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Efficiency of Oxygen Therapy by Simple Face Mask and Nasal Cannula for Acute Respiratory Failure in Infants and Young Children

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Abstract

Premises: Acute respiratory failure caused by respiratory diseases, which is a frequent pathology in infants and young children, requires oxygen therapy, which can be administered by different devices. Objectives: To evaluate the efficiency of two devices for oxygen administration by determining a clinical appraisal score for acute respiratory failure in infants and young children by oxygen therapy using simple face masks and nasal cannulas. Material and methods: 74 children, aged between one month and 3 years were included in our study. Oxygen therapy was administered by face mask to 38 patients, and by nasal cannula to 36 patients. A clinical appraisal score of respiratory failure was calculated both before and after oxygen therapy. Oxygen saturation was measured by pulse oximetry (SpO_2) and arterial or capillary blood gas (SaO_2) before, and 30 minutes and 60 minutes after the initiation of oxygen therapy. Results: We found an improvement in the clinical score regardless of the method of administration; this improvement was more obvious at 60 minutes than at the 30 min evaluation ($p < 0.001$). The differences were statistically significant ($p < 0.0001$) for all the measurements (baseline vs. 30 minutes, baseline vs. 60 minutes, 30 minutes vs. 60 minutes). An increase in both SaO_2 and SpO_2 values was found ($p < 0.001$). Conclusions: The clinical score for acute respiratory failure and the SaO_2 and SpO_2 values significantly improved after oxygen therapy.

Keywords*:* acute respiratory failure, face mask, nasal cannula, oxygen therapy, SaO_2 (capillary blood gas parameters on pH Astrup), SpO_2 (oxygen saturation measured in capillary blood by pulse oximeter)

Introduction

Acute respiratory failure is a syndrome resulting from the incapacity of the respiratory system to provide sufficient oxygen for metabolic needs and / or to eliminate the carbon dioxide produced within the body (Gherasim, 2003; Frankel and DiCarlo, 2003). Adequate tissue oxygenation is achieved physiologically by spontaneous ventilation and adequate circulation. The etiology of acute respiratory failure (ARF) in infants and young children varies; however, acute respiratory infections are predominant, accounting for more than 50% of the cases (Man and Nanulescu, 2006; Andreica and Miu, 2010). Besides etiologic treatment, patients with respiratory diseases and acute respiratory failure also require oxygen treatment by oxygen therapy, which is essential for maintaining adequate tissue oxygenation (Acalovschi, 2002; Ionescu, 2010; Lee *et al.*, 2013). Oxygen therapy uses numerous methods, which have proved their validity for both adults and older children with spontaneous breathing (AARC, 2002; Stoll and Kliegman, 2003). The techniques of oxygen therapy for infants and young children are still highly controversial, and can be administered by simple face mask, nasal cannula or oxygen hood. The therapeutic response to oxygen administration is appraised by monitoring respiratory failure and oxygen saturation (SaO_2) (Wood, 1975; Butnariu *et al.*, 2005).

The aim of this study was to assess the efficiency of oxygen therapy by two methods: simple face mask and nasal cannula for acute respiratory failure caused by respiratory diseases in infants and young children.

Materials and methods

A number of 74 patients suffering from acute respiratory failure were studied. The sample was divided into two groups, according to the method of oxygen therapy: oxygen was administered by simple face mask to 38 patients, and by nasal cannula to 36 patients. The study was a prospective cohort study, and was conducted between October 2007 and December 2012 in the 3rd Pediatrics Department in Cluj-Napoca. The inclusion criteria were: patients aged one month to 3 years, with acute respiratory diseases evolving into acute respiratory failure, di=agnosed on the basis of clinical parameters (dyspnea, tachypnea, nasal flaring, head bobbing, moaning, intercostal, subcostal and supraclavicular retraction recession), and paraclinical parameters (oxygen saturation measured in capil-

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lary blood by pulse oximeter – SpO_2 and capillary blood gas parameters on pH Astrup - arterial or capillary blood gas – SaO_2). Informed consent was obtained from family members. Patients with chronic respiratory failure, cardiac pathology and prematurity were excluded from the study. Each case was evaluated by determining a clinical score (Wood, 1975; Butnariu *et al.*, 2005), which appraised five parameters (Tab. 1) according to intensity quantified as: absence (0), medium presence (1), and severe presence (2). SpO2 was monitored using a H100N (EDNA) pulse oximeter (noninvasive method), after a state of equilibrium had been reached, while SaO_2 (blood gas parameters in arterialized capillary blood) was monitored using Blood Gas System AVL 995 - Medical Instruments Graz Austria. The blood had been collected after prior extremity massaging. These measurements were conducted before, and 30 min and 60 min, respectively, after the initiation of oxygen therapy.

