Ventimask in exacerbation of chronic obstructive pulmonary disease and mild acidosis before starting with bilevel positive airway pressure

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Abstract

Patients with chronic obstructive pulmonary disease (COPD) during an episode of acute or acute on chronic respiratory failure due to infection present a special problem with regard to the relief of hypoxia. In a prospective, randomized, multicenter controlled trial, we evaluated the efficacy of oxygen delivery by Ventimask compared with Venturi mask in patients affected by exacerbation of COPD and mild acidosis before starting with non-invasive bilevel-positive airway pressure (PAP). The study involved 80 patients with exacerbation of COPD divided in two groups: Group A=40 patients randomized to Ventimask plus standard therapy and Group B=40 patients randomised to Ventury mask plus standard therapy. The primary endpoint was to evaluate the efficacy of oxygen therapy with Ventimask compared with Venturi mask in terms of avoiding the need for non-invasive bilevel-PAP during the 1st h and reducing $PaCO_2$ retention. Twenty-five patients (62%) started with bilevel-PAP in Group A and 28 (70%) in Group B (not significant). There were no significant changes in arterial blood gases values between the two groups. In Group A, pH and $PaCO_2$ were 7.32±0.11 and 68.5±13.6 mmHg at admission, and 7.33±0.05 and 64.8±4.9 mmHg after 1 h (not significant). In Group B, pH and $PaCO_2$ were, respectively, 7.32±0.11 and 65.7±13.6 mmHg at admission, and 7.33±0.03 and 64.0±5.5 mmHg after 1 h (not significant). Our conclusion did not show any significant differences between the two oxygen masks delivery in terms of preventing the need of bilevel-PAP and reducing $PaCO_2$, despite the trend towards a reduction of the utilization of non-invasive positive pressure ventilation was in favor of Ventimask.

Introduction

Patients with chronic obstructive pulmonary disease (COPD) during an episode of acute or acute on chronic respiratory failure due to infection present a special problem with regard to the relief of hypoxia. Oxygen therapy to correct the hypoxemia becomes necessary, but it may sometimes lead to a reduction in ventilation and may worsen the inequality of ventilation/perfusion ratio caused by release of hypoxic vasoconstriction.[1] Various attempts to overcome this adverse effect, namely a dangerous rise in the arterial carbon dioxide tension ($PaCO_2$), include oxygen by nasal probes or catheter or simple disposable masks based on the Venturi principle which allow for fixed concentrations of oxygen. Ventimask (Flexicare Medical Ltd, Mountain Ash, Wales, UK) is a fixed mask that permits a better adhesion to the face compared with a Venturi mask. In addition, it could decrease a surplus gas through flushing out of expired CO_2 thus limiting CO_2 rebreathing.[2] Our aim was to evaluate the new mask of oxygen delivery with regard to the pathophysiologic effects.

Materials and Methods

In a prospective, randomized, controlled trial, we studied 80 consecutive patients admitted to two different Emergency Departments (Sant'Anna Hospital, Como, and San Paolo Hospital, Milan) after an episode of acute hypercapnic respiratory failure due to exacerbation of COPD. pH ranged from 7.32 to 7.35.

Inclusion criteria were: i) exacerbation of COPD (where diagnosis of COPD is made on the basis of history, symptoms and/or FEV1/FVC <50% of predicted values);[3,4] ii) age >18 years old; iii) dyspnea at rest with respiratory rate >25 breath/min or signs of respiratory distress; iv) $PaCO_2$> 45 mmHg; v) pH between 7.32-7.35. Exclusion criteria were: i) diagnosis of other causes of severe acute respiratory failure; ii) unstable angina or acute myocardial infarction; iii) severe respiratory acidosis (pH<7.3); iv) hemodynamic instability; v) severe arrhythmias; vi) Kelly score >3; vii) respiratory arrest or need of immediate endotracheal intubation (ETI); viii) pregnancy.

In order to assess patients with acute dyspnea, we are used to perform multi-area ultrasound (lung, heart and compressive ultrasound of legs) for ruling out other causes of acute respiratory failure such as acute cardiogenic pulmonary edema or thromboembolic pulmonary disease.

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Study design

Between January 2010 and December 2013, 80 patients affected by an acute or acute on chronic respiratory failure caused by exacerbation of COPD who met the above mentioned inclusion criteria and gave their consent were randomized into two groups: Group A was treated with standard therapy plus Ventimask with an inspiratory fraction of oxygen (FiO_2) between 28 to 35% set in order to maintain peripheral oxygen saturation (SpO_2) from 88% to 92 % for 1 h;[5] Group B was treated with standard therapy plus Venturi mask with FiO_2 from 28 to 35% set in order to maintain SpO_2 from 88% to 92 % for 1 h.

