Comparison rebreathing Carbon Dioxide 3 nasal mask during application of CPAP

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the fraction described *end-tidal* carbon dioxide ($F_{ET}CO_2$) caused a prototype mask (Air Products) for applying different levels of positive voltage pre continuous airway (CPAP) and compared to that developed by two nasal masks commonly used (Profile Lite and ComfortClassic, Respironics). In 11 healthy volunteers, 12 patients with obstructive apnea-hypopnea syndrome during sleep of a serious nature and 12 sick hypercapnic mos, was measured randomly in three days Su- cesivos, the $F_{ET}CO_2$ 3 min after nasal CPAP 4, 5, 6,

8, 10, 15 and 20 cmH_2 Or with each of the masks. Although a progressive reduction in F was achieved in all cases $_{ET}CO_2$ by increasing the pressure, it was higher with the veneer MAS prototype for any level of pressure. In the 3 study groups pressures achieved in the prototype mask they were similar to those generated by the CPAP machine. In conclusion, the lower concentration of carbon dioxide during nasal mask application proto- type suggests that causes less rebreathing.

Keywords: *nasal mask. CPAP. Sleep apneas. Mechanic ventilation. Rebreathing. CO_2.*

Comparison of Carbon Dioxide Rebreathing During Application of Continuous Positive Airway Pressure With 3 Types of Nasal Mask

A comparison is made Between the end-tidal fractional concentration of carbon dioxide ($F_{ET}CO_2$) During application of Obtained varying levels of continuous positive airway pressure (CPAP) mask with a prototype (from Air Products) and $F_{ET}CO_2$ Obtained with 2 commonly used nasal masks (Profile Lite and ComfortClassic from Respironics). The nasal $F_{ET}CO_2$ Measured was on 3 consecutive days in 11 healthy volunteers, 12 Patients With severe obstructive sleep apnea hypopnea syndrome-, and 12 hypercapnic patients. A mask was different on each day randomly Assigned and the $F_{ET}CO_2$ after 3 minutes was Measured of CPAP at 4, 5, 6, 8,

10, 15, and 20 cm H_2O., Although in all cases a progressive reduction in $F_{ET}CO_2$ Increasing was Observed With CPAP, the effect was greatest With the prototype mask at all pressures. In the 3 different study groups the pressures Obtained With the prototype mask similar to Those Were generated by the CPAP machine. In conclusion, the lower concentration of nasal CO_2 Obtained using the prototype mask Suggests That it causes less rebreathing.

Key words: *Nasal mask. Continuous positive airway pressure. Sleep apnea. Mechanical ventilation. Rebreathing. CO_2.*

Introduction

Over recent years there has been an increasing development of ventilation mask na- salt, both in continuous mode airway (CPAP) in positive pressure ventilation with continuous positive pressure intermittently. Furthermore, the syndrome apneahypopnea obstructive sleep (OSAS) due to its high prevalence [1] and better knowledge of their cardiovascular morbidity [2-5]

It is considered a health problem of the first magnitude. Although in our midst the availability of resources for diagnosis and treatment is li- mitada [6], It is expected that the increase in prescriptions tion of CPAP continue in the coming years. Lesser extent, ventilation nasal mask intermittent positive pressure has also experienced I mented considerable expansion, especially in pacient with hipercáp- chronic respiratory failure of diverse origin nica [7-10].

Therefore, certain technical aspects leakage monitoring [eleven], with the possibility of rebreathing in case of failure of equipment [12] and adaptation and tolerability of nasal masks increasing interest [13]. Specifically, and as before using any mask as CPAP system administration step is required to demonstrate that their air leakage is low and that rebreathing of carbon dioxide (CO_2) be within the range of pressures applied is minimal [13.14].

In our country it has developed a na- high-end mask salt (CM prototype, Metal Carbides, San Sebastian de los Reyes, Madrid) for use with CPAP equipment in the treatment of OSAHS.

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To date there has been a study in which it is verified that the prototype provides a mask leak flow rate suitable to prevent rebreathing ex- cessive CO_2 [15]. The next step in the process requires Ve- rification determine the percentage of CO_2 residual following exhalation while CPAP is used.

The objectives of this study were to describe the fraction *end-tidal* CO_2 (F_{ET} CO_2) originating with the prototype mask during application of different levels of CPAP in healthy subjects, patients with SA- HOS hypercapnic patients and chronic Latoria ventilated failure, and compared with those developed by two nasal masks are commonly used.

