths per minute with no grunting and minimal retraction. He was on non-invasive ventilation in SIMV mode with RR set at 40, FiO₂ 30%, PEEP 6, PIP 20, and Ti 0.4. His temperature ranged from 36.7 to 37.1°C, and his SpO₂ ranged from 40-80%, with daily averages of 60-80%. Examination of his head revealed no

cranial abnormalities, cyanosis, or nasal flaring. Heart examination showed a single S1, inconsistently split S2, and a pansystolic murmur. His lungs had symmetrical expansion with minimal retractions and no rhonchi or wheezes. The abdomen was soft with normal bowel sounds and no hepatomegaly. The extremities showed no edema, cyanosis, or clubbing, and capillary refill time was less than 2 seconds.

Preoperative laboratory examination showed the following results: hemoglobin/ hematocrit at 10.5/31.3, liver enzymes with ALT at 337 U/L and AST at 10.3 U/L, coagulation profile with PT at 10.5 seconds, APTT at 35.6 seconds, and INR at 0.95. Electrolytes were measured with sodium at 132 mmol/L, potassium at 4.3 mmol/L, and chloride at 87 mmol/L. Blood urea nitrogen/creatinine levels were 20/0.08 mg/dL, and albumin was 4.35 g/dL. A thoracic ultrasound revealed right pleural effusion with approximately 21.2 ml of fluid, and a chest X-ray showed *pulmonary edema* with *homogeneous opacity* in the right hemithorax suggestive of *trapped effusion*. The result of cardiac catheterization on June 4th, 2024, showed successful PDA stenting, with

the results is a totally blocked R-BT shunt, TGA, a vertical and tortuous PDA, and ASD. The preoperative screening examinations concluded that the patient had an ASA (American Society of Anesthesiologists) III physical status due to *Cyanotic Congenital Heart Disease (CCHD)*, *pulmonary atresia*, *transposition of the great arteries (TGA)* with *ventricular septal defect (VSD)*, *atrial septal defect (ASD)*, post-right *Blalock-Taussig (R-BT)* shunt (total obstruction of BT shunt), post *patent ductus arteriosus (PDA)* stenting, and *trapped pleural effusion* (Figure 1).

Obtaining approval for surgery was carried out with an explanation that the operation carried a high risk. It was also explained that anesthesia would be administered using general anesthesia techniques and a thoracic paravertebral block. After the operation, the patient would be treated in the intensive care unit (NICU) first. While in the operating room, monitoring tools were installed, including an ECG, NIBP, and SpO2. The intravenous line and urinary catheter had been placed beforehand. Before induction of anesthesia, blood pressure was monitored at 86/42 mmHg, heart rate at 140-150 bpm,

respiratory rate at 49 breaths per minute, and SpO₂ at 68%.

Induction of anesthesia was done by injecting Fentanyl 5 mcg IV, Atracurium 1 mg IV, and inhalation of Sevoflurane 2-2.5 vol%. Intubation was attempted twice. The first attempt resulted in bradycardia (HR dropped from 150 to 90 bpm) upon laryngoscope insertion, necessitating ventilation with bagging and administration of 0.1 mg atropine. The second intubation attempt revealed *laryngeal edema* but was successful with one attempt using ETT. Recurrent desaturation and bradycardia episodes occurred post-intubation, with the lowest SpO₂ at 9% and HR at 50 bpm, suspected due to *bronchospasm*. Administered norepinephrine via syringe pump and repeated boluses of atropine and epinephrine, resolving the issues. Total fluid administered during

this period was 100 cc. CVC was placed in the right jugular vein using ultrasound guidance, though it was challenging and took 90-120 minutes. Arterial line placement was unsuccessful despite assistance from the pediatric team, so blood pressure was monitored with NIBP. Thoracic paravertebral block was performed before the incision with USG guidance by placing a transverse scan with in-plane needle insertion and injecting Bupivacaine 0.5% 20 mg (4 cc). Thoracotomy and decortication were performed in the left lateral decubitus (LLD) position. Empyema in the right upper lobe was cleaned by the thoracic surgeon team. During this period, SpO₂ ranged from 80-100% with 1-2 episodes of desaturation and bradycardia, which were managed with atropine and epinephrine.



Figure 1: Intraoperative Monitoring

Post-operation, the patient was repositioned to supine and experienced desaturation and bradycardia again, managed with continuous administration of atropine and epinephrine. The anesthesia duration was 4.5 hours, and the surgery duration was 2.5 hours. Fluid in included 135 cc (100 cc crystalloids, 5 cc medications, 30 cc blood), and fluid out included 60 cc (30 cc blood, 20 cc REL, 10 cc urine). Blood component transfused was +75 cc, and urine output was 1.6 cc/kg/hour. The patient was transported to the NICU with ongoing epinephrine support. In the NICU, a brief desaturation episode was resolved with manual bagging, restoring SpO₂ to 80%. Postoperative status in NICU included the following observations: airway was maintained with an endotracheal tube (ETT) size 3.5 cuff at 10 cm, breathing was supported on ventilator mode PC-AC with P_{insp} 17, PEEP 5, FiO₂ 40%, and SpO₂ 86%. The patient had symmetrical chest movement, no rhonchi, and no wheezing. Circulation was stable with a heart rate of 142 bpm, regular heart sounds, no murmur, warm extremities, and capillary refill time less than 2

seconds. The patient was sedated and had a temperature of 36.9°C.