The initial pharmacological therapy in both groups followed COPD treatment guidelines [inhaled bronchodilators (four puff of albuterol every 20 min) plus steroid iv (metilprednisolone 60 mg iv)].[4] Arterial blood analysis was sampled at the emergency room (ER) at time 0 and 60 min after the beginning of oxygen therapy. Arterial blood pressure, visual electrocardiography and SpO_2 were monitorized continuously.

When patients entered the ER, arterial blood gases at time 0 were performed after 5 min of wash out (without oxygen). Indication for starting bilevel-positive airway pressure (PAP) during exacerbation of COPD were: $PaCO_2$> 45 mmHg and pH<7.35 despite 1 h of pharmacologic therapy. Indication for ETI were: respiratory arrest, intolerance to mask, need to protect airways, increase $PaCO_2$ >20% in spite of non-invasive ventilation (NIV).

Randomization

The randomization was realized by using opaque sealed envelopes. Each center received a number of envelopes corresponding to the

number of patients to enrol (for each center the randomization was organized in groups 1:1 to each technique).

The study involved 80 patients divided into two well balanced groups of treatment. We hypothesized that 25% of patients randomized to standard therapy (Ventury mask) could reach the primary end-point (the need of NIV) during the first hour and that the intervention treatment (Ventimask) could reduce the proportion of 2/3, corresponding to 8.3%. Based on 80% power to detect a significant difference with alpha error ≤0.05 two-tailed, 39 patients (78 in all) were required for each study arm. The study population for the statistical analysis was formed by all randomized subjects who did not withdraw the study consent before the application of the technique.

Results

The baseline characteristics of the patients are shown in Table 1. Age of patients was similar in the two groups and did not influence the need of bilevel-PAP.

Twenty-five patients (62%) started with bilevel-PAP in group A and 28 (70%) in group B (not significant) because they did not improve gas exchange after 1 h of oxygen and pharmacologic therapy (Table 2).

Our results did not show any significant changes of arterial blood gases values between the two groups and after 1 h. In Group A, pH and $PaCO_2$ were 7.32±0.11 and 68.5±13.6 mmHg, at admission, and 7.33±0.05 and 64.8±4.9 mmhg after 1 h. In Group B, pH and $PaCO_2$ were 7.32±0.11 and 65.7±13.6 mmHg at admission, and 7.33±0.03 and 64.0±5.5 mmHg after 1 h (Table 3).

Respiratory rate decreased significantly in both groups after 1 h ($P<0.01$), whereas SpO_2 increased significantly ($P<0.01$).

There were not any significant differences in both groups with regard to FiO_2.

Discussion

In individuals with COPD who receive supplemental oxygen, carbon dioxide accumulation may occur through three main mechanisms.

First, ventilation/perfusion matching: underventilated lung usually has a low oxygen content which leads to localized vasoconstriction limiting blood flow to that lung tissue. Supplemental oxygen abolishes this constriction, leading to poor ventilation/perfusion matching. This redistribution of blood to areas of the lung with poor ventilation reduces the amount of carbon dioxide eliminated from the system.[6]

Second, the Haldane effect: most carbon dioxide is carried by the blood as bicarbonate, and deoxygenated hemoglobin promotes the production of bicarbonate. Increasing the amount of oxygen in the blood by administering supplemental oxygen reduces the amount of deoxygenated hemoglobin, and thus reduces the capacity of blood to carry carbon dioxide.[7]

Third, respiratory homeostasis: in healthy individuals, a rise in carbon dioxide causes an increase in the drive to breathe. However, in some COPD patients, this response has been blunted, leaving low oxygen levels as the main stimulus of respiration (hypoxic drive). Hence, giving supplemental oxygen reduces their stimulus to breathe, causing hypoventilation, and allowing carbon dioxide to accumulate in the body.[8] To allow for more precise control of the rise of PaO_2, mainly in patients with exacerbation of COPD, the Venturi principle determining fixed concentrations of 24-28-35 and more oxygen was adopted. Simultaneously this avoided rebreathing by the high air flow entering the mask.[9] Patients with acute on chronic respiratory failure due to exacerbation of COPD and a mild respiratory acidosis are at risk for both hypoxemia and worsening hypercapnia. In these patients, the minimal safe goal of oxygen therapy can be accepted as the achievement of a SpO_2 of 90-92%.[9,10] At the same time, patients have to be submitted to pharmacological therapy by inhaled bron-

Table 1. Baseline characteristics of the patients.

	Group A	Group B	P
Baseline characteristics			
Age (years)	74.8±6.9	76.8±6.6	0.98
Male/female ratio	22/18	24/16	
Condition (n)			
APACHE II score	17.4±2.6	18.9±4.6	0.23
History (n)			
Chronic heart failure	6 (15)	4 (10)	0.50
Hypertension	16 (44.4)	16 (44.4)	0.99
Diabetes	10 (25.0)	14 (38.8)	0.72

Values in brackets are expressed as percentage.

