Non invasive spontaneous dual ventilation in critically ill patients with chronic obstructive pulmonary disease

Khaled Hussein *

Assiut University Hospital, Faculty of Medicine, Assiut University, Assiut, Egypt

Received 12 July 2015; accepted 31 August 2015
Available online 1 October 2015

Abstract  Background: Effective non-invasive ventilation (NIV) is dependent on optimal ventilator settings for alveolar ventilation. Volume-assured pressure support (VAPS) is a mode of servoventilation, providing constant automatic adjustment of pressure support (PS) to achieve a target ventilation. Our aim is to evaluate the effectiveness of the new dual spontaneous mode of ventilation named intelligent volume assured pressure support (iVAPS) in comparison with conventional pressure support using S/T mode in patients with acute hypercapnic respiratory failure due to acute exacerbation of COPD.

Patients and methods: Forty patients with hypercapnic respiratory failure and respiratory acidosis due to acute exacerbation of COPD after failure of conventional medical treatment including oxygen therapy were recruited into the study. Patients were categorized into two groups, Group I ventilated with S/T mode and Group II ventilated with iVAPS mode. Patients were fitted with an oronasal mask (Ultramirage, ResMed) connected to VPAP ST (ResMed).

Results: Both groups were comparable on admission. The successful outcome was achieved in 15 patients (75%) in the PS group vs 16 patients (80%) in the iVAPS group. Both groups show significant (p < 0.01) improvement after 1 h NIV compared with pre-ventilatory level in respiratory rate (25.7 ± 1.6 vs 34.5 ± 1.8 for PS and 27.9 ± 4.8 vs 34.6 ± 1.3 for iVAPS) without significant difference between the two groups. In the iVAPS group, there were a significantly (p < 0.01) higher pH (7.34 ± 0.02 vs 7.31 ± 0.02 for PS group) and significantly (p < 0.001) lower PaCO2 (74.00 ± 2.3 vs 79.00 ± 3.7 for PS group) after 1 h NIV. There was a significant (p < 0.01) higher minute ventilation and significant (p < 0.001) lower peak inspiratory pressure in the iVAPS group after 1 h, and 6 h NIV.

Abbreviations: ABGs, arterial blood gases; AVAPS, average volume assured pressure support; COPD, chronic obstructive pulmonary disease; EPAP, expiratory positive airway pressure; FiO2, Fraction of inspired oxygen; IPAP, inspiratory airway pressure; iVAPS, intelligent volume-assured pressure support; Va, alveolar ventilation; VE, minute ventilation; NIV, non-invasive ventilation; PaCO2, Partial pressure for arterial carbon dioxide; PaO2, Partial pressure for arterial oxygen; PIP, peak inspiratory pressure; PS, pressure support; PCO2, transcutaneous partial pressure of CO2; RR, respiratory rate; SpO2, Oxygen saturation measured by pulse oximetry; VAPS, volume-assured pressure support

Tel.: +20 1006184912
E-mail address: khalidhussein@yahoo.com

Peer review under responsibility of The Egyptian Society of Chest Diseases and Tuberculosis.

http://dx.doi.org/10.1016/j.ejcdt.2015.08.016
0422-7638 © 2015 The Author. Production and hosting by Elsevier B.V. on behalf of The Egyptian Society of Chest Diseases and Tuberculosis. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Introduction

Noninvasive ventilation (NIV) has gained increasing acceptance as a way to avoid intubation and improve outcomes in selected patients with acute respiratory insufficiency [1]. Compared with optimum medical treatment plus oxygen therapy, NIV can reduce duration of intensive care unit stay and decrease complication in patients with chronic obstructive pulmonary disease (COPD) exacerbations [2].

Prospective randomized controlled trials of the use of NIV in acute exacerbation of COPD have been performed in a variety of different locations and healthcare systems and in patients with exacerbations of varying severity. A meta-analysis of these studies has shown more rapid improvements of in respiratory rate and pH, a reduction in the need for intubation and improved survival, reduced complications and length of hospital stay [3].

Pressure support (PS) can assist spontaneous ventilation and can be used in-patients with stable ventilatory requirements or during weaning. Once breath is initiated, pressure rises rapidly to a preset plateau where it is held for the duration of inspiration. The end of inspiration occurs when inspiratory flow falls below a certain level, usually 25% of peak inspiratory flow [4]. In most new ventilators, there are different levels of flow cycling that can be adjusted and not fixed. The patient therefore determines respiratory frequency and timing of each breath and if the patient fails to make respiratory effort, no respiratory assistance will occur [5]. Tidal volume is variable from breath to breath.

Volume assured pressure support (VAPS) is a new spontaneous dual mode using closed loop technique to obtain target tidal volume or alveolar ventilation with variable pressure support from breath to breath [6]. Two generations of VAPS are developed: average volume assured pressure support (AVAPS) with target tidal volume and variable pressure support; and intelligent volume assured pressure support (iVAPS) with target alveolar ventilation (Va) and variable pressure support.

In iVAPS, patients receive the minimum pressure required to maintain optimal Va and hence it is called intelligent volume assured pressure support [7].