Method

healthy subjects, patients with severe OSAHS, and hypercapnic patients: 3 study groups were defined. Non-smoking volunteers were considered healthy, with no respiratory symptoms in the questionnaire of the European Coal and Steel Community (ECSC) [16], respiratory disease and cardio- vascular patients without prior known and normal spirometry Toria. For inclusion in the severe OSAHS group the presence of excessive daytime sleepiness (Epworth> 10) and an index apneahypopnea over 30 h was required $^{-1}$ measured by car- diorrespiratoria polygraphy. Hypercapnic group was composed of patients with blood pressure of CO_2 greater than 45 mmHg response pirando atmosphere air prior diagnosis (> 6 months) of chronic ventilatory in- sufficiency of thoracic box ca disease, neuromuscular, chronic obstructive pulmonary disease or hypoventilation syndrome.

Exclusion criteria prior diagnosis or evidence of blebs in a conventional chest x-ray, the presence of other associated respiratory diseases das any heart disease, glaucoma or the existence of clinical instability or change in the usual treatment were considered in 2 weeks prior.

The sample size was estimated from a previous study in which, from an F_{ET} CO_2 mean baseline of 4.5% were regarded as significant increases of 1.5% [17]. For detecting changes of this magnitude with an alpha error of 0.05 and a beta error of 0.95, the minimum number of cases in each study group should be 10. All participants signed informed consent and the study it was approved by the Ethics Committee of the Clinical Research center. All subjects performed a baseline spirometry with MasterScreen 4.2 (Jaeger, Würzburg, Germany), as recommended by the American Thoracic Society [18] and emple- ando as reference values ECSC [19].

The study rebreathing CO_2 It took place on 3 consecutive days, using randomly mask the proto- and 2 masks commonly used ports themselves Espinal equipped ries: Profile Lite and ComfortClassic (Respironics Inc., Pennsylvania, USA). After 30 minutes rest, the subjects were placed in supine position and are fitted the corresponding nasal mascari- lla verifying that there was no leakage. The mask is adapted by a corrugated pipe 2 m equipment REMstar Pro (Respironics). CPAP is applied with an ascending rate of 4, 5, 6, 8, 10, 15 and 20 cmH_2O over a period of 3 min for each level pres-. During the administration of CPAP it was verified directly to patients breathed with the mouth closed and maintained a regular breathing regime, with a fre- quency respiratory always less than 30 breaths / min. the F_{ET} CO_2 It was measured continuously from a probe na- salt by infrared absorption analyzer (Os- car II, Datex, Helsinki, Finland) (range 0-10.0%, accuracy: 1%; response speed: 75 ms). The analyzer was calibrated prior to performing ba each with a bolus of pure nitrogen and other gas with 4% CO_2, 16% oxygen and the rest nitrogen. The pressure generated by the CPAP the prototype mask was measured by a pressure transducer DWD (Jaeger) and a converter analogous Screenbox digital logical (Jaeger) connected to the output *Luer lock* the mask. Signals CO_2 REGISTERS rum and pressure in real time and continuously through LabVIEW (National instruments, Austin, Texas, USA) program, with a sampling rate of 100 MHz. For the purposes of analysis, they considered F_{ET} CO_2 and mask pressure reached in the last 20 s of each step of CPAP.

Statistic analysis

Data are presented as mean ± standard error of the mean. For comparisons between types of masks an analysis of variance with repeated measures, considered as a covariate the application sequence, and multiple comparison of means it was used *post hoc* by the Bonferroni test (SPSS version 11.0, SPSS Inc., Chicago, IL, USA). A value of $p < 0.05$ was considered significant.

results

Table I shows the general characteristics of the enrolled subjects are presented. The study was conducted in 11 healthy vol- unteers, 12 patients with severe OSA (apnea-hypopnea index: 49.3 ± 11.6 h^{-1}; arterial oxygen saturation mean nighttime: 90 ± 2%; arterial oxygen saturation night minimum: 74 ± 11%) and 12 hypercapnic patients (blood pressure of CO_2: 51 ± 4 mmHg; PaO: 62 ± 6 mmHg; pH: 7.41 ± 0.03). The OSAHS and hypercapnic groups were integrated degrees older subjects than healthy volunteers. Hypercapnic group had a rate higher than that of healthy subjects body mass, and among them was greater frequency of active smokers than in the other 2. In addition, forced vital capacity and forced expiratory volume in the first second of this group they were lower than in the other, both in absolute value and as a percentage of the reference value.

