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Original Article

Comparison of SpO2/FiO2 and PaO2/FiO2 ratios as markers of acute lung injury

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Abstract

Background One of the diagnostic criteria for acute lung injury (ALI) is the PaO_2/FiO_2 (P/F) ratio. This measurement is obtained by blood gas analysis, which involves an invasive procedure (arterial blood draw). In order to reduce invasive procedures on critically ill patients, an alternative non-invasive marker for ALI is needed. The SpO_2/FiO_2 (S/F) ratio attained by pulse oximetry may be a suitable alternative.

Objective To investigate for a correlation between S/F ratio and P/F ratio, in order to find an alternative non-invasive marker of ALI.

Methods A cross-sectional study was conducted in the pediatric intensive care unit (PICU) at Haji Adam Malik Hospital, Medan from August 2012 to June 2013. Subjects (children aged 1 month – 18 years) underwent blood gas analysis when their pulse oximetry showed saturation of 80-97% within 24 hours of ventilator use. We measured PaO_2, SpO_2, and FiO_2 and calculated S/F and P/F ratios. Data were analyzed by Spearman's correlation and linear regression tests.

Results Of 69 PICU patients, 39 children fulfilled the criteria for ALI. The S/F ratio and P/F ratio had a weak correlation ($r=0.2$; $P=0.18$). The linear regression equation was S/F ratio = 129.67 + 0.11 (P/F), with S/F ratio values of 162.67 and 151.67 correlating to P/F ratio values of 300 and 200, respectively.

Conclusion The S/F ratio has a weak correlation with P/F ratio for ALI in children. **[Paediatr Indones. 2017;57:30-4. doi: 10.14238/pi 57.1.2017.30-4]**.

Keywords: *acute lung injury; children; S/F ratio; P/F ratio*

Acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) continue to be significant causes of morbidity and mortality for patients admitted to the PICU.[1] A US study reported that the incidence of pediatric ALI was 12.8 cases per 100,000 person-years, with a hospital mortality rate of 18%. The population incidence rates was lower than that of adult acute lung injury, with 78.9 cases per 100,000 person-years and mortality rates up to 38.5%.[2]

The ALI and ARDS are disorders of pulmonary inflammation, characterized by hypoxemia and respiratory failure.[3] They have been defined as acute hypoxic respiratory failure resulting from pulmonary or extra-pulmonary causes, except cardiogenic factors.[4] ARDS has more severe clinical findings than ALI. All patients with ARDS have ALI, but not all patients with ALI have ARDS.[5] A prospective study in Beijing reported that the survival rate was higher in patients

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with pulmonary disease origin (69.2%) than in the those with extrapulmonary disease origin (33.3%).[4]

In 1994, the American-European Consensus Conference (AECC) defined ALI/ARDS by the criterion of PaO_2 /FIO_2 (P/F) ratio, with ARDS, being the more severe form of ALI.[5] However, obtaining the P/F ratio requires arterial blood gas sampling.[6] In order to reduce invasive procedures in critically ill children, a non-invasive alternative marker for P/F ratio is needed. Routine use of pulse oximetry in most PICUs can minimize the use of blood gas analysis.[6] Generally, PaO_2 changes have correlated to pulse oximetric saturation (SpO_2) changes, in defining hypoxemic grade.[7] A prospective study in children in Los Angeles demonstrated that the SpO_2/FiO_2 (S/F) ratio had a strong correlatation to the P/F ratio, and could be used to identify ALI and ARDS.[8]

The aim of our study was to investigate for a correlation between S/F ratio and P/F ratio, with the goal of identifying an alternative non-invasive marker of ALI.

Methods

This cross-sectional study was conducted in the PICU, Haji Adam Malik Hospital, Medan from August 2012 to June 2013. Subjects were children aged 1 month to 18 years using ventilators. Subjects were collected by consecutive sampling. Specimens for blood gas analysis were taken when the patient's pulse oximetry showed a saturation of 80-97%, within 24 hours of ventilator use. Measurements were excluded if the SpO_2 values were not between 80% and 97%, or if the patient had a diagnosis of congenital heart disease (CHD), arrhythmia, dysrhythmia, shock, or hypothermia. SpO_2 values higher than 97% were excluded because the oxyhemoglobin dissociation curve showed no changes at >97%. This study was approved by the Medical Ethics Committee of the University of Sumatera Utara Faculty of Medicine.

