Patient Comfort During Pressure Support and Volume Controlled-Continuous Mandatory Ventilation

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BACKGROUND: Pressure-support ventilation (PSV) is more comfortable than volume controlled-continuous mandatory ventilation (VC-CMV) in acute hypercapnic respiratory failure, in patients undergoing noninvasive ventilation. Physiologic measurements of patient status have been compared in PSV and VC-CMV in endotracheally intubated patients, but patient perception of comfort has not been measured in this population. OBJECTIVE: To determine if PSV is more comfortable than VC-CMV (volume-cycled, flow-limited) in intubated mechanically ventilated patients. METHODS: In a randomized prospective trial, patients underwent PSV and VC-CMV for 30 min each, separated by a 30 min washout with the baseline ventilation mode (pressure-regulated volume-control ventilation [PRVC]). The level of pressure support was set as the plateau pressure on VC-CMV with a tidal volume of 8 mL/kg minus the end-expiratory pressure. After each mode the patient was asked to mark his or her comfort level on a visual analog scale. RESULTS: Eleven of the 14 patients were more comfortable during PSV. The baseline mean comfort score (during PRVC) was 62 ± 18 (95% confidence interval 51.7–72.5). The mean comfort score for PSV was 83 ± 11 (95% confidence interval 76.9–89.6). The mean comfort score for VC-CMV was 70 ± 18 (95% confidence interval 59.4–79.9). PSV was significantly more comfortable than VC-CMV ($p = 0.02$) or PRVC ($p = 0.009$), whereas the comfort scores for VC-CMV and PRVC were not significantly different ($p = 0.278$). Respiratory rate, blood pressure, heart rate, minute ventilation, and blood oxygen saturation showed no difference between PRVC, VC-CMV, and PSV. CONCLUSIONS: On average the patients felt more comfortable during PSV than during VC-CMV or PRVC, so PSV may be the preferred mode for awake intubated patients. *Key words: mechanical ventilation, intubation, pressure support, volume controlled-continuous mandatory ventilation, pressure-regulated volume-control ventilation, comfort.* [Respir Care 2008;53(7):897–902. © 2008 Daedalus Enterprises]

Introduction

Volume controlled-continuous mandatory ventilation (VC-CMV) is the most commonly used mode for patients with respiratory failure who require endotracheal intubation.[1,2] Modern-day ventilators, though, can provide an assortment of modes, and pressure-support ventilation (PSV) is available on almost all mechanical ventilators. VC-CMV is flow-limited and volume-cycled, whereas PSV is pressure-limited and flow-cycled. It has been hypothesized that PSV may be more comfortable than VC-CMV and reduce the patient's work of breathing (WOB).[3]

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One previous study[4] investigated the effects of PSV on respiratory mechanics, gas exchange, hemodynamics, and oxygen consumption. Those researchers enrolled patients who were endotracheally intubated and had a pulmonary artery catheter in place. Each patient was evaluated during a period of VC-CMV and a period of PSV ventilation. PSV had significantly higher tidal volume (V_T), minute ventilation, and inspiratory time, and lower airway pressure. Those researchers did not assess patient comfort.[4]

Girault et al compared patient comfort in VC-CMV and PSV, but their subjects were noninvasively ventilated. Fifteen patients with COPD were ventilated with a nasal mask, in both VC-CMV and PSV. Those patients found PSV significantly more comfortable than VC-CMV.[5]

PSV augments the patient's spontaneous inspiratory efforts with a clinician-selected level of positive airway pressure.[3] In PSV, patient effort interacts with the machine-delivered pressure to determine the inspiratory flow and V_T; this interaction allows the patient to control the rate and the inspiratory-expiratory ratio.[6] In contrast, during VC-CMV, the ventilator delivers each cycle with a preset volume and flow. The cycle is either triggered by the patient's inspiratory effort or delivered independently if a patient effort does not occur within a pre-selected period. In addition to better comfort, because the patient influences the volume, flow, and inspiratory-expiratory ratio, possible advantages of PSV over VC-CMV may include lower work of spontaneous breathing, better muscle training, and better patient-ventilator synchrony.[7] It is important to realize that the magnitude of pressure support can influence the work required from the patient.