Objective

To evaluate the new dual spontaneous mode of ventilation named intelligent volume assured pressure support (iVAPS) in comparison with conventional pressure support using S/T mode in patients with acute hypercapnic respiratory failure due to acute exacerbation of COPD.

Patients and methods

The study was conducted from June 2013 to January 2015 at Respiratory intensive care unit of Assiut university hospital.

Patients

Patients were offered enrollment into the study if they had acute hypercapnic respiratory failure due to acute exacerbation of COPD despite standard medical treatment including O2 therapy via venturi mask delivering FiO2 35% with worsening dyspnea and at least one of the following: (1) pH < 7.35 but > 7.10; (2) SpO2 < 90%; (3) Respiratory rate > 30 breath/min.

Patients were excluded if they met any of the following criteria: shock (mean blood pressure < 60 mmHg); upper airway obstruction; facial trauma; bulbar paralysis; haemoptysis; upper gastrointestinal bleeding; polycythemia; serum albumin < 30 gm/L; hypokalemia; severe underlying illness likely to be terminal as hepatocellular or renal failure.

Patients were categorized into two groups, Group I ventilated with S/T mode and Group II ventilated with iVAPS mode.

Introduction of non invasive ventilation (NIV)

Patients were fitted with oronasal mask (Ultramirage mask, ResMed) connected to VPAP-ST(ResMed). Group I was adjusted to S/T mode which is a combined mode; pressure support (S) and pressure control (Timed or T). PS was begun at an expiratory pressure (EPAP) of 4 cm H2O and increased to maximum 8 cm H2O according to PaCO2 level where increasing EPAP help CO2 wash, and inspiratory pressure (IPAP) set at a level that maintains IPAP – EPAP ≥ 8 cm H2O as a pressure support. Then IPAP level was increased to maintain tidal volume 8 ml/kg and O2 saturation > 90%. We try to set IPAP not more than 20 cm H2O to prevent gastric insufflation.

Timed mode (T) in S/T is a time triggered pressure limited, time cycled mode (pressure controlled ventilation). This ensures that patients will receive a minimum number of breaths per minute in the event that the spontaneous breathing rate drops below the rate setting. If the patient fails to initiate an inspiration within the interval determined by rate control, the unit triggers a timed breath resulting in a pressure controlled (pressure limited, time cycled) breath at the Set IPAP level (equal IPAP in S mode). The duration of each timed breath is controlled by an inspiratory time control. Respiratory rate was set at 15 breaths/min.

Group II was adjusted to iVAPS mode. Adjust EPAP as in Group I. iVAPS settings included height, patient target rate, target alveolar ventilation (Va), minimum and maximum PS.
Non invasive spontaneous dual ventilation in patients with COPD

Target rate is adjusted at 15 breath/min. Va was adjusted provided that tidal volume is 8 ml/kg of ideal body weight (IBW). Minimum PS at 8 cm H2O, and maximum PS at 16 cm H2O.

In both modes, FiO2 was adjusted to maintain O2 saturation ≥90%, trigger was adjusted at low set, cycle at high set, Ti max at 2 sec, Ti min at 1 sec, and rise time at 200–300 ms. Aerosolized bronchodilator therapy was delivered by temporarily interrupting ventilatory assistance and using standard nebulizers.

**Monitoring of both groups**

A strict observation and monitoring through the first hour of initiation of NIV of the following:

1. Continuous monitoring of Heart rate, respiratory rate, blood pressure, and SpO2.
2. ABG analysis: obtained by blood sample from radial artery and analyzed using automated blood gas analyzer.
3. Mechanical parameters: Tidal volume (VT), minute ventilation (VE), Peak inspiratory pressure (PIP), and respiratory rate (RR).

Follow up of these parameters at 6 h, 24 h and before discontinuation of NIV. Through this period of observation, the presence of one major criterion was considered as an indication for immediate intubation while the presence of two minor criteria at the end of first hour was considered to indicate the need for intubation [8].

- Major criteria for intubation were: (a) Respiratory arrest, (b) Haemodynamic instability with systolic pressure less than 70 mmHg, and a heart rate of 50 beats/min or less, and (c) Coma.
- Minor criteria of intubation were, (a) A respiratory rate more than 35 breaths/min and higher than the value recorded on admission, (b) An arterial pH ≤7.30 and lower than the value recorded on admission, (c) A PaO2/FiO2 less than 200 despite oxygen supplementation, and (d) Deterioration of one or more points of the neurological scale of Kelly and Matthay [9].

**Outcome measures**

Successful treatment was defined as objective improvement during NIV, included the following changes from spontaneous breathing: (1) pH > 7.35, (2) Decrease in PaCO2 of >15–20%, (3) SaO2 with or without oxygen) of ≥90%, (4) A decrease of ≥20% in respiratory rate compared with spontaneous breathing, and (5) Normal sensory state. Subjective criteria included improvement of dyspnea and the patient’s comfort [10].

Failure is defined as the patient required intubation by fulfillment of one major criterion at any time or two minor criteria after 1 h NIV.

