Case Report

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SUCCESSFUL ONE-LUNG VENTILATION WITH FOGARTY BALLOON FOR THORACOTOMY LOBECTOMY IN A 5-YEAR-OLD GIRL

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ABSTRACT

Introduction: Pediatric thoracic surgery, particularly lung resection, has special difficulties due to anatomical and physiological differences compared to adults. One-lung ventilation (OLV) is often necessary to optimize surgical exposure while minimizing lung injury. Traditional methods, like double-lumen endotracheal tubes, can be difficult to use in children due to their smaller airways and the risk of trauma. Thus, alternative approaches, such as bronchial blockers like Fogarty occlusion catheters, have gained prominence.
Objective: This case report aims to highlight the use of the Fogarty balloon in a pediatric patient undergoing lobectomy for organized pleural effusion linked to pneumonia.
Case Report: A 5-year-old girl with recurrent pneumonia presented with persistent cough, intermittent fever, and respiratory distress. Physical examination revealed decreased breath sounds and mild cyanosis. Imaging confirmed a large organized pleural effusion, suspected to be empyema. The surgical team chose a right thoracotomy lobectomy to remove the affected lung tissue. Preoperative consultations included pediatric surgery, anesthesiology, and respiratory therapy to ensure comprehensive care. A multi-modal pain management strategy, emphasizing regional anesthesia through epidural blocks, was implemented. For OLV, the anesthetic team selected a Fogarty balloon catheter to minimize airway trauma. After intubating with a single-lumen endotracheal tube, the balloon was inserted into the right main bronchus and inflated to occlude it, allowing ventilation of the left lung.
Discussion: The Fogarty balloon effectively provided lung isolation while preserving airway integrity, facilitating optimal surgical exposure and stable oxygenation. Continuous monitoring of oxygenation during OLV was crucial for patient safety.
Conclusion: The use of a Fogarty balloon for bronchial blockade and epidural anesthesia was successful in this pediatric lobectomy case. These techniques enhanced surgical safety, efficacy, and postoperative recovery, suggesting that there must be ongoing research to establish standardized protocols for pediatric thoracic procedures.

Keywords: Bronchial Blocker; Fogarty Balloon; One-Lung Ventilation; Pediatric Medicine; Thoracic Surgery

ABSTRAK

Pendahuluan: Bedah toraks pediatrik, terutama yang melibatkan reseksi paru, menghadirkan tantangan unik karena perbedaan anatomi dan fisiologis dibandingkan dengan orang dewasa. Ventilasi satu paru (OLV) sering diperlukan untuk mengoptimalkan eksposur bedah sambil meminimalkan cedera paru. Teknik tradisional, seperti tabung endotrakeal ganda, dapat sulit diterapkan pada anak-anak karena saluran napas yang lebih kecil dan risiko trauma. Oleh karena itu, metode alternatif seperti penghalang bronkial, termasuk kateter oklusi Fogarty, semakin menarik perhatian.
Tujuan: Laporan kasus ini bertujuan untuk menyoroti penggunaan balon Fogarty pada pasien pediatrik yang menjalani lobektomi akibat efusi pleura terorganisasi yang berkaitan dengan pneumonia.
Laporan Kasus: Seorang gadis berusia 5 tahun dirawat karena riwayat pneumonia berulang, dengan gejala batuk persisten, demam intermiten, dan distress pernapasan. Pemeriksaan fisik menunjukkan suara napas yang menurun dan sianosis ringan. Pencitraan mengonfirmasi adanya efusi pleura besar terorganisir dengan kecurigaan empyema. Tim bedah memutuskan untuk melakukan lobektomi torakotomi kanan untuk mengangkat jaringan paru yang terkena. Konsultasi praoperatif melibatkan tim bedah pediatrik, anestesiologi, dan terapi pernapasan.
Diskusi: Penggunaan balon Fogarty sebagai penghalang bronkial terbukti efektif dalam memberikan isolasi paru sambil menjaga integritas saluran napas. Metode ini memungkinkan eksposur bedah yang optimal dan oksigenasi yang stabil. Pemantauan oksigenasi selama OLV sangat penting untuk memastikan keselamatan pasien.
Kesimpulan Integrasi balon Fogarty dan anestesi epidural dalam kasus ini menunjukkan keberhasilan dalam menangani lobektomi pada pasien pediatrik. Teknik inovatif ini tidak hanya meningkatkan keselamatan bedah tetapi juga memperbaiki pemulihan pascaoperasi. Penelitian lebih lanjut diperlukan untuk menstandarkan protokol isolasi paru dan manajemen nyeri pada bedah toraks pediatrik.

