Asynchronous independent intermittent positive pressure ventilation (IPPV) as a solution to refractory hypoxemia during chest surgery

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Introduction:

Improving surgical exposure during thoracic operations in the lateral decubitus position is one of the indications for one lung ventilation (OLV).\textsuperscript{1} OLV provides satisfactory oxygenation in the majority of patients. However, hypoxemia may develop secondary to the obligatory right to left transpulmonary shunt through the nonventilated, nondependent lung.\textsuperscript{2-3} PEEP and nitric oxide (NO) application to the dependent lung have been used to improve oxygenation during OLV. CPAP, high frequency jet ventilation (HFJV), intermittent manual inflations and partial ventilation to the non dependent lung were used for the same objective.\textsuperscript{4-5} We report a case of severe hypoxemia related to OLV during anterior thoracic spine fusion that resolved only with the use of differential intermittent positive pressure ventilation (IPPV).
**Case report:**
A 63-year-old male was diagnosed as suffering from T5-T6 vertebrae osteomyelitis and paravertebral abscess. His past medical history included chronic renal failure, non-insulin dependent diabetes mellitus, hypertension, hypothyroidism, and epilepsy. The patient underwent an uneventful emergent abscess drainage and posterior spine fusion in the prone position. On the third post operative day the patient required a second emergent operation due to worsening of paraparesis. Anterior thoracic spine fusion via right thoracotomy was indicated. Blood tests were significant for abnormal renal function tests. Chest X-Ray prior to surgery showed atelectasis of the left lower lobe (Fig. 1). Anesthesia was induced with midazolam, etomidate and fentanyl intravenously. Vecuronium bromide was administered to facilitate tracheal intubation. The trachea was intubated with a 41F left sided double lumen tube (Broncho-cath™, Mallinckrodt Medical, Ireland). Tube positioning was confirmed by auscultation and fiberoptic bronchoscopy in the supine as well as the left lateral decubitus position. Patient monitoring included (in addition to standard monitoring) radial artery catheter for invasive blood pressure measurement, and a left internal jugular vein catheter. Anesthesia was maintained with isoflurane and 50% nitrous oxide in oxygen supplemented by intermittent boluses of fentanyl and vecuronium. The lungs were ventilated with a tidal volume of 10 ml/kg; respiratory rate was adjusted to maintain normoventilation and PEEP of 4 cmH₂O. Arterial blood gas values and ventilation parameters are shown in table 1. Several minutes before non-dependent right lung deflation oxygen concentration was raised to 100%. Once the chest was opened and the right
lung deflated, a significant decrease in the arterial saturation (from 98% to 63%) was noted. Oxygenation did not improve significantly neither by 10 cmH\textsubscript{2}O continuous positive airway pressure (CPAP) applied to the non dependent lung nor by 10 cmH\textsubscript{2}O positive end expiratory pressure (PEEP) application to the dependent lung. Fiberoptic bronchoscopy confirmed proper positioning of the DLT without mucous plugging or increased secretions. Restoration of two-lung ventilation improved oxygen saturation but surgery could not continue because the right lung obstructed the surgical field. HFJV was considered, but the ventilator was unavailable.

At this stage differential lung ventilation was initiated as follows (table 1): dependent lung was ventilated by the anesthesia machine with a tidal volume of 6 ml/kg, respiratory rate of 16 breaths/min, PEEP 10 cmH\textsubscript{2}O and FiO\textsubscript{2} 1.0. The nondependent lung was ventilated by a volume control, battery powered, servo-controlled, transport ventilator (Flight III, Flight Medical, Israel) with a tidal volume of 1 ml/kg, respiratory rate of 20 breaths/min, PEEP 0, FiO\textsubscript{2} 1.0. Peak inspiratory pressures (PIP) were 35 cmH\textsubscript{2}O and 25 cmH\textsubscript{2}O respectively.