Tab. 1. Clinical appraisal score of respiratory failure

Clinical parameter	Points
Respiratory rate	
normal	0
bradypnea (< normal value)	1
tachypnea (> normal value)	2
Nasal flaring	
absent	0
present	1
present + head bobbing / moaning	2
Retraction	
absent	0
intercostal or subcostal	1
intercostal and supraclavicular and subcostal	2
Cyanosis	
absent	0
perioral while crying	1
perioral at rest	2
Sensorial	
normal	0
agitated child	1
drowsy / lethargic child	2

Intensity: 0 = absence, 1 = medium presence, 2 = severe presence
Adapted from: Wood (1975) and Butnariu *et al.* (2005)

Acute respiratory failure was classified according to the value of SaO_2 into grade I: SaO_2 = 90 - 92 %, grade II: SaO_2 = 85% - 89%, and grade III: SaO_2= 80% - 84%.

Statistical analysis

The qualitative variables were summarized as absolute frequencies, and relative frequencies and 95% confidence interval (95%CI, values provided in squared brackets), respectively, calculated by applying a method similar to those presented in (Bolboacă and Jäntschi, 2008; Jäntschi and Bolboacă, 2010). The Z-test for proportions was applied in order to identify statistically significant differences between two groups, by using a significance threshold of 5%.The quantitative variables were summarized as means and standard deviations in the case of data that had normal distribution, and as median and variation interval for which the lower limit was the 25th percentile and the higher limit the 75th percentile in the case of quantitative data that did not follow normal distribution.

Comparisons of repeated measurements were performed by appropriate parametric (paired t-test, repeated measurements ANOVA with Bonferroni correction) or non-parametric tests (Mann-Whitney U test, Sing in ANOVA, Sign test), adjusting the significance threshold accordingly (0.05 for comparison of two groups and 0.0167 for comparison of three groups). The Statistica v.8 program was used for statistical analysis. Some of the graphical representations were created in Microsoft Excel.

Results

A number of 74 patients suffering from acute respiratory failure caused by respiratory diseases were included in the study; oxygen therapy was delivered by simple face mask to 38 patients (51.35% [39.21; 63.50]), and by nasal cannula to 36 patients (48.65% [36.51; 60.79]).The characteristics of the subjects included in the study are given in Tab. 2.

Tab. 2. General characteristics of subjects with acute respiratory failure included in the study

Characteristics	Oxygen therapy		p-value
	Simple face mask	Nasal cannula	
Age (months) a	15.66±11.11	14.89±9.17	0.7472
Gender [b]			0.7655
Female	39.47 [23.75; 57.83]	36.11 [19.52; 52.70]	
Male	60.53 [42.18; 76.25]	63.89 [47.30; 80.48]	
Area of origin b			0.8210
Rural	52.63 [36.91; 68.35]	50.00 [33.41; 66.59]	
Urban	47.37 [31.65; 63.09]	50.00 [33.41; 66.59]	
Birth weight (kg) a	3.32±0.48	3.18±0.49	0.2298
Current weight (kg)a	9.82±3.15	9.85±3.03	0.9636
Height (cm) a	77.32±12.51	76.39±10.76	0.7342
Body mass index a (n1=16, n2=18)	15.67±1.93	16.47±1.78	0.2223
Ponderal index c (n1=21, n2=18)	1.08 (1.01; 1.20)	1.05 (0.99; 1.10)	0.2719
Temperature on admissionc	37.4 (36.8; 38.2)	37.3 (36.8; 38.4)	0.8381
Grade of ARF b			
I	36.84 [21.12; 55.19]	36.11 [19.52; 52.70]	0.9480
II	47.37 [31.65; 63.09]	55.56 [38.97; 72.15]	0.4796
III	15.79 [5.33; 31.51]	8.33 [2.86; 22.15]	0.3197

a mean±standard deviation; independent samples t-test;b %[IC 95%], where IC 95% = 95% confidence interval; Z-test forcomparing two proportions; c median (Q1; Q3), where Q1 = 25th percentile, Q3 = 7^{5th} percentile; Mann-Whitney U test

The age of the patients with grade I acute respiratory failure included in the study proved to be significantly younger (9.04±8.29 months, n=27) both compared to the age of patients with grade II acute respiratory failure (17.66±9.48 months, n=38), and compared to the age of patients with grade III acute respiratory failure (24.00±7.60 months, n=9) (p-values associated to Bonferroni post-hoc test: $7.30 \cdot 10^{-4}$ for ARF I vs. ARF III; $1.17 \cdot 10^{-4}$ for ARF I vs. ARF III).

