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Correlations between pulse oximetry and peak expiratory flow in acute asthma

C. Ribeiro de Andrade[1], M.C. Duarte[2] and P. Camargos[1]

[1]Departamento de Pediatria, Faculdade de Medicina, Universidade Federal de Minas Gerais, Belo Horizonte, MG, Brasil
[2]Departamento de Saúde Materna e Infantil, Faculdade de Medicina, Universidade Federal de Juiz de Fora, Juiz de Fora, MG, Brasil

Abstract

Few studies are available concerning correlations between pulse oximetry and peak expiratory flow in children and adolescents with acute asthma. Although the Global Initiative for Asthma states that measurements of lung function and oximetry are critical for the assessment of patients, it is not clear if both methods should necessarily be included in their evaluation. Since there is a significant difference in cost between pulse oximetry equipment and peak expiratory flow devices, we determined whether clinical findings and peak expiratory flow measurements are sufficient to determine the severity of acute asthma. The present prospective observational study was carried out to determine if there is correlation between pulse oximetry and peak expiratory flow determination in 196 patients with acute asthma aged 4 to 15 years diagnosed according to the Global Initiative for Asthma criteria. Patients experiencing their first or second wheezing episode, with fever, related acute or chronic diseases, and unable to perform the peak expiratory flow maneuver were excluded. Measurements of peak expiratory flow and pulse oximetry were performed at admission and after 15 min of each inhaled salbutamol cycle. Correlations obtained by linear regression using the Pearson correlation coefficients (r) were 0.41 ($P < 0.0001$), 0.53 ($P < 0.0001$), 0.51 ($P < 0.0001$), and 0.61 ($P < 0.0001$) at admission and after the first, second and third cycles of salbutamol, respectively. These correlations showed that one measure cannot substitute the other (Pearson's coefficient <0.7), probably because they evaluate different aspects in the airways, suggesting that peak expiratory flow should not be used alone in the assessment of acute asthma in children and adolescents.

Correspondence
P. Camargos
Departamento de Pediatria
Faculdade de Medicina, UFMG
Av. Alfredo Balena, 190, Sala 4061
30130-100 Belo Horizonte, MG
Brasil
Fax: +55-31-3248-9664
E-mail: pcamargs@medicina.ufmg.br

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- Acute asthma
- Pulse oximetry
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Introduction

Clinical findings are usually insufficient to properly determine the severity of acute asthma (1-9). Significant changes in lung function may be present despite the lack of clinical manifestations (1,2,6), as first reported in the 1970's (1) and confirmed by subsequent studies (2-9). The severity of acute asthma is classified as mild, moderate, severe, and very severe based on clinical and functional criteria (10), the most widely used being pulse oximetry (SpO_2) and peak expiratory flow (PEF).

Few reports are available about possible correlations between these two methods in children and adolescents. Although the Global Initiative for Asthma (GINA) states that measurements of lung function and oximetry are critical for patient assessment (10), it is not clear whether both methods should be included in the evaluation of acute asthma, since no critical comparison of the two measurements has been done.

Since there is a significant difference in costs between SpO_2 equipment and PEF devices, with SpO_2 being about 20 times more expensive, it seems reasonable to determine whether clinical findings and PEF measurements are sufficient to assess the severity of acute asthma. Thus, the objective of the present study was to determine the correlation between SpO_2 and PEF in children and adolescents with acute asthma in order to determine whether SpO_2, the more expensive procedure, could be avoided in the evaluation of exacerbations. The answer may be particularly relevant in low-income countries, where the two measurements are not performed routinely in emergency departments.

Material and Methods

In this prospective cohort study, 196 consecutive patients with acute asthma were evaluated. The patients were admitted to an emergency room where they were treated with standard doses of inhaled salbutamol.

Inclusion and exclusion criteria

Since most asthma exacerbations are classified as mild or moderate (10), patients with this level of severity, aged 4 to 15 years, and with PEF between 50 and 80% of the predicted value at admission were studied. Patients experiencing their first or second wheezing episode, patients with axillary temperature of 38ºC or higher, with related acute or chronic diseases, and patients unable to perform the PEF maneuver were excluded.

Each patient was included only once in the study protocol.

