

## Independent lung ventilation for treatment of post-traumatic ARDS

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### Abstract

**Background.** Independent lung ventilation (ILV) has been recommended for unilateral pulmonary pathology. We describe a case of a multiple trauma patient treated with ILV for unilateral lung injury.

**Case report.** Following a road accident, an 18 year-old male patient was referred to the university hospital with multiple organ failure, a ruptured liver and spleen, a fractured spine at the Th<sub>1-2</sub> level, and left lung contusion. Splenectomy and liver repair had been performed in a regional hospital. On admission, a left sided pneumothorax and haemothorax were diagnosed and an emergency thoracotomy was performed, with partial resection of the left lower lobe. Because of the failure of recruitment of the left upper lobe, the patient was intubated with a double lumen tube and ILV was started using a single ventilator and a prototype flow separator, allowing separation of volume and PEEP settings. The left lung was ventilated with larger volumes and a higher PEEP than the right side, resulting in rapid improvement of gas exchange, reduction of air leak, and a return to conventional ventilation within two days. The patient underwent spinal stabilisation, and was extubated a few days later and transferred to a rehabilitation unit.

**Conclusions.** ILV with a larger tidal volume and high PEEP may be indicated in unilateral lung injury with a significant air leak from the injured tissue.

**Key words:** complications, pneumothorax; lung, contusion; respiratory insufficiency, independent lung ventilation; trauma, multiple organ

In the majority of cases, the inflammatory-atelectatic changes during respiratory failure affect both lungs to a similar extent. They are located relatively symmetrically, which enables their appropriate treatment using endotracheal intubation and a ventilator. In rare cases, the pathology involves only one lung or its part [1–5].

An asymmetric or unilateral pulmonary pathology results from biomechanical non-homogeneity of the lungs. Marked differences in lung compliance and airway resistance lead to uneven distribution of the respiratory mixture. The respiratory gases most readily penetrate the areas of the highest compliance and lowest resistance, exacerbating the existing pathology as the “diseased” lung is insufficiently ventilated whereas the “healthy” one receives the excessive tidal volume.

In cases of asymmetric location of lesions, the diverse biomechanical properties of the lungs are essential for the choice of ventilation strategies. In such cases, the classi-

cal artificial lung ventilation may deteriorate the patient's condition; therefore, the use of independent lung ventilation (ILV) combined with bronchial intubation is indicated. The method allows to carry out the therapy with different volumes, flows and pressures for each lung; ILV can be administered using two (more often) or one ventilator (rarer) in the synchronous or asynchronous mode.

The objective of the report is to present a case of acute respiratory failure treated with independent lung ventilation in a patient after multiple organ trauma.

### CASE REPORT

An 18-year-old male patient (height 174 cm, body weight 68 kg) was hospitalised due to multiple organ trauma sustained in a traffic accident, including the fracture of thoracic spine at the Th<sub>1</sub>-Th<sub>2</sub> level with spinal cord injury, contusion of the left lung with haematoma, left sided pneumothorax, and injuries to the liver and spleen. He was first transported

to a regional hospital where artificial lung ventilation was instituted and laparotomy performed to remove the spleen and suture the left hepatic lobe; the patient recovered from hypovolaemic shock.

On admission to the department of intensive therapy of the Teaching Hospital, the patient's condition was still severe; he was unconscious under the influence of hypnotic drugs. SIMV was continued at  $F_{I,O_2}$  0.5,  $V_T$  650 mL,  $f$  14  $\text{min}^{-1}$ , PEEP + 6  $\text{H}_2\text{O}$  (0.6 kPa). The circulation was supported by the infusion of dobutamine.

Based on the clinical symptoms and radiographic imaging, pneumothorax and left sided haemothorax were found to persist, despite thoracic drainage. For these reasons, thoracotomy was conducted and the most damaged parts of the left lung were excised and sutured; moreover, haemothorax was evacuated. The injured left upper lobe was spared assuming that it can be expanded after the procedure using a ventilator. After surgery, SIMV was continued at  $F_{I,O_2}$  0.6,  $V_T$  600 mL,  $f$  14  $\text{min}^{-1}$ , PEEP + 10  $\text{H}_2\text{O}$  (1.0 kPa). Gasometry of arterial blood revealed  $\text{PaO}_2$  74 mm Hg (9.87 kPa) and  $\text{PaCO}_2$  68 mm Hg (9.07 kPa); these values did not markedly improve despite multi-directional correction of ventilation parameters.

After two days of hospitalization, considering the lack of lung expansion, presence of the bronchopleural fistula and poor gasometric findings, the initiation of synchronous ILV was decided. The patient was intubated with a double-lumen tube and a divider of tidal volumes (designed by the Institute of Biocybernetics and Biomedical Engineering, Pol-

ish Academy of Science) was fitted into the ventilator system. The divider enabled to supply the suitably adjusted volumes to each lung separately and to determine the optimal PEEP.

