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A comparison of volume control and pressure-regulated volume control ventilation in acute respiratory failure

Henrik Guldager[2], Soeren L Nielsen[1], Peder Carl[1], Mogens B Soerensen[1]

Abstract

Background: The aim of this study was to test the hypothesis that a new mode of ventilation (pressure-regulated volume control; PRVC) is associated with improvements in respiratory mechanics and outcome when compared with conventional volume control (VC) ventilation in patients with acute respiratory failure. We conducted a randomised, prospective, open, cross over trial on 44 patients with acute respiratory failure in the general intensive care unit of a university hospital. After a stabilization period of 8 h, a cross over trial of 2 × 2 h was conducted. Apart from the PRVC/VC mode, ventilator settings were comparable. The following parameters were recorded for each patient: days on ventilator, failure in the assigned mode of ventilation (peak inspiratory pressure > 50 cmH_2O) and survival.

Results: In the crossover trial, peak inspiratory pressure was significantly lower using PRVC than with VC (20 cmH_2O *vs* 24 cmH_2O, $P < 0.0001$). No other statistically significant differences were found.

Conclusions: Peak inspiratory pressure was significantly lower during PRVC ventilation than during VC ventilation, and thus PRVC may be superior to VC in certain patients. However, in this small group of patients, we could not demonstrate that PRVC improved outcome.

intensive care mechanical ventilation, respiratory failure

Introduction

During mechanical ventilation, the application of positive pressure with a peak inspiratory pressure (PIP) in excess of 50–60 cmH_2O may result in a barotrauma [1]. Gross overinflation leads to rupture of the airways which may result in pneumothorax, pneumomediastinum or subcutaneous emphysema.

Animal experiments have established that even PIP at a level of 30–40 cmH_2O results in lung overinflation and may cause pulmonary interstitial edema, inflammation and elevated vascular permeability, a picture that resembles acute respiratory distress syndrome (ARDS) or acute lung injury (ALI) [2-5]. The pulmonary injury is often distributed quite heterogeneously. This means that normally functioning parts of the lung are scattered between parts that are diseased, either as totally consolidated lung or as collapsed potentially expandable lung [6].

Conventional ventilation may lead to overdistention of the normally functioning lung while expanding collapsed parts. Thus, mechanical ventilation may exacerbate the pulmonary pathology and/or delay recovery. In two studies of patients with ARDS, it was concluded that survival is better when high ventilation pressures are avoided [7,8]. There have been no such studies in patients with acute respiratory failure without ARDS.

Pressure-regulated volume control (PRVC) is a new mode of ventilation that combines the advantages of the decelerating inspiratory flow pattern of a pressure-control mode with the ease of use of a volume-control (VC) mode.

The aim of this study was to test the hypothesis that PRVC associated with improvements in respiratory mechanics, outcome and length of intensive care unit stay when compared with conventional VC ventilation.

[1]Department of Anaesthesia and Intensive Care, Hvidovre University Hospital, DK-2650 Hvidovre, Denmark
Full list of author information is available at the end of the article

Materials and methods

The study was approved by the ethics committee of Copenhagen (reg no 01-182/93) and was conducted in accordance with the Helsinki declaration. Data were collected prospectively, and randomization was achieved using scaled envelopes.

The inclusion criteria were acute respiratory failure, a partial pressure of arterial oxygen (PaO_2; mmHg)/FiO_2 ratio of < 300 with a PEEP of 5 cmH_2O, FiO_2 between 0.4 and 0.6, and age 18 years or more. Patients with an expected ventilator therapy of less than 24 h were excluded as were patients with intracranial pathology.

After an initial stabilization period (up to 8 h) the patients were randomized to PRVC or VC. The following variables were instituted for both groups during ventilation: tidal volume (VT) 5–8 ml/kg, a respiratory rate to achieve the desired partial pressure of arterial carbon dioxide ($PaCO_2$), inspiratory time 30% (no pause) and constant PEEP. After a period of 2 h, the patients were switched to the alternative method of ventilation (PRVC or VC) for a further 2 h without any other ventilatory changes. After measurement, the patients were returned to the mode of ventilation initially assigned. The patients assigned to PRVC were weaned on volume support and the patients assigned to VC were weaned on pressure support. To ensure that the two groups of patients received the same kind of ventilator management a protocol was used (which can be obtained from the authors on request).

All patients were ventilated using a Siemens Servo 300 ventilator (Siemens Elema AB, Solna, Sweden). The following variables were measured: PIP, mean airway pressure, PaO_2, $PaCO_2$, pH and mean arterial pressure (MAP). The number of days on the ventilator, failure of the assigned mode of ventilation (PIP > 50 cmH_2O) and survival were also recorded.

Airway pressures were recorded on the display monitor of the ventilator and arterial blood gases were measured using an arterial blood gas analyser (ABL 2; Radiometer, Copenhagen, Denmark).

