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Original Article

Forced expiratory volume in 1-second and blood gas analysis in children during asthma attacks

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Abstract

Background Asthma is the most common chronic disease in the world, with a high incidence in children. Blood gas analysis and pulmonary function test using spirometry are recommended to evaluate the degree of asthma in children. Spirometry test is non-invasive and easier to implement compared to blood gas analysis.

Objective To evaluate for a possible correlation between forced expiratory volume in 1 second (FEV1) measured by spirometry test and blood gas analysis (pO_2 and pCO_2 levels) in children during an asthma attack.

Methods This cross-sectional study was done in children with asthma attacks who were admitted to Sanglah Hospital, Denpasar, Bali, between November 2016 and April 2017. Subjects underwent spirometry tests and blood gas analyses. Potential correlations between FEV1 and pO_2 and pCO_2 levels were analyzed by Spearman's correlation test.

Results A total of 50 subjects, consisting of children aged 6 to 12 years, were diagnosed with asthma attacks during the study period. Subjects' mean FEV1 level was 43.6%, mean pCO_2 was 38.36 mmHg, and mean pO_2 was 121.92 mmHg. There were no significant correlations between FEV1 and pCO_2 level (r=0.206; P=0.152) or FEV1 and pO2 (r=0.157; P=0.277) found in this study.

Conclusion FEV1 does not correlate with pCO_2 and pO_2 level in children during asthma attacks. **[Paediatr Indones. 2018;58:221-6; doi: http://dx.doi.org/10.14238/pi58.5.2018.**221-6 }

Keywords: *spirometry; blood gas analysis; asthma; children*

Asthma remains a serious problem worldwide, since it is the most common chronic disease in children and adults.[1] Approximately 300 million people around the world have been diagnosed with asthma. The asthma prevalence in children aged 5-14 years in the US reached 69.8 cases per 1,000 children.[2] The prevalence in Indonesian children is unknown, but in adults approximately 10% of 25 million Indonesians have asthma with high morbidity and mortality.[3]

An asthma attack is an emergency requiring oxygenation, ventilation, and acid-base management.[4] Optimal management includes not only symptom control, but lung function monitoring and blood gas analysis.[1] Lung function test is necessary to assess severity, obstruction, reversibility, and diagnostic accuracy of the asthma. Spirometry is recommended at least once a year in children with asthma to assess respiratory function.[5] Decreased FEV1 can be used to assess the degree of obstruction. Variation in FEV1 is also a good predictor of asthma severity.[6]

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Blood gas analysis is recommended for all asthma attack patients who come to the hospital. Blood gas analysis results are a good estimate of asthma severity. More severe obstruction tends to correlate with higher CO_2 and lower pH in arterial blood.[7] Blood gas analysis is more invasive and traumatic for children compared to spirometry. Several studies were done to assess for a correlation of FEV1 decrease with pO_2 and pCO_2 level in adults with obstructive respiratory diseases, but with varying results.[8,9] We evaluated for correlations between FEV1 decrease and pO_2 and pCO_2 levels in children with asthma attacks.

Methods

This cross-sectional study was performed in the Emergency Department of Sanglah Hospital, Denpasar, Bali, from November 2016 - April 2017. Subjects were children diagnosed with asthma, aged >6 years, and brought to the Emergency Department due to asthma attacks. Study subjects were recruited using consecutive sampling until the minimum required sample size was achieved. The sample size was determined for a cross-sectional study with 5% significance level (α) and 80% power (β), and estimated to be 50 from minimal difference in previous studies.[10,11]

Subjects classified to mild-moderate and severe asthma attack based on clinical finding. The clinical findings of mild-moderate asthma attacks were shortness of breath, no exertion of additional respiratory muscle, spoke in sentence, prefer in sitting position, and a loud expiratory-inspiratory wheeze on auscultation. While in severe asthma attacks, the clinical findings were shortness of breath, exertion of additional respiratory muscles, difficulty speaking, leaning forward sitting position, irritable, and a loud expiratory-inspiratory wheeze can be heard without a stethoscope.[12,13]

Exclusion criteria were children diagnosed with impending respiratory failure, chronic lung disease, acute or chronic lung infection, congenital lung diseases, heart diseases, history of lung surgery, or systemic diseases that impaired lung function. Subjects' parents provided written informed consent. This study was approved by the Human Study Ethics Committee of Sanglah Hospital.