Data were processed and analyzed with *SPSS version 17*, Spearman's correlation and linear regression tests were used for statistical analyses, with 95% confidence intervals.

Results

Of 69 patients who used ventilators during the study period, a total of 39 patients met the inclusion criteria. Thirty patients were excluded. Six patients had CHD and 24 other did not met ALI criterias. Data were

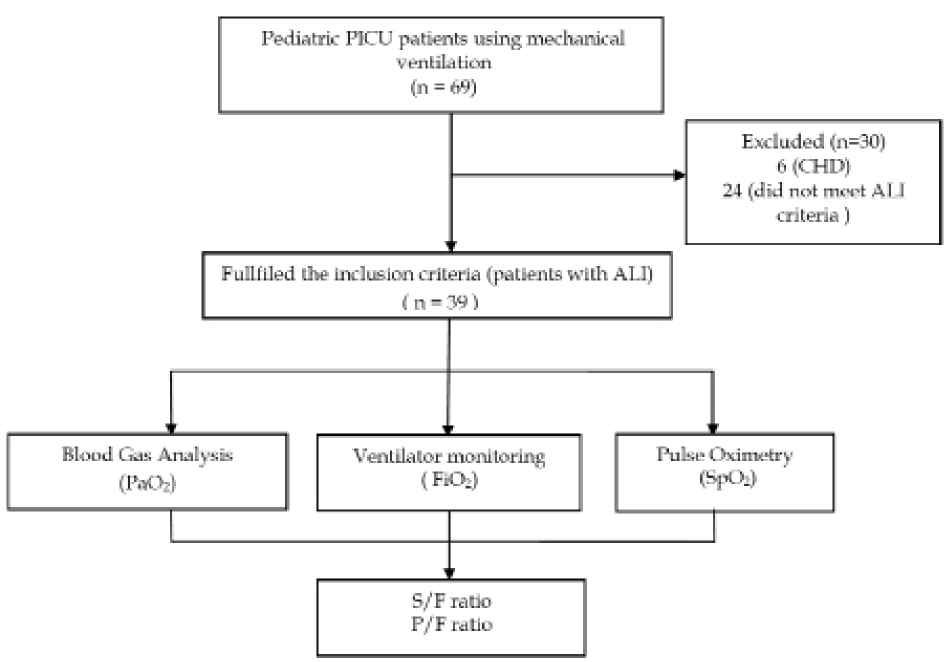

Figure 1. Study profile

collected during the first 24 hours of ventilator use. Blood specimens were used for blood gas analysis to assess PaO_2. At the same time, SpO_2 data from pulse oximetry and FiO_2, as seen from the ventilator readings, were recorded. The study profile is shown in **Figure 1**.

Basic characteristics of subjects are shown in **Table 1**. Subjects were predominantly male, had a mean age of 57 months, mean weight of 18.37 kg, and mean height of 98.01 cm.

Most subjects had bronchopneumonia on chest radiograph results and sepsis was the most common diagnosis in patients with ALI (**Table 1**).

Subjects' mean FiO2 was 60.76. Their mean PaO_2 and SpO_2 were 155.63 mmHg and 94.89%, respectively. The mean P/F ratio was 256.41 and mean S/F ratio was 159.00 (**Table 2**).

Table 1. Characteristics of subjects

Characteristics	(N = 39)
Mean age (range), months	57 (1-204)
Sex, n (%)	
Male	23 (59)
Female	16 (41)
Mean body weight (range), kg	18 (4-65)
Mean body height (range), cm	98 (45-150)
Mean heart rate (range), times/min	105 (76-170)
Mean respiratory rate (range), times/min	24 (14-50)
Mean temperature (range), °C	36.91 (35.8-37.6)
Mean blood pressure (range), mmHg	
Systolic	94.56 (70-140)
Diastolic	55.18 (40-90)
Radiography, n(%)	
Bronchopneumonia	26 (66.66)
Pleural effusion	6 (15.38)
Others	7 (17.94)
Diagnosis at ALI onset, n(%)	
Pneumonia	10 (25.64)
Sepsis	21 (53.84)
Multiple trauma	7 (17.94)
Drowning	1 (2.56)

Since the data were not normally distributed, Spearman's correlation was used to assess for a correlation between S/F ratio and P/F ratio (r=0.215; P=0.18).