Kata Kunci: Penghalang Bronkial; Balon Fogarty; Ventilasi Satu Paru; Ilmu Kedokteran Anak; Bedah Toraks

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INTRODUCTION

Pediatric thoracic surgery, particularly procedures involving lung resection, poses special difficulties due to anatomical and physiological differences compared to adult patients. One-lung ventilation (OLV) is commonly necessary during these procedures to optimize surgical exposure and minimize lung injury (1). Traditional techniques, including the use of double-lumen endotracheal tubes, can be difficult to implement in children due to their smaller airways and the potential for airway trauma (2). Consequently, alternative methods, such as the use of bronchial blockers, including Fogarty occlusion catheters, have gained attention (1–3). This report examines the successful utilization of a Fogarty balloon as a bronchial blocker in a 5-year-old girl undergoing lobectomy due to organized pleural effusion associated with pneumonia.

CASE REPORT

A five-year-old girl was referred to our facility with a history of repeated episodes of pneumonia. Her symptoms included persistent cough, intermittent fever, and noticeable respiratory distress. Mild cyanosis, tachypnea, and diminished right-sided breath sounds were detected by auscultation. Initial imaging studies, including a chest X-ray, revealed a significant accumulation of fluid in the right-sided pleural cavity. Subsequent chest ultrasound and CT imaging confirmed the presence of an organized pleural effusion, with suspicion of empyema and a localized lesion in the right lower lobe.

The patient’s medical history included a previous hospitalization for pneumonia six months prior, during which she was treated with antibiotics. She was fully immunized for her age and had no known drug allergies. Laboratory tests revealed moderate anemia, likely secondary to chronic disease or recurrent infections, but the patient maintained a satisfactory nutritional status and was otherwise healthy.

Preoperative Evaluation

Preoperative assessments included a thorough evaluation of the patient’s respiratory status and nutritional condition. Pulmonary function tests were performed to evaluate her baseline lung capacity, although their interpretation was limited by her age. The patient was also seen by a pediatric nutritionist to ensure optimal nutritional support leading up to the surgery.

Informed consent was obtained from the guardians after thoroughly discussing the surgical procedure, potential complications, and the anesthetic plan. The anesthetic approach focused on minimizing perioperative stress and pain, particularly given the patient's age and underlying respiratory condition.

Anesthetic Management

The anesthetic team planned a multi-modal approach for pain management, emphasizing the importance of regional anesthesia. The choice of epidural anesthesia was made to provide effective analgesia throughout the surgical procedure and postoperative recovery.

One-Lung Ventilation Strategy

For OLV, a Fogarty balloon catheter was selected as the bronchial blocker. This decision was based on the catheter's ability to provide effective lung isolation while minimizing the risk of airway trauma, particularly in small pediatric patients. The Fogarty balloon, TufTex® Embolectomy Catheter size 4Fr, was prepared for insertion, ensuring that it was compatible with the size of the patient’s airway.

The approach involved introducing the Fogarty balloon into the right main bronchus following the insertion of a single-lumen endotracheal tube. First, a 4.5-cuffed endotracheal tube was inserted and auscultation was performed to ensure and measure the depth when both lungs were symmetrically ventilated. After the initial insertion of the endotracheal tube, it was advanced further to confirm that ventilation was more effective in the right lung than in the left.