Subjects underwent history-taking and physical examinations. Spirometry and blood gas analysis were performed after assessment before bronchodilator therapy. Blood specimens were collected in containers with anti-coagulant (heparin) for blood gas analyses using *Siemens RapidLab 348Ex®*. Diagnoses of asthma and degree of severity were made based on *National Pediatric Asthma Guidelines (Pedoman Nasional Asma Anak Indonesia)*.[12]

Characteristics of subjects were described in tables. Differences in FEV1, pO2, and pCO2 were analyzed using independent T-test or Mann-Whitney test, depending on data normality. Spearman's test was performed to analyze abnormal data distributions. Analyses were performed with *SPSS 22.0* software.

Results

A total of 50 subjects were included in this study between November 2016 and April 2017. There were 10 children with severe asthma attacks and 40 with mild-moderate asthma attacks. The male: female ratio was 2.3: 1. Characteristics of subjects are shown in **Table 1**.

Table 1. Characteristics of subjects

Characteristics	(N = 50)
Mean age (SD), years	9.06 (2.123)
Sex, n (%)	
Male	35 (70)
Female	15 (30)
Asthma severity, n (%)	
Severe	10 (20)
Mild–moderate	40 (80)
Mean FEV1 (SD), %	43.60 (16.54)
Mean PCO_2 (SD), mmHg	38.36 (8.89)
Mean PO_2 (SD), mmHg	121.92 (42.35)

Kolmogorov-Smirnov test revealed that FEV1 data were normally distributed, but pO_2 and pCO_2 data were not normally distributed. We found that FEV1 had no significant correlations with pO_2 or pCO_2, as shown in **Table 2**.

Regression correlation test on FEV1 with pO_2 and pCO_2, based on asthma severity, revealed differences in severe attack compared to mild-moderate attack.

A stronger correlation was found in severe asthma attack compared to mild-moderate attack, as seen on the scatter plots in **Figure 1**.

Table 2. Correlation of FEV 1 with pO_2 and pCO_2

		pCO_2	pO_2
FEV1	r	-0.206	0.157
	P*	0.152	0.277

*Spearman correlation test

Further analyses of FEV1, pCO_2, and pO_2 based on asthma severity were performed. Parametric analysis was performed on FEV1 and pCO_2, and non-parametric analysis was performed on FEV1 and pO_2, due to differences in data normality. Significant mean differences of FEV1, pO_2, and pCO_2 were observed according to asthma severity, as shown in **Table 3**. Children with severe asthma attacks had a significant lower FEV-1 and pO_2, and significant higher pCO_2 compared to children with mild to moderate asthma attacks.