Under this ventilation mode oxygenation increased dramatically to 100% O\textsubscript{2} saturation (table 1). The right lung inflations did not interfere with surgical exposure and the operation continued uneventfully. The patient was extubated in the operating room at the end of surgery. The patient was discharged from the intensive care unit 24 hours later and transferred back to the ward.
**Discussion:**

One-lung ventilation is routinely used during thoracic surgery. It provides good exposure and adequate surgical conditions. However, OLV creates an obligatory right-to-left transpulmonary shunt through the nondependent, nonventilated lung, and increases alveolar-to-arterial oxygen tension difference so hypoxemia may develop. Blood flow to the nondependent lung is usually reduced by gravity, lung collapse, surgeon manipulation and by active hypoxic pulmonary vasoconstriction\(^3\), thus decreasing the shunt. Hence, conventional ventilation of the dependent lung with 100% oxygen is usually associated with acceptable \(\text{PaO}_2\) values. If hypoxemia does occur optimization of oxygenation can be obtained by several ways\(^4\)-\(^5\). CPAP with 100% oxygen to the collapsed lung is the most effective means for correction of hypoxemia during OLV.\(^6\) PEEP applied to the ventilated lung can recruit collapsed alveoli and improve oxygenation. However, PEEP increases the dependent lung alveolar pressure and pulmonary vascular resistance thus diverting blood to the nondependent nonventilated lung, in turn worsening the shunt and hypoxemia.\(^7\) The result of PEEP application to the dependent lung is therefore unpredictable, usually favorable only if the dependent lung is basically ill.\(^8\)

There is considerable interest in using NO to vasodilate selectively the dependent ventilated lung and reduce the shunt. To date, the effects of NO during OLV have been disappointing. NO failed to decrease mean pulmonary artery pressure or shunt fraction in patients with normal pulmonary vascular resistance and oxygenation did not improve.\(^9\) HFJV of the nondependent lung
has been applied successfully to improve hypoxemia during OLV. However, HFJV requires the use of special equipment, not always available.

Baraka described a method of differential IPPV by partial occlusion of the adapter limb to the nondependent lung, while maintaining unrestricted ventilation of the dependent lung. Yamamura and colleagues invented a complicated, big and heavy device which enables diverting different proportions of the tidal volume to the nondependent lung, thus ventilating it differentially. Both methods lack the ability to monitor and control precisely volumes and pressures.

In our patient hypoxemia developed shortly after instituting OLV. The common practices of treating hypoxemia during OLV were taken (100% oxygen, CPAP to the nondependent lung and PEEP to the dependent), but failed to improve oxygenation. The present report describes a simple technique for differential lung ventilation that improved severe hypoxemia related to one-lung ventilation. The advantage of our technique is the use of simple equipment which is highly accessible. Ventilation parameters can be determined and monitored precisely. Finally, it keeps the ability to maintain inhaled anesthesia (after considering the negative effect on the hypoxic pulmonary vasoconstriction) by ventilating the dependent lung through the anesthesia machine. The small tidal volume applied to the nondependent lung does not interfere with the surgery. There was no need for ventilators’ synchronization, as it is already known.

In conclusion, this case demonstrates the possibility of using asynchronous differential IPPV as a simple and useful way to improve oxygenation during OLV.
References


9) Wilson W.C., Kaplenski D.P., Benumof J.L., Newhart J.W., Johnson F.W., Channick R.N.: Inhaled nitric oxide (40 ppm) during one-lung ventilation, in the lateral decubitus position, does not decrease


Table 1:
Ventilation parameters and blood gasses during two lungs, one lung and differential IPPV.

<table>
<thead>
<tr>
<th></th>
<th>Two Lung Ventilation</th>
<th>One Lung Ventilation</th>
<th>Differential IPPV</th>
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<tbody>
<tr>
<td></td>
<td>Dependent lung</td>
<td>Non dependent lung</td>
<td>Dependent lung</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non dependent lung</td>
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<tr>
<td>FiO2</td>
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<td></td>
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<td>PEEP (cm H₂O)</td>
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<tr>
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<td></td>
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<tr>
<td>PIP (CmH₂O)</td>
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<td></td>
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Figure 1:

Preoperative chest radiograph