Pulse oximetry and peak expiratory flow

SpO_2 was measured with a Palco oximeter model 30 (Palco Laboratories, Inc., Santa Cruz, CA, USA) at admission to the emergency room and after 15 min of each bronchodilator cycle. The sensor was adapted to the patient's left thumb. Single point values were recorded in order to ensure a high-quality pulse signal and no movement artifacts.

PEF was measured with a peak flow meter (Mini Wright Peak Flow Meter; Clement Clarke International Ltd., Harlow, Essex, England) on a non-linear scale ranging from 30 to 400 L/min. The best of three standing PEF values was recorded and the results were compared to the reference values described by Godfrey et al. (11).

Measurements were performed at admission and after 15 min of each inhaled salbutamol cycle. PEF and SpO_2 were measured by an observer unaware of the study aims.

Acute asthma treatment

Patients received up to three cycles of salbutamol delivered either by an oxygen-driven nebulizer or by a pressurized metered-dose inhaler attached to a spacer. Those treated with the oxygen-driven nebulizer received 0.15 mg kg^{-1} $dose^{-1}$ (minimum: 1.25 mg/dose; maximum: 5 mg/dose). The drug was diluted in 0.9% sodium chloride to a final volume of 4 mL. Nebulization was performed up to 15 min, with the device connected to the oxygen source and at a flow of 6 L/min. Those treated with the pressurized metered-dose inhaler attached to a valved spacer received 5 puffs (500 μg) in each treatment cycle.

Patients were assessed clinically and functionally, i.e., by PEF and SpO_2 measure-

ments, approximately 15 min after each salbutamol cycle. Emergency room discharge was conditioned to a satisfactory therapeutic response represented by improvement of one or more of the following factors: cough, wheezing, shortness of breath, decreased respiratory frequency, respiratory effort, and increased SpO_2 and PEF values.

Statistical analysis

Sample size. Since in three previous studies the correlation coefficient (r) ranged from -0.16 to 0.43 for SpO_2 and PEF (12-14), an intermediate value was taken (r = 0.25) for the calculation of sample size. Assuming an alpha error of 0.05 and a beta error of 0.10 (power equal to 90%), a sample size of 164 patients was required (15).

Analysis. Descriptive statistics were calculated on the basis of frequency distribution and by the Student *t*-test. Linear regression analysis was used to determine the relationship between SpO_2 measurements and predicted PEF values at admission and after each bronchodilator cycle. A P value <0.05 was considered significant.

Ethics

The study protocol was approved by the Research Ethics Committee of the Federal University of Minas Gerais and the parents or persons responsible for the children gave written informed consent.

Results

Table 1 presents the demographic and clinical characteristics of the 196 patients studied. Boys predominated in the study population with a 2:1 ratio. Age ranged from 4 to 15 years (mean ± SD: 8.7 ± 2.19 years). Regarding asthma characteristics, the first exacerbation occurred before two years of age in 71.4% of the patients and only approximately 50% of the subjects were asymptomatic between exacerbations and had acute attacks at 8- to 30-day intervals. Previous asthma hospitalization and use of antiasthmatic medicines was reported by about one third of the patients. Bronchodilators and/or antibiotics had been used within 24 h preceding emergency room admission by 86 patients, although none within 8 h or less.

Table 2 shows SpO_2 and PEF values at admission and after three cycles of bronchodilator treatment. The mean ± SD SpO_2 for the 196 patients was 93.6 ± 2.90 and 95.0 ± 2.70% at admission and after the first salbutamol cycle, respectively (P < 0.001).

Table 1. Characteristics of the study population.

Characteristics	N (%)
Gender	
Male	132 (67%)
Female	64 (33%)
Age group	
4 to 5 years	18 (9%)
6 to 9 years	114 (58%)
10 to 12 years	62 (32%)
13 to 15 years	2 (1%)
Age at first exacerbation	
<2 years	140 (71%)
>2 years	56 (29%)
Between exacerbation periods	
Asymptomatic	102 (52%)
Symptomatic	94 (48%)
Days between exacerbations	
7 days	40 (21%)
8 to 30 days	103 (52%)
>30 days	53 (27%)
Number of hospitalizations due to acute asthma	
None	127 (65%)
1	22 (11%)
2 or more	47 (24%)
Previous use of asthma-preventing medications	
Yes	62 (32%)
No	134 (68%)
Use of bronchodilators and/or anti-inflammatory drugs in the last 24 h	
Yes	86 (44%)
No	110 (56%)

Data are reported as number of patients with percent in parentheses.