**Discontinuation of NIV**

When clinical stability was achieved, which was defined as respiratory rate less than 24 breaths/min, a heart rate of 90 beats/min, improved awareness, compensated normalized pH values, with adequate SaO2 at low percentage of inspired O2 (3 l)[11].

**Statistical analysis**

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS-version 16). Results were given as a mean ± SD for numerical data and as frequency using chi-square test for nominal data. Groups were compared by using t-test for numerical data (paired inside each group, and unpaired to compare both groups at different points). Differences were considered significant when p < 0.05.

**Results**

Forty patients were enrolled and included 20 patients in Group I as well as 20 patients in Group II.

Demographic and baseline data of both groups are shown in **Table 1**. There was no significant difference between the two groups. The successful outcome was achieved in 15 patients (75%) in the PS group Vs 16 patients (80%) in the VAPS group as shown in Fig. 1.

**Figure 1** The outcome of both groups.
significantly \( p < 0.001 \) lower \( \text{PaCO}_2 \) in Group II after 1 h ventilation and up to 24 h ventilation. No significant differences were found in oxygenation between both groups at any time.

Mechanical parameters of both groups are compared in Tables 2 and 3. There was a significant \( p < 0.01 \) higher minute ventilation and significant \( p < 0.001 \) lower peak inspiratory pressure in Group II after 1 h, and 6 h ventilation.

Fig. 6 shows a significant positive correlation between minute ventilation and \( pH \) after 1 h ventilation in Group I (a) \( (r = 0.798; \text{and } p = 0.000) \) and Group II (b) \( (r = 0.575; \text{and } p = 0.008) \).

**Discussion**

Effective non-invasive ventilation is dependent on optimal ventilator settings to maximize clinical benefit and patient tolerance. The proper use of NIV in appropriately chosen patients with COPD can improve quality of life and increase survival [12].
Intelligent volume-assured pressure support (iVAPS) is a hybrid mode of servoventilation, providing automatic adjustment of PS to achieve a target alveolar ventilation [7].

The results of our prospective randomized controlled trial revealed that iVAPS, was not inferior to standard PS ventilation regarding improvement of respiratory rate, pH, hypercapnia, and oxygenation.

The first study that exists in the medical literature describing the benefits of using NIV with AVAPS in acute hypercapnic respiratory failure revealed statistically significant differences in favor of the AVAPS group in consciousness, PaCO2 and peak inspiratory positive airway pressure. However, no significant differences in terms of length of stay or days on NIV were observed [11].

Our results demonstrated a significantly higher pH and significantly lower PaCO2 in the iVAPS group after 1 h ventilation. This is consistent with Briones Claudett et al [11] who revealed statistically significant differences in favor of the AVAPS group in pH and PaCO2. Oxygenation in our study revealed no advantage of iVAPS mode and appreciate that the main advantage of this dual mode is improvement of alveolar ventilation and hence its indication in hypercapnic respiratory failure. This is consistent with Briones Claudett et al [10] who recorded a PaO2 of 83.1 ± 17.8 and 78 ± 19.1 mmHg for ST and iVAPS groups respectively after 1 h NIV.

VAPS was studied for stable hypercapnic COPD patients in a limited number of previous recent clinical trials. Ekkernkamp [13] compared non invasive iVAPS mode and high intensity PS in forty patients and revealed that there was a greater decrease in transcutaneous partial pressure of CO2 (PtCO2) during iVAPS. On the other hand, other studies demonstrated no advantage of AVAPS versus PS in chronic stable COPD patients [14,15].

In chronic patients with obstructive sleep apnea and alveolar hypventilation syndrome, some authors reported a rapid improvement in PaCO2 and sleep quality using VAPS [16,17] while others reported no difference between AVAPS and PS [6].

As regards mechanical parameters, our results demonstrated that minute ventilation is higher and more stable (as deduced from lower standard deviation) in the iVAPS group. Minute ventilation is positively correlated to pH and this illustrates the greater improvement of respiratory acidosis in the iVAPS group.

Figure 6 Correlation between minute ventilation and pH after 1 h ventilation in Group I (a) and Group II (b) VE = minute ventilation; $r = \text{correlation coefficient}; p = \text{significance}$. 

(a) 

(b)
Peak inspiratory pressure is significantly lower and more variable (as deduced from higher standard deviation) in the iVAPS group. This variability is due to variable PS from breath to breath and hence lower total pressure than fixed level recorded in the PS group. In a recent study comparing iVAPS with standard PS, iVAPS was as effective as standard PS with significantly ($p = 0.001$) lower median PS [7]. Also, Briones Claudett et al [11] recorded a statistically significant reduction of peak inspiratory pressure in the AVAPS group ($p = 0.005$).

Conclusion

Non invasive spontaneous dual ventilation using intelligent volume assured pressure support (iVAPS) is characterized by stable alveolar ventilation with lower and variable inspiratory pressure and earlier improvement of respiratory acidosis when compared with conventional pressure support.

Conflict of interest

The author had no conflict of interest.

References