TABLE I
General characteristics of the patient groups

	healthy (N = 11)	SAHOS (N = 12)	Nonhypercapnic (N = 12)
Sex, male (%)	82	100	fifty
Age (years)	44 ± 2	63 ± 2[b]	65 ± 3[b]
Height (cm)	170 ± 3	166 ± 2	160 ± 3[b]
Weight (kg)	75 ± 5	83 ± 4	85 ± 5
BMI (kg / m^2)	25.6 ± 3.5	30.0 ± 4.8	33.0 ± 4.5[b]
active smokers (%)	0	0	18[b, c]
FVC (l)	4.50 ± 0.40	3.63 ± 0.21	2.14 ± 0.17[a, d]
FVC% predicted	110 ± 3	103 ± 4	77 ± 7[a, c]
FEV_1 (l)	3.71 ± 0.28	2.81 ± 0.27	1.42 ± 0.12[b, d]
FEV% theoretical	111 ± 4	99 ± 6	67 ± 10[b, c]
FEV_1/ FVC (%)	83 ± 2	77 ± 4	67 ± 6

Values are expressed as mean ± standard error of the mean. FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; BMI: body mass index; OSAHS apneahypopnea obstructive sleep syndrome.

[b] $p < 0.001$ vs. control group. [b] $p < 0.05$ vs. control group. [c] $p < 0.05$ vs. group OSAS. [d] $p < 0.001$ vs. SAHOS group.

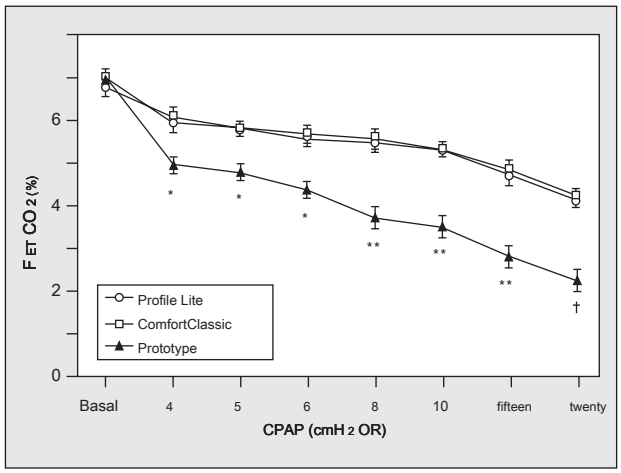

Fig. 1. Evolution of the fraction *end-tidal* CO_2 (F_{ET} CO_2) dif- ferent levels for continuous positive pressure airway (CPAP) employees located on all study subjects. The points correspond to the set for the covariable sequence and error bars stan- dard average. * P <0.01 compared to other masks at a similar level of CPAP. ** p <0.001 compared with the other masks at a ni- vel like CPAP.

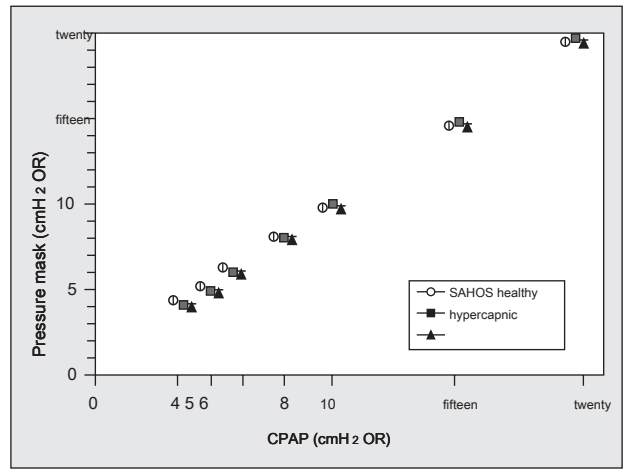

Fig. 2. Pressure reached the prototype mask applied during tion of continuous successive levels of airway pressure (CPAP) in the various groups of study positive pressure. OSAHS obstructive apnea-hypopnea syndrome during sleep.

the F_{ET} CO_2 I achieved after the application of dif- ferent pressure levels in all study patients are shown in Figure 1. 3 mascari- llas gradually reduced by increasing the CPAP pressure, which was already evident achieved from 4 cmH_2O (p <0.001 by MANOVA). However, for any pressure level decreased F_{ET} CO_2

It was more intense with the prototype mask with the other (fig. 1). In Table II the behavior of F is broken $_{ET}$ CO_2 in each of the groups de Estudios gave. 2 relative to conventional masks, the prototype mask achieved a more intense reduction of F_{ET} CO_2 from 4 cmH_2O Or in the hypercapnic group and from 8 cmH_2O Or in the other 2 study groups.