Statistical analysis

For categorical data, Fisher's exact test was used. For numerical data, non-parametric tests were used: the Wilcoxon test in the crossover trial and the Mann–Whitney test in the general trial.

Results

Forty-Four patients with acute respiratory failure were included. No patient was excluded after randomization.

There were no statistically significant differences between demographic data for the two groups: median age 57 years (95% confidence interval 52–66) and 60 years (95% confidence interval 55–70), an APACHE II score of 18 (95% confidence interval 16–22) and 16 (95% confidence interval 14–19) and a male/female ratio of 16/6 and 10/12 for the PRVC and VC groups, respectively.

The results of the crossover study are shown in Table 1, where the number of patients in each group is given as 44 because every patient was crossed over (paired comparison). There was a significantly lower PIP in the PRVC group ($P < 0.0001$).

The results of the general trial are shown in Table 2. Two patients in the VC group failed the assigned mode of ventilation of PIP > 50 cmH_2O.

Discussion

This study shows the advantage of using the PRVC mode for ventilation during acute respiratory failure. PIP was lower for all patients using the PRVC mode compared to the VC mode, and alveolar ventilation was unchanged as indicated by the constant $PaCO_2$. The new mode of ventilation did not improve outcome or duration of treatment, despite a statistically significant difference in peak pressures (4 cmH_2O). Though this difference in peak pressure is small, it may be more relevant in situations where larger tidal volumes are contemplated.

This study is the only study that has measured the difference between PIP on the two modes of ventilation, PRVC and VC. In contrast to other studies comparing pressure-limited ventilation with various forms of ventilation, our patients had only mild respiratory insufficiency. In the studies by Rappaport *et al* [9] and Hickling *et al* [7], the inclusion criterion was a PaO_2/FiO_2 ratio < 150, whereas < 300 was used in our study. However, two of our patients failed the assigned VC mode, while no patient on PRVC failed (P = 0.24). For this tendency to have achieved statistical significance, 110 patients should have been enrolled in the study.

Table 1 Physiological variables during the two modes of mechanical ventilation, pressure-regulated pressure control (PRVC) and volumne control (VC)

	PRVC (n = 44)	VC (n = 44)	P
PIP (cmH_2O)	20 (19-23)	24 (23-27)	< 0.0001
MAIP (cmH_2O)	10 (9-11)	10 (9-11)	ns
PaO_2 (mmHg)	98 (93-111)	96 (92-108)	ns
$PaCO_2$ (mmHg)	43 (40-46)	43 (40-46)	ns
pH	7.38 (7.11-7.65)	7.38 (7.10-7.65)	ns
MAP (mmHg)	76 (73-83)	77 (74-84)	ns

Values are means (95% confidence limits). PIP = peak inspiratory pressure; MAIP = mean airway pressure; PaO_2 = partial pressure of arterial oxygen; $PaCO_2$ = partial pressure of arterial carbon oxide; MAP = mean arterial blood pressure.

Table 2 Results of the general trial

	PRVC (n = 22)	VC (n = 22)	P
Days on ventilator	7.0 (3.8-10.3)	6.2 (3.8-8.5)	ns
Failing	0/22	2/22	ns
Survival	12/22	11/22	ns

Days on ventilator = median (95% confidence limits) number of days spent on mechanical ventilation; Failing = number of patients failing the assigned mode of ventilation; Survival = survival in the two groups.

The risk of type 2 error for an overlooked difference of 10% failing VC is only 20% with 1-β = 80%.

Further studies are needed to decide if PRVC improves outcome when compared with VC in patients with acute respiratory failure. Other subgroups, such as acute severe asthma or ARDS, could be a focus for attention.

A recent review recommends pressure-control ventilation in all clinical circumstances requiring artificial ventilation [10]. During PRVC, as with pressure control, there is a maximum pressure difference between the ventilator and the lung at the beginning of the inspiratory cycle. The resulting flow is also maximal. With the increase in intrathoracic pressure this difference diminishes, as does the resulting inspiratory flow. The flow pattern is therefore called decelerating inspiratory flow. In VC ventilation, there is a constant inspiratory flow and the resulting intrathoracic pressure is always increasing. Pressure-regulated ventilation is therefore capable of delivering the same volume at a lower PIP. This fact may play a more significant role when higher tidal volumes are required, and greater differences in peak pressures between PRVC and VC may be expected.

Our conclusion is that, during mechanical ventilation for acute respiratory failure, PIP was significantly lower on PRVC than VC, and thus PRVC may be superior to VC in certain patients.

Our results emphasize one of the basic problems in intensive care research-that therapeutic signals are too weak to be discovered in clinical trials consisting of few patients.

Author details
[1]Department of Anaesthesia and Intensive Care, Hvidovre University Hospital, DK-2650 Hvidovre, Denmark. [2]Department of Anaesthesia and Intensive Care, Slagelse Central Hospital, DK-4200 Slagelse, Denmark.

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