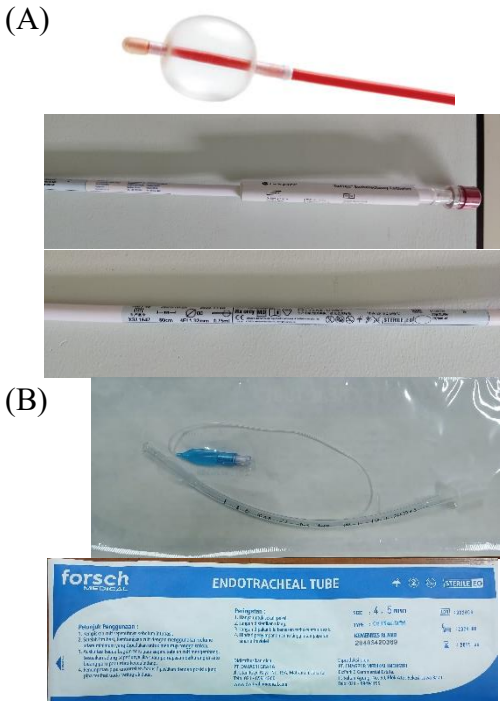

Figure 1. (A) Fogarty balloon TufTex® Embolectomy Catheter size 4Fr, length 80 cm, balloon volume 0.75 ml, Inflated Balloon Diameter 10.5 mm, Deflated Balloon Diameter 1.32 mm; (B) Endotracheal tube Forsch Medical size 4.5 cuffed, diameter 6.0 mm

Figure 2. Bronchial block procedure in a patient. (A) Intubation using Endotracheal tube; (B) Forgaty catheter placement using three-way stopcock; (C) Forgaty catheter placement using mountpiece

This step was vital for establishing proper one-lung ventilation by ensuring that the Fogarty balloon catheter was established in the main right bronchus to facilitate lung isolation. The endotracheal tube was then retracted to its initial measured depth while ensuring that the position of the Fogarty balloon catheter remained stable. To verify successful isolation of the right lung, auscultation was performed both before and after inflating the Fogarty balloon.

Epidural Anesthesia Technique

An epidural puncture was performed at the L2-L3 interspace using a sterile technique. The anesthesiologist carefully advanced the epidural catheter until T9-T10. 0.25% bupivacaine with a total volume of 12 mL was given, with careful monitoring for any signs of intravascular or intrathecal placement. After confirming the efficacy of the epidural, a continuous infusion of 0.1% bupivacaine was planned postoperatively at a rate of 12 mL every 12 hours.

Surgical Procedure

The patient was transported to the operating room and carefully monitored. Standard monitoring devices, including electrocardiogram (ECG), pulse oximetry, and non-invasive blood pressure monitoring, were established.

Once the patient was adequately anesthetized, the single-lumen endotracheal tube was placed. After intubation, the Fogarty balloon was gently inserted into the right main bronchus using direct visualization with a flexible bronchoscope. The balloon was inflated to achieve lung isolation.

The right lateral thoracotomy was then initiated. The surgical team carefully assessed the thoracic cavity, taking care to minimize trauma to surrounding structures. The procedure involved resection of the affected lung tissue and drainage of the pleural effusion, which was found to be purulent. The operation lasted approximately 90 minutes, during which the patient's vital signs remained stable, and oxygen saturation levels consistently exceeded 95%.

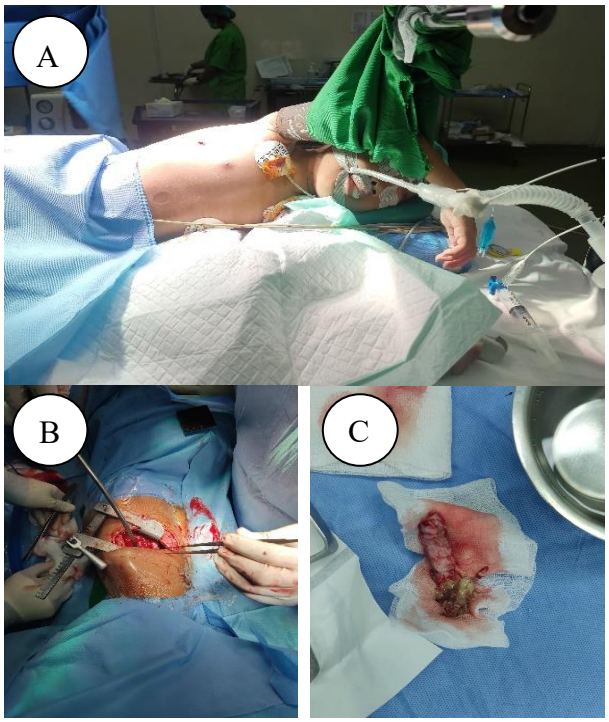

Figure 3. Positioning for the procedure patient. (A) Left Lateral Decubitus (B) One lung ventilation with the collapsed right lung (C) Successful lobectomy

Once the lobectomy was completed, the Fogarty balloon was deflated and withdrawn. The thoracic cavity was thoroughly irrigated and inspected for bleeding before closure.