Table 2. Patients' outcomes.

	Group A	Group B	P
ETI (n)°	3 (7.5)	2 (5)	ns
In-hospital death (n)°	1 (2.5)	0 (0)	ns
Length of hospital stay (days)#	13 (7-19)	14 (6-20)	ns
bilevel-PAP (n)°	25 (62)	28 (70)	ns

ETI, endotracheal intubation; PAP, positive airway pressure; ns, not significant. °Values in brackets are expressed as percentage; #values in brackets are expressed as range.

Table 3. Physiologic measurements at baseline and after 1 hour.

	Group A	Group B	P
Baseline			
Respiratory rate (breaths/min)	32.9±4.5	34.8±4.4	0.21
Arterial pH	7.32±0.11	7.32±0.11	0.55
$PaCO_2$ (mmHg)	68.5±13.6	65.7±13.6	0.26
PaO_2/FiO2 ratio	183±64	189±53	0.27
Bicarbonate (mEq)	34±4	33±6	0.76
Heart rate (beats/m)	90±20	93±23	0.71

	Baseline	1 h	Baseline	1 h	Group A	Group B
Baseline *vs* 1 h						
Respiratory rate (breaths/min)	32.9±4	26.3±5	34.8±4	27.2±4	<0.01	<0.01
Arterial pH	7.32±0.1	7.33±0.5	7.32±0.1	7.33±0.3	ns	ns
$PaCO_2$ (mmHg)	68.5±13	64.8±5	65.7±13	64.0±5	ns	ns
PaO_2/FiO2 ratio	183±64	217±78	189±53	221±60	<0.01	<0.01
SpO_2 (%)	83.6±4	92.1±3	85.1±7	92.0±2	<0.01	<0.01

SD, standard deviation; ns, not significant. Values are expressed as mean±standard deviation.

chodilators and steroid iv. When the topic and systemic pharmachological therapy do not improve pH and $PaCO_2$ after 1 h, patients have to start with bilevel-PAP. Approximately 20% of patients who are acidotic at the time of arrival in ER will correct their pH completely into the normal range just with standard medical therapy, including, most importantly, properly controlled oxygen therapy. Therefore, the delay before starting NIV within 1 h of pharmacological treatment is reasonable.[11]

A limit of our study was that we did not take into consideration the pharmacologic treatments and oxygen administration to the patients at home and during the transport to the ER.

Conclusions

The aim of our study was to evaluate the efficacy of a new mask of oxygen delivery, Ventimask, that might relief arterial hypoxemia without worsening $PaCO_2$ but reducing the need of bilevel-PAP in patients with exacerbation of COPD and mild acidosis. Our results showed that both modalities of oxygen delivery are effective in relieving hypoxemia without any significant change in $PaCO_2$, but they were unable to prevent the need to begin NIV. In any case, the trend toward a reduction of NIV utilization was in favor of Ventimask.

References

1. Muir JF, Similowski T, Derenne JP. Oxygen therapy during acute respiratory failure of chronic obstructive pulmonary disease. In: Derenne JP, Whitelaw WA, Similowski T, eds. Acute respiratory failure in chronic obstructive pulmonary disease. New York, NY: Marcel Dekker Publ.; 1996. pp 579-90.
2. Poh Soo C. Oxygen administration by Ventimask in patients with respiratory failure. Singap Med J 1969;10:178-181.
3. Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: executive summary. Am J Resp Crit Care 2007;176:532-55.
4. Quon BS, Gan WQ, Sin DD. Contemporary management of acute exacerbations of COPD: a systematic review and metaanalysis. Chest 2008;133:756-66.
5. O'Driscoll BR, Howard LS, Davison AG. BTS guideline for emergency oxygen use in adult patients. Thorax 2008;63:1-68.
6. Dunn WF, Nelson SB, Hubmayr RD. Oxygen induced hypercapnia in obstructive pulmonary disease. Am Rev Respir Dis 1991;144:526-30.
7. Christiansen J, Douglas CG, Haldane JS. The absorption and dissociation of carbon dioxideby human blood. J Physiol 1914;48:244.
8. Berry RB, Mahutte JL, Kirsch DW, et al. Does the hypoxic ventilatory response predict the oxygen-induced change in ventilation and ventilatory drive in COPD. Am J Resp Crit Care 1997;155:609-14.
9. Bone RC, Pierce AK, Johnson RL. Controlled oxygen administration in acute respiratory failure in chronic obstructive pulmonary disease. Am J Med 1978;65:896.
10. Celli BR, MacNee W. ATS/ERS Task Force. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J 2004;23:932.
11. Plant PK, Owen JL, Elliott MW. One year period prevalence study of respiratory acidosis in acute exacerbation of COPD: implication for the provision of non-invasive ventilation and oxygen administration. Thorax 2000;55:550-4.