ILV was initiated in the SIMV mode at  $F_{I,O_2}$  0.6,  $V_T$  600 mL,  $f$  14  $\text{min}^{-1}$ , with the distribution of respiratory mixture 1:1 and PEEP + 5  $\text{H}_2\text{O}$  (0.5 kPa) bilaterally. Several hours after institution of SIMV, the gasometry results were as follows:  $\text{PaO}_2$  149 mm Hg (19.86 kPa) and  $\text{PaCO}_2$  51 mm Hg (6.8 kPa); thus,  $F_{I,O_2}$  was reduced to 0.45.

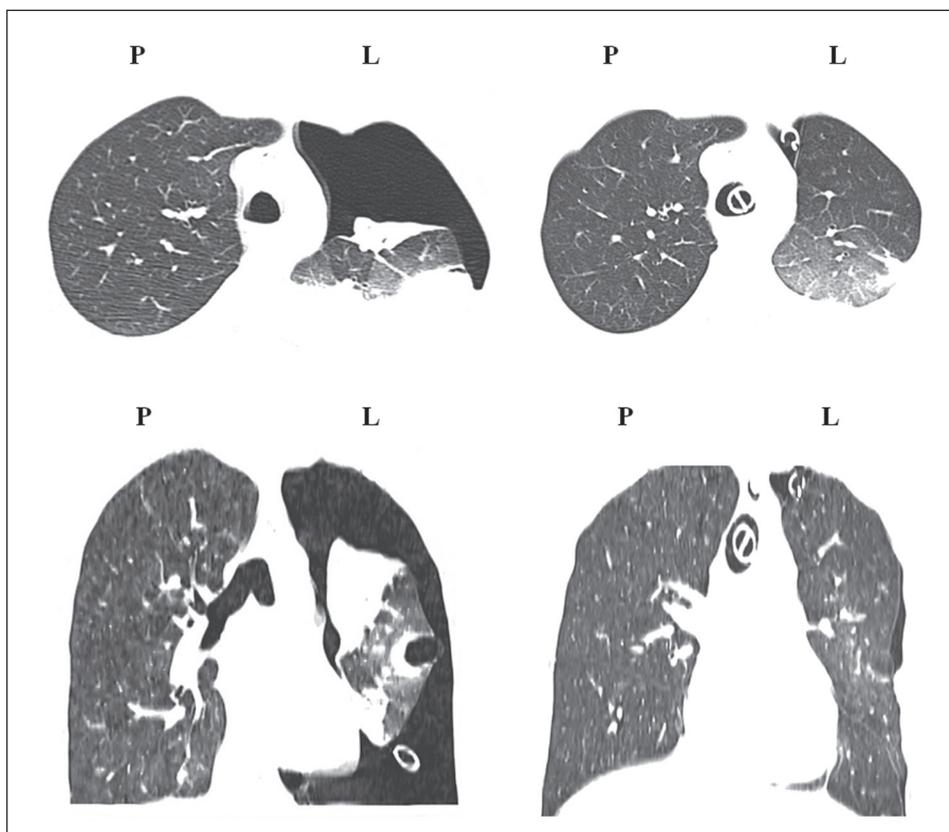
After several hours of ventilation with equal distribution of volumes, the distribution ratio was changed into 2:1, and the double volume was directed to the left lung; moreover, PEEP in this lung was increased. Thanks to that, good blood oxygenation was maintained and carbon dioxide elimination through the lungs improved ( $\text{PaO}_2$  135 mm Hg/18.0 kPa and  $\text{PaCO}_2$  44 mm Hg/5.87 kPa). The atelectatic foci in the left lung gradually decreased. The capnographic parameters of the left lung became comparable to the values of the right lung.

After 48 h of independent lung ventilation, the biomechanical parameters of the left lung reached the right lung values and gas leak through the bronchopleural fistula significantly decreased (Table 1).