Patient comfort is an important goal of care, because greater comfort may reduce the need for sedation and improve overall patient satisfaction.[8,9] PSV is more comfortable for noninvasively ventilated patients,[5] but it is not clear whether it is more comfortable for endotracheally intubated patients. The discomfort of the endotracheal tube may overshadow any comfort difference between VC-CMV and PSV. In our institution, patients are traditionally ventilated with a volume-targeted mode until they are ready for a spontaneous breathing trial. We hypothesized that stable intubated patients would find PSV more comfortable, and we designed this study to compare patients' perceptions of respiratory comfort in VC-CMV and PSV.

Methods

Study Subjects

From September 2003 to September 2004 we screened patients in the 44-bed medical intensive care unit (ICU) at Henry Ford Hospital, Detroit, Michigan. Screening and enrollment was performed by one of the investigators (IK) twice weekly. To be included, a patient had to be: mechanically ventilated via an orotracheal tube; at least 18 years old; awake and alert; off sedation for at least 12 hours; oxygen saturation $> 90\%$ on a fraction of inspired oxygen $\leq 40\%$; hemodynamically stable, without infusion of pressors; without increase in oxygen requirement for at least 24 hours; and without history of cerebrovascular accident or dementia. Patients who did not meet those criteria were excluded. One-hundred eighteen patients were screened, 19 met the study criteria, and 5 of those 19 did not wish to participate, so 14 patients were enrolled. Informed consent was obtained from each patient prior to enrollment.

Protocol

The study protocol was approved by the Henry Ford Institutional Review Board.

The same respiratory therapist (JC) adjusted the ventilator settings and administered the visual-analog-scale comfort-rating measurements with all the subjects. The VC-CMV mode we used was the "Volume Control" mode (Servo 300, Siemens, Munich, Germany), which delivers a constant flow throughout inspiration. We used a 100-mm horizontal visual analog scale to have the subjects rate their perception of comfort. Previous studies demonstrated the feasibility of using a visual analog scale with ventilated patients.[10-12] The patients received careful instructions and were required to demonstrate that they were capable of drawing a straight vertical line. At the end of each intervention the patients were asked to draw a vertical line on the visual analog scale. The left end of the scale (0 mm) was marked "Not at all comfortable" and the right end of the scale (100 mm) was marked "Very comfortable." Minute ventilation, V_T, respiratory rate, blood pressure, peak airway pressure, mean airway pressure, and arterial oxygen saturation were also recorded.

Prior to any ventilator mode changes, baseline comfort level was assessed. Plateau pressure was subsequently measured during a 5 min period of pressure-regulated volume-control (PRVC) ventilation (the default ventilation mode in our ICU), with a respiratory rate of 8 breaths/min, a V_T of 8 mL/kg, positive end-expiratory pressure of 5 cm H_2O, and fraction of inspired oxygen 0.40. The patients were then randomly assigned to begin with either PSV or VC-CMV. Each mode was used for 30 min prior to asking the patient to rate his or her comfort. After completion of the first intervention period there was a 30-min washout period during which the ventilator settings were returned to those that were being used prior to initiation of our study. In VC-CMV, the inspiratory time was set at 25% of the total breathing cycle time (ie, inspiratory-expiratory ratio 1:3) and the flow pattern was "constant" (square wave). The inspiratory rise time was not changed from our ICU default setting of 5%.

Table 1. Characteristics of Study Subjects

Patient Number	Age (y)	Sex	Diagnosis	Days Intubated at Enrollment
1	76	F	COPD	2
2	48	F	Gastrointestinal bleed	1
3	34	F	Pneumonia	1
4	79	M	Congestive heart failure	14
5	53	M	Congestive heart failure	7
6	68	M	Angioedema	2
7	59	F	Asthma	6
8	77	F	Pneumonia	5
9	73	F	Cancer	5
10	57	F	Pneumonia	14
11	81	F	Congestive heart failure	1
12	73	F	Congestive heart failure	2
13	65	F	Congestive heart failure	14
14	64	F	COPD	2
Mean ± SD	64.8 ± 13.4	78.6% female	Not applicable	5.4 ± 5.0

COPD = chronic obstructive pulmonary disease

In an attempt to match the plateau pressure (0.5-s end-inspiratory hold) while minimizing V_T differences between groups, we subtracted the positive end-expiratory pressure from the plateau pressure measured during ventilation with a V_T of 8 mL/kg, and used that result to set the pressure support level. If the mean V_T during PSV was less than 8 mL/kg, we adjusted the support to achieve a V_T of 8 mL/kg. This intervention guaranteed a minimum V_T of 8 mL/kg in both groups, even if it was not obtained by the pressure-matching strategy. The patients were unaware of which mode was being used during each period. However, all researchers were aware of which subjects were in which groups.