The pressures achieved in the prototype mask with the application of CPAP were similar in the three Gru pos study (Fig. 2). In no case they were observed significant di- ferences between the pressure supplied by the CPAP machine and inside the mask. Only the pressure developed in the mask with applying 6 cmH_2O from the ventilator was higher in the control group (6.3 ± 0.1 cmH_2O) in OSAHS (6.1 ± 0.0 cmH_2O; p = 0.032) and hipercáp- nico (6.1 ± 0.0 cmH_2O; p = 0.017).

Discussion

Our study confirms that the prototype nasal rilla masca- achieved properly transmit the pressure ge- nerada for CPAP in different groups of subjects and which causes less rebreathing CO_2 other commonly used masks. These findings emphasize the importance of choosing the mascari- llas both CPAP treatment as non-invasive ventilation tion [8]. Unlike ventilation in- intubation or tracheostomy tube, CPAP and noninvasive ventilation have as common characteristic the non hermetic nature of the system. This discontinuity between the ventilator and the airway is of great importance and can be justified in some

TABLE II

Fraction evolution *end-tidal* carbon dioxide (F_{ET} CO_2) in the different study groups

Group	Mask	Basal	CPAP (cmH_2O)						
			4	5	6	8	10	fifteen	twenty
healthy	Profile Lite	6.3 ± 0.2	5.9 ± 0.2	5.7 ± 0.3	5.4 ± 0.2	5.3 ± 0.3 $_{to}$	5.2 ± 0.3 $_{b}$	4.3 ± 0.3 $_{to}$	3.7 ± 0.3 $_{b}$
	ComfortClassic	6.6 ± 0.2	5.8 ± 0.2	5.7 ± 0.3	5.7 ± 0.2	5.6 ± 0.3 $_{b}$	5.1 ± 0.3 $_{to}$	4.6 ± 0.3 $_{b}$	3.7 ± 0.3 $_{b}$
	Prototype	6.8 ± 0.2	5.0 ± 0.3	5.0 ± 0.3	4.9 ± 0.3	3.8 ± 0.4	3.7 ± 0.3	2.9 ± 0.4	1.8 ± 0.3
SAHOS	Profile Lite	6.2 ± 0.3	5.7 ± 0.2	5.6 ± 0.3	5.4 ± 0.3 $_{to}$	5.4 ± 0.3 $_{b}$	5.2 ± 0.4 $_{to}$	4.7 ± 0.4	4.1 ± 0.4
	ComfortClassic	6.4 ± 0.3	5.5 ± 0.2	5.4 ± 0.3	5.3 ± 0.3	5.3 ± 0.3 $_{to}$	5.0 ± 0.4 $_{to}$	4.8 ± 0.4 $_{to}$	4.4 ± 0.4 $_{to}$
	Prototype	6.4 ± 0.3	5.0 ± 0.3	4.8 ± 0.3	4.2 ± 0.4	3.7 ± 0.4	3.5 ± 0.4	3.3 ± 0.4	3.9 ± 0.4
Hypercapnic	Profile Lite	7.7 ± 0.3	6.5 ± 0.4 $_{to}$	6.1 ± 0.4 $_{to}$	5.9 ± 0.4 $_{to}$	5.8 ± 0.4 $_{to}$	5.6 ± 0.4 $_{b}$	5.1 ± 0.4 $_{c}$	4.7 ± 0.4 $_{c}$
	ComfortClassic	7.9 ± 0.3	6.4 ± 0.4 $_{to}$	6.3 ± 0.4 $_{c}$	6.1 ± 0.4 $_{to}$	5.8 ± 0.4 $_{b}$	5.8 ± 0.4 $_{b}$	5.1 ± 0.4 $_{c}$	4.5 ± 0.4 $_{b}$
	Prototype	7.8 ± 0.4	4.9 ± 0.4	4.6 ± 0.4	4.2 ± 0.5	3.7 ± 0.5	3.6 ± 0.5	2.2 ± 0.4	2.0 ± 0.4

the means adjusted for the covariate sequence ± standard error of the mean is indicated.

CPAP: continuous positive pressure airway; OSAHS apneahypopnea obstructive sleep syndrome. Comparison of masks for the same level of CPAP: $_{to}$ p <0.05 vs. prototype mask; $_{b}$ p <0.01 vs. prototype mask; $_{c}$ p <0.001 vs. prototype mask.

cases ineffective treatment escape or misapplication of the contact surface between the mask and the patient.