The mean PEF was 61.8 ± 10.60 at admission and 80.2 ± 13.09% after the first treatment cycle (P < 0.001). In the present study, only 4% of the subjects showed a decrease in SpO_2 after the first salbutamol cycle.

All correlations between SpO_2 and PEF (% predicted value) determined by the Pearson coefficient were statistically significant during any phase of treatment (P < 0.001) but to a moderate extent, with "r" values of 0.41, 0.53, 0.51, and 0.61 at admission and after the first, second and third salbutamol cycle, respectively. Regarding the determination coefficient (R^2), the values obtained were statistically significant (P < 0.0001) at admission and after each salbutamol cycle. Values found at admission and after the first, second, and third cycles were 0.17, 0.29, 0.26, and 0.37, respectively, as shown in Figure 1.

Figure 1 shows the four scattergrams corresponding to each assessment. The Pearson coefficients with their respective P values and 95% confidence intervals are also shown.

A positive correlation can be observed between the two measurements at admission and after each salbutamol cycle. Since only patients suffering from mild to moderate acute asthma were admitted to the study, most points observed in the scattergrams were concentrated in values ranging from 92 to 98% and from 70 to 95% for SpO_2 and PEF, respectively. However, in 25% of the

Table 2. Pulse oximetry and peak expiratory flow reported as percent predicted values at admission and after each of the three salbutamol cycles.

	Mean ± SD
Admission (N = 196)	
SpO_2	93.6 ± 2.9
PEF	61.8 ± 10.6
After 1st cycle (N = 196)	
SpO_2	95.0 ± 2.7
PEF	80.2 ± 13.1
After 2nd cycle (N = 123)	
SpO_2	94.8 ± 2.7
PEF	81.0 ± 9.9
After 3rd cycle (N = 72)	
SpO_2	95.2 ± 2.4
PEF	82.1 ± 7.6

SpO_2 = pulse oximetry; PEF = peak expiratory flow.

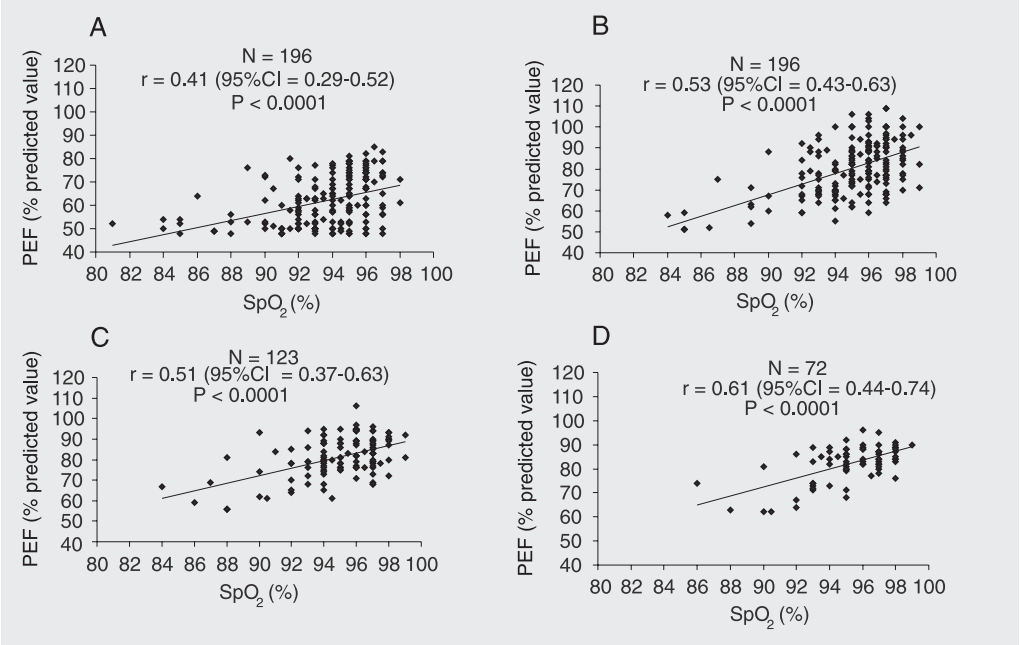

Figure 1. Scattergrams plotting pulse oximetry and peak expiratory flow. *A*, At admission (N = 196). *B*, First cycle (N = 196). *C*, Second cycle (N = 123). *D*, Third cycle (N = 72). PEF = peak expiratory flow; SpO_2 = pulse oximetry; r = Pearson correlation coefficients; CI = confidence interval.

subjects discrepancies were observed for both SpO_2 <95% and PEF ≥80% of the predicted value and vice versa. Some patients with PEF values above 70% of the predicted value showed low SpO_2 values. Furthermore, 6% of the patients presented SpO_2 <90% and PEF ≥60% of the predicted value.

