Influence of SIMV plus inspiratory pressure support on \(V_A/Q\) distributions during postoperative weaning

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Abstract. Since the introduction of synchronized intermittent mandatory ventilation (SIMV) several advantages have been attributed to this ventilatory mode, one of them being a more homogeneous distribution of ventilation and perfusion than during controlled mechanical ventilation (CMV). Up to now no data are available to confirm whether this is true when SIMV is used in combination with inspiratory pressure support (IPS). Therefore, we compared the influence of CMV and SIMV+IPS on the distributions of ventilation and perfusion in 9 patients undergoing weaning from postoperative mechanical ventilation. Continuous distributions of ventilation and perfusion were assessed using the multiple inert gas elimination technique (MIGET). SIMV+IPS did not induce any change in the hemodynamic or oxygenation parameters, in particular CI and \(\text{PaO}_2\) remained constant. Physiological dead space (\(V_D/V_T\)) increased, but \(\text{PaCO}_2\) remained unchanged due to increased minute ventilation (from 9.5 \(\pm\) 0.9 to 11.3 \(\pm\) 1.2 \text{l} \text{min}^{-1}). The perfusion distributions remained unaltered; there was no change in \(Q_S/Q_T\) nor in the perfusion of the low \(V_A/Q\) lung regions. This result was underscored by the unchanged dispersion of the perfusion distribution (log SDQ). The increased \(V_D/V_T\) was caused by increased inert gas dead space (from 22.0 \(\pm\) 9.6 to 26.8 \(\pm\) 8.7%) which was accompanied by increased ventilation of lung regions with high \(V_A/Q\) ratios (10 < \(V_A/Q\) < 100) in 3 patients. These results show that in our group of patients partial removal of CMV together with pressure support assistance of spontaneous ventilation did not induce a clinically significant loss of the efficiency of the breathing pattern. Since the unchanged hemodynamic parameters were accompanied by increased minute ventilation, arterial blood gases did not deteriorate. Hence, SIMV+IPS proved to be useful for weaning from postoperative mechanical ventilation.

Key words: Inspiratory pressure support – Synchronized intermittent mandatory ventilation – Ventilation/perfusion distribution – Weaning

Synchronized intermittent mandatory ventilation (SIMV) has an important place during weaning from controlled mechanical ventilation (CMV). Since its introduction [1] several advantages have been attributed to this ventilatory mode. One of these potential advantages is a more homogeneous distribution of ventilation and perfusion (\(V_A/Q\)) than during CMV. Weismann and coworkers [2] hypothesized that the spontaneous breathing during SIMV improves the ventilation of dependent lung regions: spontaneous breathing preferentially distributes ventilation to basal lung regions and thus compensates for the mechanical positive pressure breaths which favour the ventilation of non-dependent lung regions due to the inactive diaphragm. In fact, Wolff and coworkers [3] found increased efficiency of alveolar ventilation for the spontaneous breaths during SIMV compared to CMV in patients after open-heart surgery.

Up to now no data are available whether this assumption is also valid when the spontaneous breath is assisted by inspiratory pressure support (IPS), a ventilatory mode which is frequently combined with SIMV in order to reduce the work of breathing, in particular its components attributable to the resistance of the ventilatory circuit and the endotracheal tube [4]. Therefore the aim of our study was to compare the effects of SIMV combined with IPS with those of CMV on the distributions of ventilation and perfusion.

Patients and methods

Nine consecutive patients (male, age 61.4 \(\pm\) 9.3 years) were studied during weaning from postoperative controlled mechanical ventilation after major abdominal aortic surgery. The mean ventilation period was 30 h (range 24 – 36 h). None of the patients had a history nor clinical or radiological signs of chronic obstructive lung disease (COPD). All pu-
The ventilation and perfusion (VA/Q) distributions were calculated using an appropriate algorithm [7]. The remaining sum of inert gas data are summarized in Table 2. SIMV+IPS did not induce any changes of the intravascular pressures or the CI. The overall inert gas data are summarized in Table 2. SIMV+IPS did not induce any changes of the intravascular pressures or the CI.

**Average tidal volume and airway pressure**

Fig. 1. Original recording of tidal volume (above) and airway pressure (below) during SIMV+IPS. The time scale demonstrates that the mechanical respiratory rate was reduced to 4 breaths/min in this patient. The upper panel registration demonstrates that the spontaneous tidal volumes reached about 30–50% of the mechanical breath (mean VA and mean Q) were calculated to evaluate the dispersion and a putative shift, respectively, of these distributions.

**Statistical analysis**

Statistical analysis was performed using a non-parametric Wilcoxon rank sign test for paired variables. Significance was assumed when the p value was below 0.05.

**Protocol**

The order of the ventilatory modes was randomized. During CMV the patient was ventilated with a tidal volume of 14–16 ml/kgBW and a respiratory rate of 8–10 breaths/min. During SIMV+IPS the mechanical respiratory rate was reduced to 4–5 breaths/min, i.e. 50% of the CMV value. The spontaneous breaths were assisted by an IPS, its level being adjusted so that the spontaneous tidal volumes reached about 50% of the mechanical breaths (IPS = 5–8 cm H₂O). A representative recording of airway pressures and tidal volumes is presented in Fig. 1. For each ventilatory mode the respective set of measurements was obtained after 45 min had elapsed at stable hemodynamic and respiratory conditions, i.e. vascular pressures and CI were constant as well as respiratory rate and minute ventilation.

**Results**

When switched to SIMV+IPS, none of the patients showed any signs of respiratory muscle dysfunction, such as hypercapnia, tachypnea, dyspnea or paradoxical breathing [9]. Consequently, in all patients the weaning attempts were successful except one patient with a history of chronic obstructive pulmonary disease. The hemodynamic and the O₂ and CO₂ exchange parameters showed no significant changes. The oxygenation parameters PaO₂, QVA/QT and calculated oxygen uptake remained unaltered as well. In all patients the weaning attempts were successful except one patient with a history of chronic obstructive pulmonary disease.

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- **Tidal volume**
- **Airway pressure**
- **VA/Q ratio**
- **QVA/QT**
- **QVA/Q**
- **Ventilation**
- **Perfusion**
- **SIMV**
- **CMV**