The therapeutic effects achieved allowed discontinuation of ILV, endotracheal re-intubation and return to conventional artificial lung ventilation. During the next stage of therapy, the injured thoracic spine was stabilized. Several days later, artificial lung ventilation was withdrawn and the left pleural drainage system removed. After 30 days of hospitalization, the patient was transferred to the rehabilitation

**Tabela 1.** Changes in biomechanical parameters during independent lung ventilation

Parameter	Lung	Onset of Ilv 1:1	Ilv 2:1 After 8 h	Ilv 2:1 After 24 h	Ilv 1:1 After 48 h
Volume assumed/obtained (ml)	Left	300/160	400/280	400/370	300/270
	Right	300/300	200/200	200/200	300/300
Peak airway pressure (cm $\text{H}_2\text{O}$ )	Left	31	26	19	23
	Right	16	13	12	16
Mean airway pressure (cm $\text{H}_2\text{O}$ )	Left	14	12	11	11
	Right	10	8	8	10
Dynamic lung compliance (mL cm $\text{H}_2\text{O}^{-1}$ )	Left	6,7	17,2	21	19,9
	Right	22,6	20,7	21,8	24
Static lung compliance (mL cm $\text{H}_2\text{O}^{-1}$ )	Left	9,1	21,2	24,5	22
	Right	29,3	26,9	26,5	34
Airway resistance (ml cm $\text{H}_2\text{O}^{-1}$ L $^{-1}$ sets $^{-2}$ )	Left	158	88	55	53
	Right	47	41	43	45
PEEP (cm $\text{H}_2\text{O}$ )	Left	5	8	8	8
	Right	5	3	5	5
ETCO $_2$ (mm Hg)	Left	14	20	22	22
	Right	50	27	23	24



**Figure 1.** Thoracic CT scans: A, B — during conventional lung ventilation; C, D — during independent lung ventilation

ward for further therapy. The thoracic CT scans illustrate the outcome of treatment of unilateral lung pathology (Fig. 1).

## DISCUSSION

Our experiences regarding the treatment of the patient with severe post-traumatic unilateral lung injury coexisting with the bronchopleural fistula and atelectasis unresponsive to conventional therapy demonstrated practical usefulness of independent synchronous artificial lung ventilation. The management was hindered by the fact that trauma-related atelectatic regions of the left lung parenchyma were not initially aerated due to a gas leak through the bronchopleural fistula. Under such circumstances, persistent hypoxia inclined us to direct the increased tidal volume to this lung, following its partial resection. The proportion of spontaneous distribution of volumes promotes the right (bigger) lung whereas independent lung ventilation at a ratio 1:1 — the left lung (smaller). Our decision, albeit risky due to persistent bronchopleural fistula, proved to be right as the total gas exchange in the lungs improved spectacularly; the affected lung compliance and airway resistance also changed beneficially. Moreover, the best therapeutic effects were achieved once the double tidal volume was directed to the affected lung.

The literature data offer various options of the use of independent lung ventilation for treatment of respiratory failure caused by one lung pathology. In such cases, the choice of parameters of artificial ventilation depends on the functional state of the lungs. The best therapeutic effects are observed when the volumes for both lungs are similar [6], yet the pressures in the airway of the injured lung (without the fistula) are higher, which may lead to barotrauma. For these reasons, the tidal volume should be adjusted to the plateau pressure in the affected lung [7]. Another method for proper selection of the tidal volume is based on the criterion of equalization of  $E_T\text{-CO}_2$  differences and the shape of capnographic curves of both lungs [8, 9]. Such correlations were also observed in our case.

PEEP is an essential element of modern ventilation therapy. In our patient, PEEP was not high. Higher values for the injured lung, although improving its aeration, are likely to delay the fistula closure. Moreover, PEEP should be adjusted to the level that does not induce circulatory dysfunction [10].

Since the gas exchange has to be optimised, in unilateral lung pathology both non-synchronous and synchronous independent lung ventilations are carried out in different modes. Konstantinow and colleagues [11]

used two ventilators working synchronically. The injured lung received a halved volume and PEEP was set at 0 cm H<sub>2</sub>O whereas in the opposite lung — 10 cm H<sub>2</sub>O (1.0 kPa). Independent lung ventilation was continued for 5 days reaching the intended therapeutic goals, i.e. improved blood oxygenation, reduced gas leak through the fistula and expanded atelectatic lung.

Otherwise, Koch and co-workers [12] demonstrated the effectiveness of therapy with two ventilators working asynchronously, in different modes of ventilation. They generated different tidal volumes, almost the doubled volume was directed to the injured lung, for which PEEP was also markedly higher.

Thanks to wide availability of medical devices, which each intensive therapy unit is equipped with, asynchronous independent lung ventilation can be initiated and controlled. Furthermore, there are specially programmed and connected processors of two ventilators for synchronous therapy, yet they are not available in the majority of hospitals due to their high costs [13].

In the present case, independent lung ventilation was carried out in a synchronous mode. The divider of gases used, although a prototype, precisely directed required volumes to the lungs in accordance with the set values, which had been demonstrated in earlier publications [14].

Our experiences with the use of independent lung ventilation in intensive therapy, although limited to one case, explicitly confirm the therapeutic usefulness of this method, which cannot be overestimated. In some cases, unilateral, complex lung pathology, resulting from the coexisting fistula and lobar atelectasis, can be controlled only using this method of management.

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