DISCUSSION

Cyanotic Congenital Heart Disease (CCHD) encompasses a diverse group of complex congenital cardiac anomalies that result in systemic arterial desaturation due to right-to-left shunting of blood.

These conditions, including pulmonary atresia, *transposition of the great arteries* (TGA), *ventricular septal defect* (VSD), and *atrial septal defect* (ASD), are associated with significant morbidity and mortality, particularly in the neonatal and infant population (Figure 2).

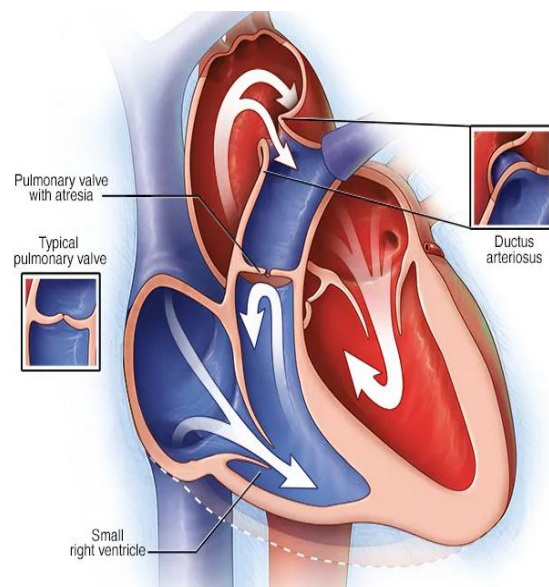


Figure 2: Atresia Pulmonary

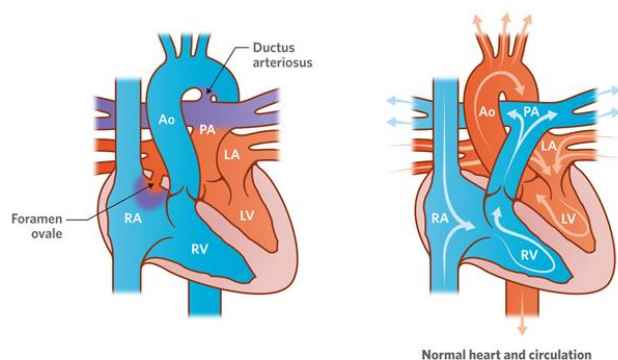


Figure 3: Normal Heart compared with Transposition of the Great Arteries (TGA)

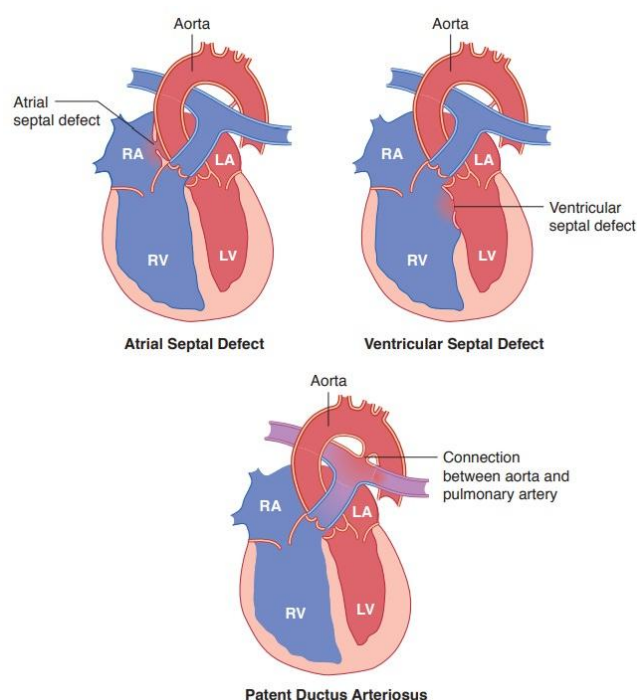


Figure 4: Cardiac anomalies ASD, VSD, PDA

Pulmonary atresia is characterized by the complete closure of the pulmonary valve, obstructing blood flow from the right ventricle to the pulmonary arteries. In TGA, the aorta and pulmonary artery are transposed, leading to parallel circulations that prevent effective oxygenation of blood (Figure 3). VSD

and ASD further complicate the hemodynamic scenario by allowing abnormal mixing of oxygenated and deoxygenated blood (Figure 4)^{1,2}. Management of CCHD often involves multiple surgical interventions, each posing unique anesthetic challenges due to the patients fragile cardiovascular status.