Postoperative Care

Upon completion of the procedure, the patient was shifted to the post-anesthesia care unit (PACU) for monitoring. Extubation was performed four hours postoperatively, following careful assessment of her respiratory function and overall stability. Continuous monitoring of vital signs and oxygen saturation was maintained throughout her recovery.

The epidural catheter was connected to the infusion pump for continuous delivery of 0.1% bupivacaine at a rate of 12 mL every 12 hours. This approach effectively managed postoperative pain and minimized the need for systemic opioids, which could complicate recovery.

Postoperative recovery was uneventful. The patient was observed for signs of respiratory distress, infection, or complications related to the surgical procedure. By postoperative day two, she was transitioned to oral analgesics and demonstrated good pain control, allowing for early mobilization.

DISCUSSION

The management of pediatric thoracic surgery demands a customized method that takes into account the distinct physiological and anatomical features of children. Issues related to managing the airway in newborns are significant contributors to morbidity, as they can lead to oxygen desaturation and hypoxia. Pediatric groups possess unique physiological characteristics, including higher oxygen consumption and limited oxygen reserves, making them less tolerant of episodes of apnea (4). Selecting the appropriate size of the airway device for pediatric patients undergoing general anesthesia can be a challenging and meticulous process. Multiple attempts at intubation may result in airway swelling or injury, potentially leading to serious complications (5). In this case, the integration of a Fogarty balloon for OLV and the use of epidural anesthesia for pain management proved to be successful strategies that enhanced the patient's surgical experience and recovery.

OLV Techniques

OLV is crucial during thoracic surgeries, especially when clear visualization and exposure to the surgical site are crucial. The Fogarty balloon catheter as an airway occluder provides several advantages in pediatric patients. Unlike traditional double-lumen tubes, the Fogarty balloon offers effective lung isolation with a lower risk of trauma to the airway, which is particularly important given the smaller size and delicate nature of pediatric airways.

The Fogarty occlusion embolectomy catheter, developed by Dr. Thomas J. Fogarty by the end of 1940s, was primarily intended for vascular applications. Nonetheless, numerous cases have documented the efficient use of the Fogarty catheter to occlude the bronchus. In 1969, Vale and Lines both noted the use of the Fogarty catheter to

control ventilation in the lung being surgically treated. It serves as an effective bronchial occluder for both adults and children (2).

An optimal bronchial occluder should have a small volume balloon, secured in the bronchus, be adaptable, and feature a route for air release and drainage located beyond the blocker (6). The Fogarty catheters offer effective lung isolation and shield the dependent lung from contamination from the non-dependent lung. However, they have considerable drawbacks. When the Fogarty catheter is in place with the balloon inflated, suctioning of the operated lung is not feasible. While frequent suctioning and ventilation of the lung, require releasing the air from the balloon, potentially leading to contaminant exposure of the dependent lung. Additionally, lung collapse after isolation is often partial and usually results from the absorption atelectasis of the blocked lung. The balloon at the tip of the Fogarty catheter is built for high pressure, and excessive air inflation carries the risk of bronchial rupture. The reported bronchial blocker malpositioning rate ranges between 7 and 33% (7).

In this case, the technique was executed smoothly, with the Fogarty balloon allowing for optimal surgical exposure while maintaining sufficient airflow of the left lungs. The ability to inflate and deflate the balloon as needed provided flexibility during the procedure, enabling the surgical team to manage the airway effectively. A previous case report by the same anesthesiologist had shown the successful single lung ventilation using a fogarty catheter as the endobronchial occluder (8).

Various methods have been outlined for the extraluminal positioning of Fogarty catheters (1). Three methods for inserting a Fogarty catheter include extraluminal, intraluminal, and the slip joint section techniques [Figure 4].