Measurements and Statistical Analysis

The primary outcome was comparison of the mean PSV comfort score and the mean VC-CMV comfort score. A

Table 2. Ventilator Settings and Comfort Ratings

Patient Number	Baseline Comfort*	Baseline Tidal Volume (mL)	Baseline Frequency (breaths/min)	Observed Frequency (breaths/min)	Baseline Inspiratory-Expiratory Ratio	Comfort on PSV†	PSV Pressure (cm H_2O)	Comfort on VC-CMV‡
1	89	350	12	17	1:3 (0.25)	90	14	23
2	60	500	12	16	1:3 (0.25)	69	21	80
3	60	500	12	15	1:3 (0.25)	92	15	80
4	60	600	12	12	1:3 (0.25)	90	14	60
5	30	500	12	13	1:4 (0.20)	80	26	90
6	40	600	12	13	1:3 (0.25)	76	12	55
7	61	600	12	23	1:3 (0.25)	85	18	70
8	40	450	16	30	1:3 (0.25)	59	16	48
9	69	450	12	15	1:3 (0.25)	71	26	74
10	62	550	12	18	1:3 (0.25)	98	18	82
11	93	650	12	12	1:3 (0.25)	88	14	84
12	68	450	12	16	1:3 (0.25)	86	18	77
13	82	650	10	10	1:3 (0.25)	86	20	78
14	55	500	12	15	1:3 (0.25)	95	13	74
Mean ± SD	62.2 ± 18.0	525 ± 87.2	12.1 ± 1.2	16.1 ± 5.1	1:3 ± (0.25 ± 0.01)	83.2 ± 11.0	17.5 ± 4.5	69.6 ± 17.8

*Baseline comfort while on pressure-regulated volume-control ventilation (PRVC) (the baseline ventilation mode) prior to ventilation-mode changes, measured via 100-mm visual analog scale.
†Comfort after 30 min of pressure-support ventilation (PSV). Mean patient comfort after the 30-min PSV period was significantly greater than baseline ($p = 0.001$) and greater than after volume controlled-continuous mandatory ventilation (VC-CMV) ($p = 0.02$). The mean patient comfort after VC-CMV ventilation was not significantly different than baseline ($p = 0.31$).
‡Comfort after 30 min of VC-CMV

secondary outcome was comparison of the mean PSV comfort score and the mean baseline comfort score. Measurement (to the nearest millimeter) from the original visual-analog-scale score sheet was performed by ADB.

Values are expressed as mean ± standard deviation. We used paired *t* testing to compare the mean comfort scores; we compared VC-CMV to PSV, and PRVC to PSV. We used 1-way repeated-measures analysis of variance (Medcalc version 6.16.000, Mariakerke, Belgium) to compare the means of the 3 groups.

Results

Tables 1 and 2 show the patient characteristics. All the patients were on the PRVC mode at baseline. The mean duration of mechanical ventilation prior to enrollment was 5.4 ± 5.0 d.

Eleven of the 14 patients gave PSV a comfort score at least 4 points higher than VC-CMV, and 8 of those gave PSV a score at least 10 points higher than VC-CMV. The mean comfort for PSV was 83 ± 11, compared to 70 ± 18 for VC-CMV ($p = 0.02$). The 95% confidence interval for the difference in the mean comfort scores was 2.0 to 25.2 (Fig. 1). The 3 patients who gave VC-CMV a higher score each required pressure support > 20 cm H_2O to achieve the 8 mL/kg V_T minimum. These three had diagnoses of heart failure, gastrointestinal bleed, and cancer.

The mean comfort score at baseline was 62 ± 18, which was significantly lower than that of PSV ($p = 0.001$). Mean comfort with VC-CMV was no different than baseline ($p = 0.27$). Arterial blood pressure, heart rate, respiratory rate, mean airway pressure, minute ventilation, and arterial oxygen saturation were not statistically different in any of the groups (Table 3).