Discussion

The correlations between SpO_2 and PEF values obtained in the present study were statistically significant in every salbutamol cycle. There are few reports in the literature concerning the use of both measurements in acute asthma, although GINA and most Brazilian asthma guidelines recommend both for the management of patients with acute asthma in emergency rooms.

Only three studies have measured the correlation between SpO_2 and PEF in acute asthma in childhood and adolescence (12-14). All of them have different methodologies compared with the present study and in only one study the investigators performed sequential assessments of SpO2 and PEF (13) as we did. Kano and Nishima (13) detected a correlation in only 52 patients aged 6 to 16 years before and after one bronchodilator cycle, obtaining r = 0.47 and 0.52, respectively ($P < 0.0001$). Their limited number of subjects should be taken into consideration. Yamamoto et al. (14), in a study of 632 patients aged 5 to 20 years with acute wheezing episodes, obtained r = 0.41 at admission, a value similar to that obtained in the present study ($P < 0.0001$). However, these investigators included subjects who did not have asthma. Patients with viral respiratory infections and *Mycoplasma pneumoniae*, croup, chronic lung disease, and bronchopulmonary dysplasia were enrolled in their study, which could cause different physiopathological processes, for instance, similar abnormalities in proximal and distal airways, resulting in different correlations between SpO_2 and PEF. Finally, Connett and Lenney (12) assessed only 26 children with severe acute asthma and obtained negative correlation coefficients, i.e., r = -0.16 and -0.10, with no statistical significance. Because in their study mean predicted PEF value at admission was only 28.3%, its external validity can be questioned, considering that most patients suffering from acute asthma admitted in emergency rooms did not present such low PEF values.

We found patients with high values of PEF and less than 91% SpO_2 and vice versa. These findings conflict with the values proposed by GINA to classify asthma severity and may make some contribution to the understanding of these values in acute asthma. The lack of a higher correlation between PEF and SpO_2 may be ascribed to the type of events assessed by the two methods. Some investigators have suggested that PEF may partially reflect phenomena observed in acute asthma, i.e., only changes observed in the proximal airways (5,16). In contrast, SpO_2 may indirectly reflect the ventilation/perfusion mismatch, expressing alterations observed in both proximal and distal airways (5,16). Therefore, the presence of normal PEF values in patients with acute asthma does not exclude the possibility of important abnormalities that may go unnoticed by patients and physicians.

This view is substantiated by the different patterns observed for the two measurements throughout the treatment of acute asthma. Generally, PEF improvement can be more pronounced and faster than SpO_2. Considering the physiopathology of acute asthma, the response to treatment in exacerbations seems to have a two-phase course, i.e., a quick initial response followed by a slower one (17-20). The quick phase is probably related to the improvement of smooth muscle contraction (18) and patients in whom this is the major contribution to their disability respond quite well to minimal treatment, even if the obstruction is significant. The slow phase probably depends on the time

needed to heal the inflammatory process, which has a rather more indolent behavior.

Mihatsch et al. (19), assessing 28 children with acute asthma aged 4 to 14 years, observed that PEF was stabilized 12 h before SpO_2, which was normalized 48 h later. In addition, Wagner et al. (20) reported a poor association between spirometric alterations and abnormalities in gas exchanges in acute asthma. These investigators stated that the correlation between these parameters tends to improve gradually as the treatment progresses, and concluded that the degree of obstruction in the small airways may differ from those in medium and large airways, explaining the r values detected in the present study.

The moderate correlation between SpO_2 and PEF measurements found in the present study supports the view that PEF partially reflects the complex physiopathological findings observed in acute asthma. Therefore, when assessing a patient suffering from an acute attack, the physician should be encouraged to perform both SpO_2 and PEF tests in order to define the most adequate treatment.

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