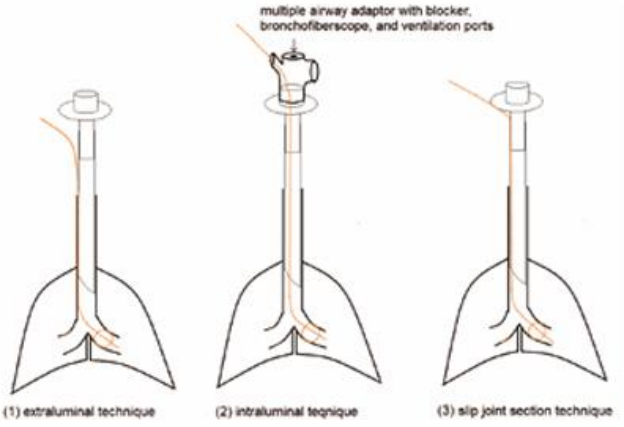

Figure 4. Three methods for inserting a Fogarty catheter (1)

Table 1. Average Balloon Size of Fogarty Catheters (9)

Age Category (yrs)	Average Balloon Caliber After Rapid Inflation (mm)	Smallest Internal Bronchial Caliber (mm)	Ratio of Balloon Caliber After Rapid Inflation to Smallest Bronchial Caliber (%)	Average Internal Bronchial Caliber (mm)	Ratio of Balloon Caliber After Rapid Inflation to Average Internal Bronchial Caliber (%)	Size of Fogarty (F)
1-2	5.4	3.5	152.9	4.2	127.4	3
2-4	8.0	4.0	199.0	5.6	142.1	5
4-6	8.0	3.6	221.1	5.4	147.4	5
6-8	8.0	4.6	173.0	6.7	118.8	5
8-10	8.0	5.7	139.6	7.3	109.0	5
10-12	8.0	6.4	124.4	7.8	102.1	5
12-14	8.7	7.2	120.7	8.9	97.6	7
14-16	8.7	9.2	94.5	10.0	86.9	7

In the extraluminal approach, a Fogarty catheter is introduced into the trachea before intubating, with the endotracheal tube then being placed afterward through its side. The intraluminal technique requires the insertion of the Fogarty catheter into the trachea via a multi-airway adapter equipped with dedicated ports for both the catheter and fiberscope. The adapter cannot be detached while the Fogarty catheter is being utilized. In the slip-joint technique, the catheter is introduced into the trachea through the slip-joint connection after intubation. This procedure necessitates a multi-

airway adapter equipped with a fiberscope port. Once the Fogarty catheter is correctly placed and adjusted, the adapter can then be removed.

Providing oxygen to an anesthetized patient undergoing one-lung ventilation is a complicated process that relies on factors such as hemoglobin levels, oxygen saturation, and cardiac output. It is essential for oxygen delivery to surpass oxygen consumption to prevent cellular hypoxia. Decreases in oxygen transport have a multiplicative effect rather than an additive one, and desaturation caused by anemia or reduced cardiac output can lead to harmful consequences during the intraoperative period. Intraoperatively, it is often the peripheral oxygen saturation component that garners the most attention (10).

Extrapolating data from outside of the operating room, it seems plausible that mild transient (85–90%) hypoxemia would be well tolerated when coexisting with adequate cardiac output and hemoglobin.

Mechanical ventilation strategy during OLV should be adjusted to deal with two different challenges: oxygenation and lung protection. In some cases, application of positive end-expiratory pressure (PEEP) during OLV increases functional residual capacity, improves the V/Q relationship in the dependent lung, and prevents alveolar collapse at end-expiration (11). High FiO2 (1.0) should be avoided unless necessary. "Protective ventilation" has three intraoperative components: low tidal volume, recruitment maneuvers, and positive end-expiratory pressure. The combined use of these 3 components can avoid both hypoxemia and acute lung injury.

During OLV, an unavoidable intrapulmonary shunt can lead to hypoxemia due to the collapse of the non-dependent lung and the expansion of atelectatic regions in the dependent lung. This hypoxemic condition triggers hypoxic pulmonary vasoconstriction, causing the vascular smooth muscle in the pulmonary circulation to contract in response to reduced local partial pressure of alveolar oxygen. As a result, this method minimizes shunting by diverting blood flow to the well-oxygenated dependent lung (12). The occurrence of hypoxemia during one-lung ventilation (OLV) has decreased to below 4%, largely due to the use of flexible fiberoptic bronchoscopy, which ensures precise positioning for effective lung isolation. During one-lung ventilation, the non-operative lung receives approximately 60% of pulmonary blood flow, resulting in greater perfusion, while the operative lung accounts for the remaining 40%.

Wesley et al. found that hypoxemia and severe hypoxemia were frequently observed in pediatric patients undergoing this procedure. Additionally, the use of a bronchial occluder in surgeries requiring single lung ventilation was associated with a decreased risk of oxygen deprivation (13).