The clinical scores of the subjects included in the study, who were delivered oxygen therapy by simple face mask and nasal cannula, respectively, measured on inclusion in the study and 30 minutes and 60 minutes, respectively, after the initiation of oxygen therapy are given in Fig. 1 and Fig. 2, respectively.

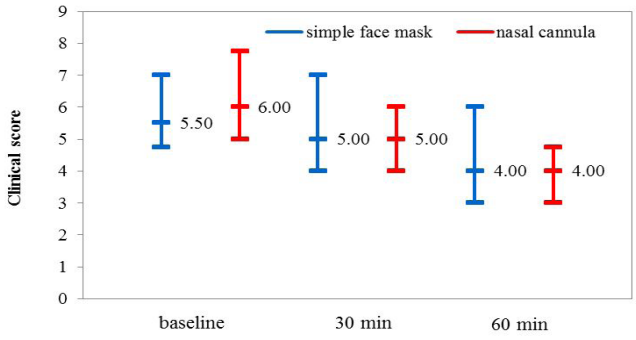

Fig. 1. The clinical score in moment 0 (baseline), and 30 minutes and 60 minutes after oxygen therapy by simple face mask (blue) and by nasal cannula (red). The middle points represent the value of median while the extreme points are the 25th and 75th percentiles

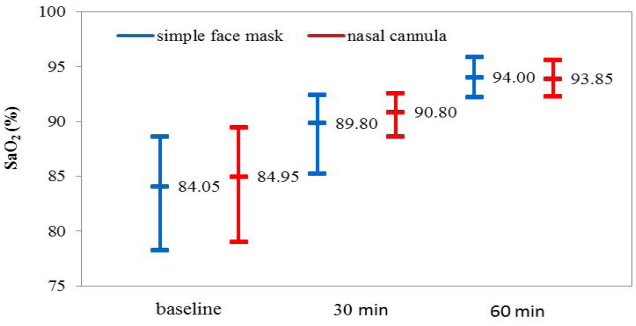

Fig. 2. SaO_2 in moment 0 (baseline), and 30 minutes and 60 minutes after oxygen therapy by simple face mask (blue) and by nasal cannula (red). The middle points represent the value of median while the extreme points are the 25th and 75th percentiles

Statistically significant differences were identified between the clinical scores calculated dynamically after oxygen therapy by simple face mask: Friedman ANOVA: statistics = 65.09, $p < 0.001$ (p-value associated to Sign test: $1.77 \cdot 10^{-4}$ for baseline vs. 30 minutes; $1.95 \cdot 10^{-9}$ for baseline vs. 60 minutes; $4.25 \cdot 10^{-8}$ for 30 minutes vs. 60 minutes); nasal cannula: Friedman ANOVA: statistics = 64.58, $p < 0.001$ (p-value associated to Sign test: 0.0077 for statistics; $5.43 \cdot 10^{-9}$ for baseline vs. 60 minutes; $2.54 \cdot 10^{-8}$ for 30 minutes vs. 60 minutes).

No significant differences were identified between the values of the clinical score calculated on baseline, and after 30 minutes and 60 minutes, respectively, between the two studied groups (baseline: Z (Mann-Whithey U test) = -0.2758, p = 0.7827; 30 minutes: Z = 0.5678, p = 0.5702; Z = 0.3082, p = 0.7579). The distribution of SaO_2 and SpO_2 according with the type of oxygen therapy is presented in Figs. 2 and 3.

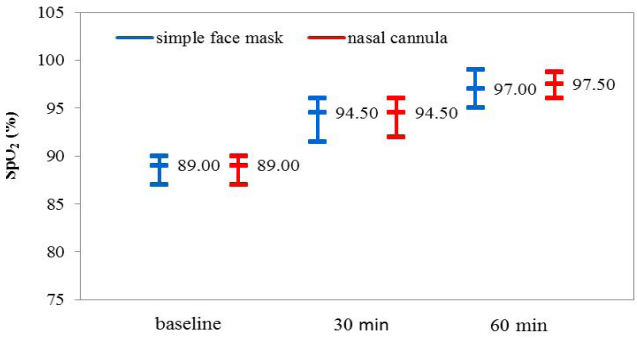

Fig. 3. SpO_2 in moment 0 (baseline), and 30 minutes and 60 minutes after oxygen therapy by simple face mask (blue) and by nasal cannula (red). The middle points represent the value of median while the extreme points are the 25th and 75th percentiles

The comparison of SaO_2 and SpO_2 in the subjects who were delivered oxygen therapy by simple face mask and nasal cannula is given in Tab. 3.

