# When to abandon single-lung anesthesia during video-assisted thoracoscopic surgery (VATS) in infants and young children: A case-based review

**ABSTRACT**

Video-assisted thoracoscopic surgery (VATS) in infants and young children increasingly require one-lung anesthesia. However, the maintenance of norms of gas exchange is difficult during one-lung anesthesia in some infants. A combination of factors including added dead space of HME and the circle Y piece, intrathoracic inflation of $CO_2$ and its pressure, airway resistance and bilateral lung disease contribute. Seeping blood from the operating lung soiling the endobronchial tube causes airway narrowing and obstruction adding to this difficulty especially during prolonged thoracoscopy. We report two cases: hypoxemia in one and hypercapnia in the other. Guidance on safe limits of permissive hypoxemia or hypercarbia in this scenario is vague. Therefore, irreversible hypoxemia and hypercarbia with changes in acid–base status should be considered as indications for swift conversion to open thoracotomy and abandon one-lung ventilation.

**Key words:** Anesthesia; risk-benefit; one-lung ventilation; utility; video-assisted thoracoscopic surgery

## Introduction

Congenital pulmonary airway malformation (CPAM) is a rare deformity usually diagnosed antenatally by ultrasound. Urgent operative therapy may be required in a small number of neonates with respiratory difficulty,[1] preferably by open thoracotomy. A majority of infants, however, remain asymptomatic and are conservatively managed although some centers are geared to offer surgical excision electively in infancy.[2] The thoracoscopic approach is increasingly favored for CPAM resections because of the advantages of smaller incisions in a region associated with a high incidence of chronic pain and improved cosmetic appearance compared with thoracotomy. For this, one-lung ventilation is preferred unless precluded by surgical difficulties.[3] The purpose of this report is to illustrate when an anesthetist should avoid or abandon single-lung ventilation for anesthesia reasons and request surgeons consider open thoracotomy. Two cases selected from among 74 cases reviewed with ethical approval from the UK Health Research Authority (18/NW/0294) are described in detail here to illustrate this point.

## Case 1

A 12-kg-weighted girl, aged 2.6 years, was admitted for her third video-assisted thoracoscopic surgery (VATS)

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intervention, a left lower lobectomy. She had bilateral cystic lung anomalies on antenatal scanning and was born at 32 weeks by emergency caesarean section and required mechanical ventilation for 24 h and CPAP for 6 days following birth. She had one episode of croup and bronchiolitis during her infancy but thrived normally. Since her follow-up chest CT scan demonstrated large bilateral cavitating lesions, she underwent wedge resection of the left lower lobe at the age of 1.6 years and a right lower lobectomy at the age of 2.1 years, both thoracoscopically. On both occasions, she was extubated on the same day and recovered without complication. Histology confirmed a CPAM type-2 lesion.

The third thoracoscopic intervention was for a left lower lobectomy. On this occasion, she had an intravenous induction with propofol (2 mg/kg) and fentanyl (3 mcg/kg) followed by atracurium 0.6 mg/kg along with right bronchial intubation using a 4.0-mm-cuffed endotracheal tube and was in the right lateral position. Oxygen, air, and sevoflurane were used for maintenance. She was transfused to maintain hemoglobin above 110 g/L during the procedure.

In the right lateral position, initially, her vital parameters were maintained satisfactorily, but oxygenation became increasingly difficult 3 h into surgery. Her $SpO_2$ lowered to 85% but recovered to 88–90% with 70–80% $FiO_2$ and lung recruitment maneuvers. Her arterial serum lactate remained 1.3–1.4 mmol/l, with the lowest $PaO_2$ recorded 9.1 kPa. Since the surgery was complicated by extensive post-inflammatory changes, an open thoracotomy was performed at 7 h. by surgeons. One-lung ventilation (OLV) was also abandoned concurrently preventing the right lung contamination by bronchial suction. Her $SpO_2$ improved to 92–95% with the reinstatement of bilateral lung ventilation. Following a 12-h operation, she was extubated on the same day but developed subcutaneous emphysema that resolved spontaneously. Her $SpO_2$ on room air was 96% at discharge 5 days later.