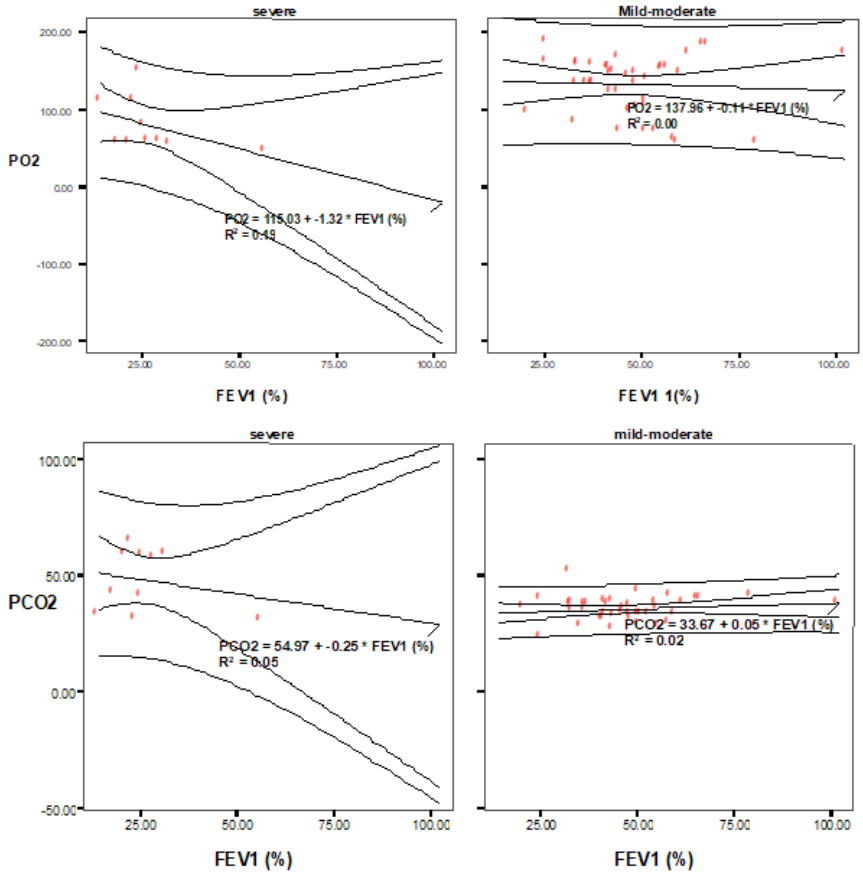

Figure 1. Correlation of FEV1 with pCO_2 and pO_2, based on asthma severity

Table 3. Differences of FEV1, pO_2, and pCO_2 levels, based on asthma severity

Variables	Asthma severity		P value
	Severe	Mild-moderate	
Mean FEV1 (SD), %	26.99 (11.5)	47.75 (15.0)	0.002[a]
Mean PCO2 (SD), mmHg	48.20 (13.40)	35.90 (5.17)	0.018[b]
Mean PO2 (SD), mmHg	79.39 (34.81)	132.55 (37.34)	0.001[a]

a: Mann-Whitney test; b: Independent T-test

Discussion

Asthma is defined as chronic inflammation of the airway. Many cells types and cellular elements have roles in its pathogenesis. This chronic inflammation is related to bronchoconstriction, airway swelling, airway hyperresponsiveness, and remodelling.[1,13,14] The natural history of the disease usually starts in childhood, and continues to impose a high economic burden, high morbidity and mortality, as well as reduced quality of life.[1,7]

Diagnosis of asthma in children is based on episodic and reversible airway obstruction or airway hyperresponsiveness, when other differential causes have been excluded. Diagnosis can be made by history-taking, physical findings, and spirometry test. Spirometry can be used to assess the degree of obstruction and reversibility in children over 5 years of age. This test is difficult to perform in younger children. Other examinations are used to exclude other causes.[15,16] Blood gas analysis is the gold standard examination for assessing gas exchange, arterial oxygen status, and acid-base status.[4,17]

The Global Initiative for Asthma (GINA) has recommended spirometry test and blood gas analysis to assess the severity of asthma attacks.[1] Spirometry is valuable for assessing airway patency and degree of obstruction, while blood gas analysis is valuable to assess gas exchange and ventilation/perfusion. The FEV1 levels vary according to the severity of the attack: mild >60%, moderate 40-60%, and severe <40%. Blood gas analysis cut-off points for severity are as follows: mild has normal pO_2, pCO_2 <45 mmHg, and SaO_2 >95%; moderate has pO_2 >60 mmHg, pCO_2 <45 mmHg, and SaO_2 91-95%, and severe has pO_2 <60 mmHg, pCO_2>45 mmHg, and SaO_2 ≤90%.[12]

The mean age of our subjects was 9 years, similar to other studies that showed most asthma attacks occurred in children aged 6-12 years.[12] A Bandung study in 2012 found an asthma prevalence of 9.6% in children aged 7-14 years. We had more male subjects than females, with a male: female ratio of 2.3:1. Another study also noted more males with asthma attacks.[7] The mean FEV1 level in our subjects was 43.6%, which was in the mild-moderate asthma attack range. Subjects' mean pCO_2 level was 38.36 mmHg and mean pO_2 was 121.92 mmHg, which were also consistent with mild-moderate attack severity, as 80% of our subjects had mild-moderate attacks.