Thoracic Paravertebral Block (TPVB) has emerged as a valuable regional anesthesia technique in pediatric patients with CCHD undergoing thoracic and upper abdominal surgeries. TPVB involves the injection of local anesthetics adjacent to the vertebral bodies, resulting in unilateral blockade of the somatic and sympathetic nerves. This technique offers several advantages:

Hemodynamic Stability: TPVB provides superior hemodynamic stability compared to general anesthesia alone or systemic opioid administration. It reduces the need for high doses of systemic opioids and volatile anesthetics, minimizing hemodynamic fluctuations such as hypotension and bradycardia^{3, 4}. This stability is critical in CCHD patients, where maintaining optimal cardiac output and systemic oxygen delivery is paramount.

Reduced**Opioid**

Requirements: TPVB significantly reduces the need for systemic opioids, minimizing the risk of opioid-related side effects such as respiratory depression, nausea, vomiting, and ileus^{3,5}. This is particularly beneficial in neonates and infants with CCHD, who have limited respiratory reserve and are more susceptible to the adverse effects of opioids.

Enhanced Pain Control: TPVB provides effective and prolonged analgesia, covering multiple dermatomes and ensuring comprehensive pain control during and after surgery. This leads to improved patient comfort, reduced stress response, and potentially faster recovery times⁽⁶⁾. Effective pain control is crucial in pediatric patients to prevent the detrimental effects of untreated pain on the developing brain and cardiovascular system.

Improved Respiratory Function: By minimizing the use of systemic opioids and avoiding the respiratory depressant effects of general anesthetics, TPVB helps maintain better postoperative respiratory function⁷. This is especially important in patients with compromised respiratory status due to their

underlying cardiac condition and recent surgical interventions.

Lower Incidence of Postoperative Complications: Effective regional anesthesia with TPVB is associated with a lower incidence of postoperative complications such as atelectasis, pneumonia, and prolonged mechanical ventilation^{6,8}. These benefits are particularly relevant in the CCHD population, where the risk of pulmonary complications is inherently higher.

Feasibility and Safety: TPVB can be safely performed in neonates and infants using ultrasound guidance, enhancing the accuracy of the block and reducing the risk of complications. Ultrasound allows real-time visualization of the anatomical structures, ensuring precise placement of the local anesthetic and minimizing the risk of inadvertent injury to adjacent structures⁹.

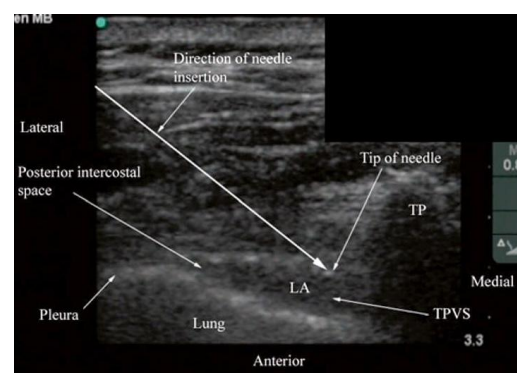


Figure 5: Transverse sonogram of the thoracic paravertebral space (TPVS) after local anesthetic injection

Comparison with Other Analgesic

Techniques: While several analgesic techniques are available for managing pain in pediatric patients undergoing thoracic surgery, TPVB offers unique advantages that make it a preferred choice, especially in high-risk populations such as those with CCHD (Figure 5). Epidural analgesia carries risks such as hypotension, motor blockade, and potential for epidural hematoma or abscess formation, making TPVB a safer alternative in CCHD patients⁵. Systemic opioids, although effective, have significant side effects, including respiratory depression, which can be detrimental in patients with compromised cardiopulmonary function. Intercostal nerve blocks require multiple injections to cover the desired dermatomes, increasing the risk of local anesthetic toxicity, while TPVB provides a more comprehensive and longer-lasting block with a single injection^{4, 8}.

In conclusion, TPVB stands out as a superior analgesic technique for pediatric patients with CCHD undergoing thoracic surgery. It offers significant benefits in terms of hemodynamic stability, effective pain control, reduced opioid requirements,

and improved respiratory function. The use of TPVB in this case highlights its potential to enhance perioperative outcomes and underscores the importance of incorporating advanced regional anesthesia techniques in the management of high-risk pediatric populations. Despite initial challenges with intubation and recurrent episodes of desaturation and bradycardia, the patient remained stable, and the procedure was completed without significant complications.

CONCLUSION

The use of *Thoracic Paravertebral Block* (TPVB) in this case provided effective pain management and hemodynamic stability during the thoracotomy and decortication procedure. Despite significant challenges with intubation, desaturation, and bradycardia, appropriate interventions and close monitoring ensured the patient's stability throughout the procedure. The use of TPVB in pediatric patients with *Cyanotic Congenital Heart Disease* (CCHD) undergoing thoracic surgery has proven to be a beneficial anesthetic technique. This case demonstrates that TPVB can provide effective analgesia and enhance hemodynamic stability,

contributing to improved perioperative outcomes in high-risk pediatric patients. Given its advantages, TPVB should be considered a valuable component of the anesthetic management strategy for similar complex cases,

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