## Case 2

A 9-month-old boy of 7 kg developing normally with an antenatally diagnosed right-sided CPAM was admitted for elective VATS. He was born at 38 weeks and had an episode of bronchiolitis at the age of 3 months. He was operated on because of the enlarging multi-cystic mass in right lower lobe with thoracic scoliosis.

He was induced with $O_2$ and sevoflurane and intubated with fentanyl 2 mcg/kg and atracurium 0.6 mg/kg. Surgery was commenced after positioning left lateral with left bronchial intubation using a 3.0-mm-cuffed tube and single-lung

ventilation. A thoracoscopic right lower lobectomy was performed and recovered with no complications. The surgical duration was prolonged (7 h) and hypercapnia became an increasing problem during the latter part (at 4.5 h) with significant respiratory acidosis. The endotracheal tube had bloodstained secretions and was blocked, which needed washout with saline to clear the obstruction. The peak $PaCO_2$ recorded was 16.1 kPa with an associated arterial pH of 6.93. His post-operative $SpO_2$ was 99% on room air on day 2 and he made an uneventful recovery.

## Discussion

VATS has become popular in pediatric surgery, including in infants, assisted by advances in both anesthetic and surgical equipment and OLV.[2] Our cases illustrate that hypoxemia and hypercarbia can be independent and extreme during OLV in thoracic surgery, and its etiologies are not always reversible.

OLV is indicated when the non diseased lung must be protected from contralateral lung pathology, such as hemorrhage, infection, or spillage of tumor cells and during VATS.[4] The simplest way of providing OLV in children is to intentionally intubate the ipsilateral mainstem bronchus with a conventional endotracheal tube using standard maneuvers.[5]

Hypoxemia during thoracic surgery (case 1), often results from increased ventilation/perfusion (V/Q) mismatch. General anesthesia, neuromuscular blockade, positioning and reduced functional residual capacity contribute. The collapse of the operated lung due to surgical retraction as well as $CO_2$ insufflation during OLV and atelectasis and compression of the dependent lung in the lateral decubitus position are other causes.

The overall effect of the lateral decubitus position on V/Q mismatch, however, is different in infants compared with older children and adults. This is because V/Q is largely well-matched due to non-symmetric branching of the pulmonary vascular and bronchial trees which occurs side-by-side. Although the gravitational model of V/Q matching has been widely accepted it is thought to explain only about 25% of the total effect.

In adult unilateral lung disease, oxygenation is optimal when the patient is placed in the lateral decubitus position with the healthy lung dependent. This improves V/Q mismatch by better perfusion of the dependent lung. In contrast, in infants with unilateral disease, oxygenation is improved with healthy lung nondependent. This is possible because of the easily

compressible rib cage may not fully support the underlying lung leading to infant's functional residual capacity be closer to residual volume. This makes airway closure more likely in the dependent lung even during normal tidal breathing. Therefore, in infants, a favorable increase in perfusion to the dependent, ventilated lung is achievable only when the non-dependent lung is collapsed. Thus, a non-collapsed lung (due to fibrosis, etc.) in bilateral lung disease as we saw in case 1, prevents improvement of V/Q match to the dependent lung leading to significant desaturation. This is because a significant proportion of pulmonary blood flow will still pass through the non-collapsed, non-ventilated, operated lung.

Another complication of OLV includes failure to provide an adequate seal of the tube in the bronchus. This prevents the operated lung from adequately collapsing whilst failing to protect the healthy, ventilated lung from contamination by blood and other material. Furthermore, hypoxemia may also ensue because of the obstruction of the right upper lobe bronchus, especially when the intubated right mainstem bronchus is short.

The anesthetic management of OLV in infants and young children is more challenging than in older children due to their smaller size and reduced capacity. When in difficulty, as was in our case 1, prevention of hypoxia is paramount. It is important to mitigate tissue hypoxia by ensuring adequate oxygen delivery through the maintenance of an adequate cardiac output and hemoglobin concentration.[6] Hence, the lower threshold for transfusion to maintain Hb above 110–120 g/L especially during OLV. However, a concern here is oxygen delivering capacity of the transfused blood may be sub-optimal compared to native red cells. Some centers may tolerate a $SpO_2$ of 90% and would not specifically abandon OLV anesthesia within the context of stable compensatory mechanisms such as suitable mean arterial pressure and adequate Hb concentration. In case 1, the Hb was maintained at 110–120 g/L to ensure hypoxia is avoided despite hypoxemia.