The aim of the study was to assess for a possible correlation between blood gas analysis and spirometry results. Spirometry is a non-invasive examination and easy to perform in children, while blood gas analysis is invasive and difficult to perform. We had hoped that spirometry results could be used to predict blood gas levels, however, we found no significant correlation between FEV1 and pCO_2 level (r=-0.206; P=0.152) nor between FEV1 and pO_2 level (r=0.157; P=0.277). To our knowledge, such a study has not been done in children. A chronic obstructive pulmonary disease (COPD) study in adult subjects in 2004 showed a significant weak correlation between FEV-1 with pCO_2 and pO_2.[8] This difference might be due to childhood asthma being a reversible disease, unlike the chronic, persistent COPD, in which only severe attacks change pO_2 and pCO_2 levels. Different results in adult subjects may also be due to greater cooperativity during spirometry, compared to our pediatric subjects.

Further data analysis revealed significant differences between asthma severity groups in terms of FEV1, pO_2, and pCO_2 levels. Mean FEV1 was significantly lower in the severe asthma attack group compared to the mild-moderate attack group (26.99 *vs.* 47.75%, respectively; P=0.002), similar to another study.[18] Lower FEV1 was also correlated to airway reversibility.10 In addition, mean pCO_2 level was significantly higher in the severe group than in the mild-moderate group (48.2 *vs.* 35.9 mmHg, respectively; P=0.018). Padmavathi *et al.* found hypercapnia in 45% of patients with severe attacks.[11] The pCO_2 levels are considered to be 41-60 mmHg in severe attack and <40mmHg in mild-moderate attack.[14] In our study, mean pO_2 level was 132.55 mmHg in the mild-moderate attack group and 79.39 mmHg in the severe attack group (P=0.001). This result was similar to another study that showed hypoxemia in 55% of cases of severe asthma attack.[11]

Blood gas analysis has low specificity and cannot be used to assess the degree of broncho constriction, hence, blood gas analysis is not suitable as a screening test for early lung disease. During asthma attacks, pO_2 gradually decreases and pCO_2 also gradually decreases due to the hyperventilation mechanism.

Levels of pO_2 and pCO_2 continue to decrease in accordance with the severity of the attack, until at some point, the inability of the lungs to dispel CO_2 leads to arterial CO_2 entrapment. This condition is only found in severe asthma attacks, while in mild-moderate attacks, increased pCO_2 and decreased pO_2 are not observed.[7] Increased pCO_2 levels can be seen if the FEV1 reaches 20-25%. As such, the lack of significant correlations in our study may have been due to our having mostly subjects with mild-moderate asthma attacks (80%). Their pO_2 and pCO_2 levels may have been less affected.

Limitations of this study were that most subjects had mild-moderate attacks, and a time lag between blood gas analysis and spirometry (spirometry was performed first while waiting for phlebotomist). Also, the child's level of cooperation might influence spirometry results.

In conclusion, there is no significant correlation between decreased FEV1 and decreased pO_2, nor between decreased FEV1 and increased pCO_2 level. The FEV1 level is significantly lower in the severe asthma attack compared to the mild-moderate asthma attack groups. Also, the level of pO_2 is significantly lower and the level of pCO_2 is significantly higher, in the severe asthma attack group compared to mild-moderate asthma attack group. Further study with a larger sample size, case-control design, and examinations performed without a time lag may yield a better understanding about asthma.

Conflict of interest

None declared.

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