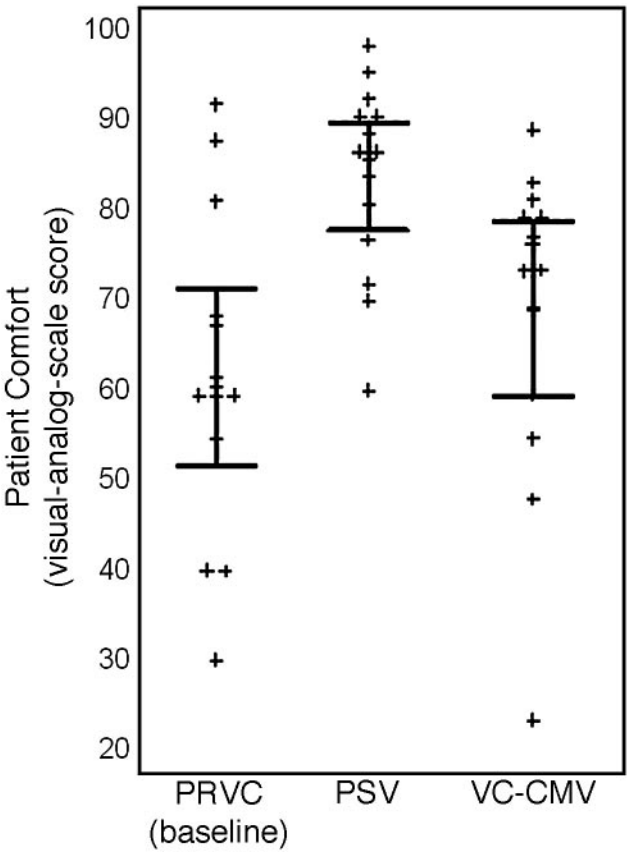

Fig. 1. Patient comfort, measured with a 100-cm visual analog scale, in pressure-regulated volume-control (PRVC) ventilation (all patients were on PRVC at baseline), and at the end of 30 min of pressure-support ventilation (PSV) or volume ontrolled-continuous mandatory ventilation (VC-CMV). The error bars represent the 95% confidence intervals of the means. Mean comfort at the end of the PSV period was greater than that after PRVC or at the end of the VC-CMV period.

Discussion

This is the first study to find greater patient comfort during PSV than during VC-CMV in orotracheally intubated patients. One study compared synchronized intermittent mandatory ventilation to PSV during ventilator weaning and found no difference in dyspnea or anxiety.[12]

The present study suggests that when a patient is improving and sedation is being reduced, PSV can relieve some of the discomfort of mechanical ventilation that exceeds the discomfort of the endotracheal tube. The magnitude of support required seemed to influence the perception of comfort; patients who required a high level of support to achieve the desired V_T found the VC-CMV mode more comfortable. This suggests that respiratory-system compliance may affect the perception of comfort.

Our study was limited by the lack of invasive measurements that would be available from a pulmonary artery catheter or esophageal-balloon pressure monitoring. This limited our ability to assess the changes in pulmonary capillary wedge pressure, cardiac output, and WOB. None of the patients had a pulmonary artery catheter in place prior to enrollment, and we could not justify the use of a pulmonary artery catheter in each patient, because some studies have suggested no benefit or even harm from that procedure.[13] Esophageal pressure monitoring, on the other hand, is relatively safe, and in the future could be a useful adjunct to determine if increased comfort correlates with decreased WOB in a similar patient population.

During VC-CMV we arbitrarily chose a clinician-set rate of 8 breaths/min, a constant-flow pattern, and an inspiratory time of 25% (inspiratory-expiratory ratio of 1:3). V_T ranged from approximately 400 mL to 700 mL, so the inspiratory flow rate range was 12–24 L/min in our patients with the VC-CMV mode. Some might suggest that a higher flow rate provides greater respiratory comfort, but a previous investigation showed that respiratory discomfort can occur both when the inspiratory flow is too low or