Tab. 3. Comparison of SaO_2 and SpO_2 in the subjects who were delivered oxygen therapy by simple face mask and nasal cannula

			p-value associated to Sign test		
Group	Variable	Friedman ANOVA (p-value)	Baseline vs. 30 minutes	Baseline vs. 60 minutes	30 minutes vs. 60 minutes
Simple face mask	SaO_2 (%)	66.36 (< 0.001)	$1.36 \cdot 10^{-8}$	$1.36 \cdot 10^{-8}$	$8.64 \cdot 10^{-8}$
	SpO_2 (%)	74.05 (< 0.001)	$1.95 \cdot 10^{-9}$	$1.95 \cdot 10^{-9}$	$1.36 \cdot 10^{-8}$
Nasal cannula	SaO_2 (%)	64.39 (< 0.001)	$5.43 \cdot 10^{-9}$	$5.43 \cdot 10^{-9}$	$5.43 \cdot 10^{-9}$
	SpO_2 (%)	72.00 (< 0.001)	$3.80 \cdot 10^{-8}$	$5.43 \cdot 10^{-9}$	$1.34 \cdot 10^{-6}$

Discussion

The two investigated groups of patients suffering from acute respiratory failure caused by respiratory diseases were homogenous in terms of age, weight, ponderal index, body mass index, and severity of respiratory failure grade of acute respiratory failure.

The clinical studies that used clinical scores to evaluate patients with acute respiratory failure caused by respiratory diseases have demonstrated that the clinical score is extremely important both for the evaluation of the severity of acute respiratory failure, and for monitoring the patients evolution and response to treatment (Wood, 1972; Butnariu *et al.*, 2005). We found that the values of the clinical score in the group who were administered oxygen therapy by simple face mask improved after 30 minutes and 60 minutes, respectively; the differences between the two measurements were statistically significant. The most obvious difference in SaO_2 was recorded after 60 minutes vs. after 30 minutes from the initiation of oxygen therapy. We also found that the values of the clinical score in the group who were administered oxygen therapy by nasal cannula improved, and the differences were statistically significant, both after 30 minutes and after 60 minutes from the initiation of oxygen therapy. Several researchers have reported better tolerance in patients suffering from acute respiratory failure who were delivered oxygen therapy by nasal cannula than in those who were delivered oxygen therapy by simple face mask, due to the possibility of simultaneous oral feeding and oxygen therapy (Neal, 2010; Oriol *et al.*, 2010).

Some studies have demonstrated that pulse oximetry (SpO_2), which is the noninvasive method, may be used to monitor patients with acute respiratory failure, in order to replace the SaO_2 method, which is invasive (Modi *et al.*, 2013; Foo *et al.*, 2013). This study has demonstrated that the SpO_2 values showed statistically significant increases both after 30 minutes and after 60 minutes from the initiation of oxygen therapy, by the two methods: simple face mask and nasal cannula (Tab. 3). The SaO_2 values recorded statistically significant increases both after 30 minutes and after 60 minutes from the initiation of oxygen therapy, both by simple face mask and nasal cannula. The specialized literature specifies the importance of initial evaluation and periodical reevaluation of SaO_2 in patients with acute respiratory failure caused by respiratory diseases by both SaO_2 and SpO_2 (Duke *et al.*, 2009; Catto *et al.*, 2011).

The analysis of Fig. 2 and 3 revealed that the values of SpO_2 were systematically higher compared to values of SaO_2 in both oxygen therapy methods (simple face mask and nasal cannula). Despite this, similar values of SaO_2 and SpO_2 were obtained respective of the used oxygen therapy suggesting the absence of significant differences between these methods. The difference between SpO_2 and SaO_2 in regards of median values seems to be similar in time and varied from 5 to 6% for simple face mask and from 3.5 to 5% for nasal cannula. This result suggests that the SaO_2 could be measured at the baseline and the evaluation could be done using SpO_2.

The efficiency of oxygen therapy by simple face mask and by nasal cannula for acute respiratory failure infants and young children was conducted as a cohort study and thus it is not possible to generalize the obtained results. Other limits of our study are represented by the small number of subjects included in the study and the absence of oxygen therapy randomization. Larger multicenter studies are needed to validate the results reported in this study.

Conclusions

Determining the clinical score for acute respiratory failure is useful for the appraisal of the patients' outcome and response to oxygen therapy. The clinical score for acute respiratory failure and the value of SaO_2 and SpO_2 showed statistically significant improvement after oxygen therapy. No statistically significant differences were found between SaO_2 after oxygen therapy by simple face mask and nasal cannula after 30 minutes and 60 minutes from the initiation of oxygen therapy. If other future randomized studies will have the same results, the SpO_2 may be used to monitor non-invasively instead the SaO_2.

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