Seeping blood from the operated lung to the dependent lung during prolonged surgery may contaminate the endotracheal tube and coat its internal lining adding to the airway resistance especially in smaller tubes such as the 3.0 mm used in case 2 [Figure 1]. The ensued partial airway 'obstruction' was the most likely reason for the exceptional hypercarbia in our case 2. We were unable to washout this coating fully. The only rectifying option in this scenario was to abandon VATS and OLV. Changing the ET tube if there was no improvement was the next prudent step. Since smaller
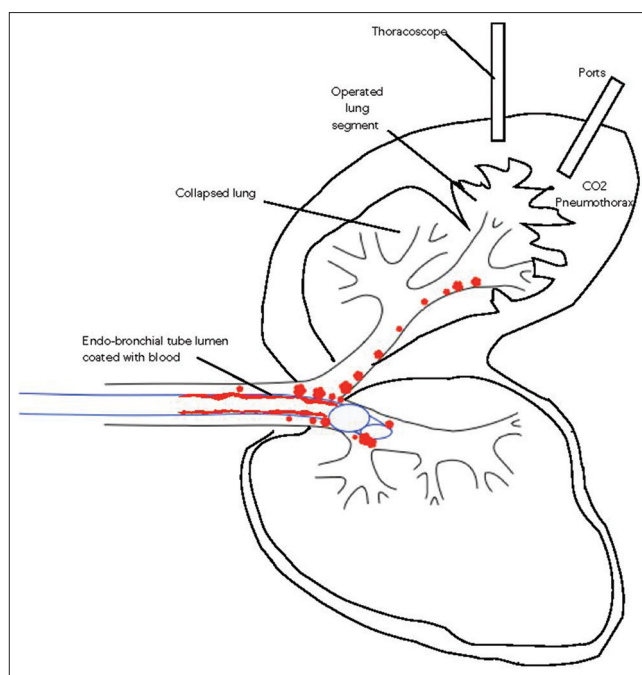


**Figure 1: A diagrammatic illustration of narrowed endobronchial tube lumen from seeping blood during VATS**

bronchial tubes are more likely to encounter these problems, OLV in young infants seems sensible.[7]

Added dead space of HME and the circle Y piece, intrathoracic inflation of $CO_2$ and its pressure may add to poor $CO_2$ elimination. Reducing dead space by alteration of the circuit by moving HME to the machine end and disposing of the whole circuit at the end is one option, but this may jeopardize the maintenance of humidity of inhaled gases.

Our challenge is to define the acceptable limits of hypoxemia and hypercarbia, concerning its degree and duration in this scenario of OLV in infants and very young children undergoing thoracic surgery. There are no specific guidelines, and the thresholds used in practice are subject to variation between centers.[8] Therefore, in an unfortunate event of a serious adverse event (e.g., cerebral ischemia/bleed), in retrospect, anesthetic liability is a risk if accepted 'norms' were used in argument against our practice.

Currently, permissive hypercapnia in critical care is limited to $PaCO_2$ of 9 and 8 kPa in adults and neonates, capped by an acceptable lowest pH of 7.2 and 7.25, respectively.[9,10] This is because of the potentially detrimental effects of hypercapnia has on the immune system, brain, lung, heart, liver, and kidney.[10]

Approximately 15% need conversion from VATS to open thoracotomy due to surgical reasons in children.[3]

Non-rectifiable hypoxemia and exceptional hypercarbia should be added to this list. How to prepare and when to allow OLV for VATS in children has no clear guidance. We hope this paper will contribute to the continuing discussions defining case 'filtering' strategies to avoid unnecessary risk.

During prolonged VATS surgery, the lung protection strategies should take priority whilst maintaining good oxygen delivery to tissues. In extreme situations of non-rectifiable poor gas exchange with changes in acid–base status, promote open thoracotomy and abandon OLV for safety reasons.

### Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form, the legal guardian has given his consent for images and other clinical information to be reported in the journal. The guardian understands that names and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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