Therefore, it is considered that a nasal mask must meet a basic set of requirements to be acceptable. Its design and structure must ensure that it is airtight and distensible compartment with low flow resistance and minimal dead space [8]. In addition, it should be easy to install, lightweight, Co- fashion, odorless and customizable, with different sizes [8,20].

To reduce the pressure exerted on the patient's face and prevent the development of cutaneous lesions lines, masks incorporate various materials, such as silicone gel or, relieving skin contact. Finally, do not forget the economic aspect, since the price is often a factor in choosing de- cisivo mask.

In addition to leakage, the possibility of rebreathing is one of the main problems the administration of CPAP or non-invasive ventilation via nasal masks. In the first case, the pa- cient breathe through a tube connecting the ma- chine with CPAP nasal mask and port Espinal tory. Under normal conditions the pressure generated by the CPAP machine creates a flow of fresh air through the tube that washes the CO_2 Exhaled through the exhalation port and minimizes rebreathing. However, it should be noted that the port Espinal tory also determines the level of pressure in the mask alcanza- do, since ports with high resistance reduce the flow necessary to generate pressure in the mask. There is an increased risk of reinha- tion when the machine is turned off [17], when low CPAP pressures are applied or when the flow provided by the machine is reduced by increased resistance of the tubing (which is exceptional nal) or the exhalation port, which is more usual and depends on their structural characteristics .

Regarding the possibility of rebreathing, the re- sults of this study confirm that the administra- tion of CPAP with any of the 3 masks analyzed lysed manages to reduce $F_{ET}CO_2$ as the pressure increases. Furthermore, it is found that for the same pressure ni- vel decreased $F_{ET}CO_2$ It is greater with the prototype mask with the other two analyzed das (fig. 1). In our view, this finding simply reflects that the leakage flow through the exhalation port of the prototype mask is greater than that supplied by the exhalation ports of the other 2 masks. In a previous study the leakage flow through the exhalation port of the prototype mask with those obtained through 2 expiratory ports tories similar to those built into masks Respironics Profile Lite and compared ComfortClassic [fifteen]. For this leak rate was collected in a canister of Serres and led to a rotameter, where the flow was measured. It was found that at pressures 10-20 cmH_2O Or the expiratory port of the prototype mask provided a leakage flow rate 4 l / min higher than the other [fifteen].

However, it is also important to note that the generation of a leak does not alter higher pressure generated in the prototype mask. In fact, in this study we have not observed significant differences between the pressure supplied by the CPAP machine and inside the mask prototype (Fig. 2). By contrast, Ferguson and Gilmartin [14] They have reported that an exhalation port Plateau type, similar to those incorporated in the masks Rados Profile Lite and ComfortClassic, the pressure reached in the mask was 1-3 cmH_2O less than that set in the ventilator. This differ- ent behavior probably means that this type of ports has a higher resistance than coupled to the prototype mask. In fact, in the study of Farré et al [17] It was verified that the exhalation ports Plateau and Whisper Swivel (Respironics) have high strength and can reach 50 cmH_2O with high flows.

The effect of nasal CPAP mask used to provide differs slightly among different groups of study subjects (Table II). In patients with hypercapnic chronic respiratory failure, the prototype mask achieves a greater reduction of $F_{ET}CO_2$ to lower pressure levels in the other two groups of subjects. In addition to the limitations originating das by the sample size, which was estimated to detect global differences and not only at low pressures it is positive ble the most CO_2 Exhaled by hypercapnic pa- cient more sensitive to the effect of CPAP, even at very low pressures.

In short, our data confirm that the type of mask and exhalation port tes difference condition rebreathing CO levels [2]. Among other things, this is especially relevant in the old controversy on whether to use conventional or custom masks con- [8,21]. While it is undeniable that masks made as of the facial charac- cas patient are useful when continuous ventilation or when considering alternative go to the fulcrum of the mask is required, it may not always well controlled flow exhalation port leak. Moreover, the incorporation of the exhalation port in the ventilator circuit, rather than integrated grarlo the mask appears not an optimal solution, as has been shown leading to a wider rebreathing CO_2 [22].

In conclusion, this study shows that a nasal mask prototypes po domestically produced causes less rebreathing of CO_2 during the administra- tion of CPAP masks other customary in our midst. Apart from cost, local availability of one kind or another mask is im- bearing in everyday clinical practice, since, although there is a large variety of nasal masks at present in the market, Plia an enlarged range of sizes and shapes, the prevailing policy sectorización companies in the National Health System presents a geographic limitation to access them.

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