Table 3. Physiologic Variables*

	Baseline (pressure-regulated volume-control)	PSV	VC-CMV	p†
Systolic blood pressure (mm Hg)	125.6 ± 28.4	130.6 ± 26.9	125.6 ± 28.0	0.86
Diastolic blood pressure (mm Hg)	61.4 ± 16.0	63.1 ± 15.5	63.4 ± 16.3	0.94
Spontaneous respiratory rate (breaths/min)	15.6 ± 3.3	12.9 ± 3.3	13.4 ± 4.7	0.16
Heart rate (beats/min)	84.9 ± 11.9	85.9 ± 11.8	86.3 ± 9.9	0.94
Minute ventilation (L/min)	9.8 ± 2.5	8.0 ± 2.4	8.1 ± 2.1	0.08
Oxygen saturation (%)	97.7 ± 2.1	97.8 ± 2.4	98.0 ± 2.0	0.94

*All values are mean ± SD. Noninvasively measured physiologic variables were not significantly different from baseline, at the end of 30 min of pressure-support ventilation (PSV), or at the end of 30 min of volume controlled-continuous mandatory ventilation (VC-CMV).
†The p values refer to the comparison of baseline to PSV and VC-CMV, via 1-way repeated measures analysis of variance.

too high.[14] We used a constant-flow (square-wave) pattern during VC-CMV. Other investigators have studied the response to different flow patterns. One study found that a decelerating-flow pattern had lower symptom scores than did a sine-wave or square-wave pattern. The symptom score in that study was a conglomeration of 7 scores (cough, wheezing, dyspnea, chest pain and tightness, substernal irritation, headache, and fatigue).[15]

Studies of the effects of flow pattern on airway pressure and WOB have yielding conflicting results. Yang and Yang reviewed the literature and discovered that 2 studies found WOB to be equal with a decelerating-flow or a square-wave pattern, one study found WOB higher with a decelerating-flow pattern, and one found WOB higher with the square-wave pattern.[15] We chose a square-wave pattern because this pattern is available on ICU, transport, and home ventilators. Also, we found that PSV was significantly more comfortable than PRVC, which uses a decelerating-flow pattern. Although both PSV and PRVC use decelerating-flow patterns, the clinician-set inspiratory-expiratory ratio and V_T in PRVC do not allow the flow to increase with an increase in patient demand.

PSV may have been perceived more comfortable than VC-CMV because the patient is allowed to control the timing of the ventilation and interact with the delivered pressure to set the inspiratory flow, V_T, and inspiratory-expiratory ratio. The perception of greater comfort does not imply that PSV routinely decreases WOB. Our finding about comfort is consistent with that of Girault et al,[5] who studied noninvasively ventilated patients, although their study found that even though comfort was better with PSV, WOB was reduced more with VC-CMV. In that study the mean V_T during VC-CMV was 11 mL/kg, whereas we used 8 mL/kg. The study by Girault et al was performed almost 10 years earlier than ours, and since then the average V_T has been decreased, to decrease the risk of ventilator-induced lung injury.[16]

The 3 patients who preferred VC-CMV over PSV all required pressure support of $>$ 20 cm H_2O to achieve a minimum V_T of 8 mL/kg. This might indicate that high pressure can be uncomfortable, which is consistent with the findings of Vitacca et al, who found a U-shaped relationship between the level of pressure support and patients' perception of comfort; that is, the higher and lower extremes of pressure were associated with worse discomfort.[11]

Clinicians have become increasingly aware of the risk of harm from excessive sedation. Oversedation of mechanically ventilated patients can increase the duration of ventilation and ICU stay.[8,9,17] Because our study was designed with only 30 min in each mode, we cannot make any definitive conclusions regarding the need for pharmacologic sedation. We hypothesize, though, that the greater the discomfort associated with the ventilator mode, the greater the need for sedation. This could be evident even in delirious patients who are unable to communicate their level of respiratory discomfort. A future study could observe patients for a few days in each mode and draw firmer conclusions regarding sedation.

Conclusions

In a selected group of patients, PSV was significantly more comfortable than VC-CMV. Because we compared only intubated patients using specific ventilator settings, we cannot conclude whether the same results apply to other populations, such as those with tracheostomy, or to other modes, such as volume-support or proportional-assist. In addition, our data cannot determine the impact of respiratory comfort on pharmacologic sedation needs.

It is clear that patient comfort is an essential component of medical critical care. Clinicians can use this information when choosing ventilation modes for intubated patients.

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