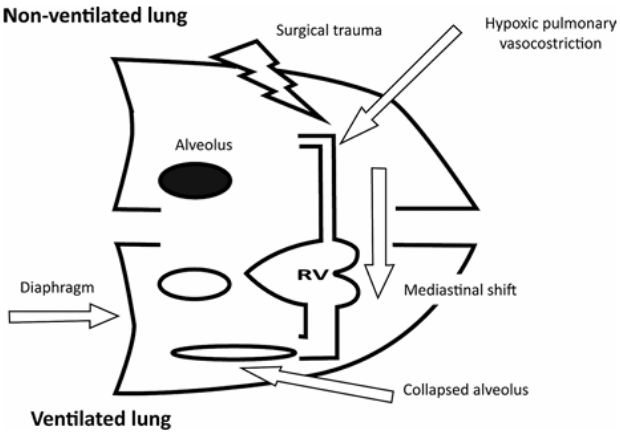

Figure 5. Factors involved in hypoxia during one lung ventilation and compensatory mechanism (14)

Epidural Anesthesia in Pediatric Surgery

Epidural anesthesia has become an increasingly popular choice for managing postoperative pain in pediatric patients. It provides localized analgesia, reducing the reliance on systemic opioids and their related adverse effects, including respiratory suppression and gastrointestinal issues. The successful implementation of continuous epidural infusion in this case contributed to effective pain control and facilitated early recovery.

The multi-modal approach to pain management, which included both regional anesthesia and oral analgesics, exemplifies best

practices in pediatric anesthetic management. This strategy not only improves patient comfort but also enhances overall surgical outcomes by promoting early mobilization and reducing complications.

Monitoring and Management of Hypoxemia

Hypoxemia remains a significant concern during OLV, particularly in young children. Continuous monitoring of oxygenation is critical to ensuring patient safety throughout the procedure. In this case, the careful management of ventilation and oxygenation, facilitated by the use of the Fogarty balloon, contributed to stable oxygen saturation levels during surgery.

The importance of proactive monitoring and intervention during OLV cannot be overstated, as hypoxemia can have serious consequences, including cardiac complications and prolonged recovery times. Future research and clinical protocols should continue to explore effective strategies for managing oxygenation during single lung ventilation, particularly in children.

This case report has several limitations. First, the selection of the Fogarty balloon catheter is still not based on objective measurements using imaging modalities, which poses a risk of size mismatch either the balloon being too small or too large. The author recommends measuring the internal bronchial diameter and comparing it to the diameter of the inflated Fogarty balloon catheter to ensure proper sizing. This approach may help minimize the risk of bronchial wall ischemia due to excessive pressure from an oversized balloon, as well as the risk of bronchial block leakage caused by an undersized balloon. Second, as previously mentioned, the use of a Fogarty balloon catheter does not allow for suctioning of the ipsilateral lung, thus posing a risk of contamination to the other branch of the bronchus, even to the contralateral lung when the balloon is deflated. Although no complications related to suspected contamination from the contralateral lung were observed in this patient, this potential risk must remain a main consideration, particularly for anesthesiology professionals intending to use bronchial blockade techniques with a Fogarty balloon catheter. Third, thoracic epidural catheter insertion in this patient was still performed using a conventional technique based on estimated vertebral corpus height without objective confirmation via ultrasound, which might have more accurately determined the catheter tip position and potentially estimated the required local anesthetic volume used.

CONCLUSION

This case illustrates the effective use of a Fogarty balloon bronchial occluder and epidural anesthesia in a 5-year-old girl undergoing lobectomy for organized pleural effusion. The integration of these innovative techniques not only enhanced surgical safety and efficacy but also improved postoperative recovery.

As pediatric thoracic surgery evolves, it is crucial to continuously study and establish comprehensive, standardized protocols for lung isolation and pain management. By integrating these innovations, medical professionals can enhance not only treatment results but also the overall care for pediatric patients undergoing thoracic surgeries.

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Conflict of Interest

The authors declare that there is no potential conflict of interest in this case report.

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Patient Consent for Publication

Written informed consent was obtained from the patient's parent or legal guardian for the

publication of this case report and accompanying images.

Author's Contributions

All authors contributed significantly to the preparation of this case report.

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