Table 2. Oxygen parameters measured

Parameters	(N = 39)
Mean FiO2 (range)	60.76 (40 - 80)
Mean PaO2 (range), mmHg	155.63 (84.2 – 210.5)
Mean SpO_2 (range), %	94.89 (89 - 97)
Mean P/F ratio (range)	256.41 (206 - 300)
Mean S/F ratio (range)	159.00 (106 - 245)

Table 3. Spearman's correlation analysis of S/F ratio and P/F ratio

		S/F ratio
P/F ratio	r	0.215
	P	0.189
	N	39

Figure 2 shows no significant correlation (P>0.05) between P/F and S/F ratios, although S/F generally increased when P/F increased . The R^2 value of 0.9% indicates that the S/F ratio contributed to the P/F ratio by 0.9%, and the remaining 99.1% was determined by other variables.

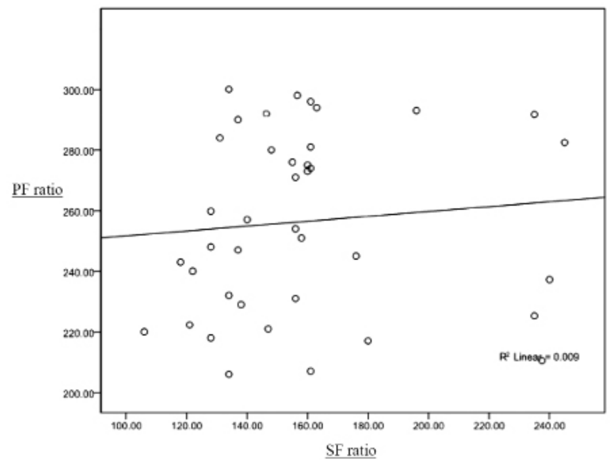

Figure 2. Scatterplot of P/F ratio and S/F ratio

Using the constant values of (a) 129.67 and (b) 0.11, we determined the regression linear equation to be: S/F ratio = 129.67 + 0.11 (P/F ratio). The S/F ratio increased by 0.11 for every 1 point increase in P/F ratio. The S/F ratios of 162.27 and 151.67 correlated with the P/F ratios of 300 and 200, respectively (**Table 4**).

Table 4. Linear regression analysis of S/F ratio and P/F ratio

Model	Correlation coefficient	P value
Constant	129.67	0.010
P/F ratio	0.11	0.545

Discussion

In the 39 children who met criteria for ALI, the most common underlying diseases were sepsis (53.84%) and pneumonia (25.64%). Similarly, a prospective study in Beijing reported that the most common causes of ALI were pneumonia (52%), sepsis (36%), multiple trauma (9%), lung contusion (5%), and drowning (2%).[4]

The result of this study showed weak correlation between S/F and P/F ratio and was not statistically significant (r = 0.2). A study in Los Angeles compared S/F ratio and P/F ratio in 383 children who suffered ALI/ARDS. From the total of 1,298 blood gas analysis results, the authors reported a moderate correlation (r=0.47).[6] The same ARDS Network study in 672 adult patients who suffered ALI/ARDS from the total of 672 blood gas analysis results showed a strong correlation (r=0.8).[8]

Non-invasive monitoring with pulse oximetry is routinely used in the emergency room and ICU. The measurement of SpO_2 with pulse oximetry may be a tool to predict the PaO_2 value, without using blood gas analysis. However, race, placement of the oximetry sensor, underlying disease, and methemoglobin can diminish the accuracy of the SpO_2 reading.[8]

We found the mean values of PaO_2 and SpO_2 to be 155 mmHg and 95%, respectively. Although the PaO_2 value was above 100 mmHg, the SpO_2 value remained in the range of 88-98%. The value of PaO_2 can increase above 100 mmHg, while SpO_2 is limited to 100%. Since many subjects had PaO_2 values above 100 mmHg, the oxyhemoglobin dissociation curve might not be applicable to our study. The relationship between PaO_2 and SpO_2 in the oxyhemoglobin dissociation curve depicted with two lines. The first line describes the relationship between SpO_2 and PaO_2, with the PaO_2 value in the range of 0 – 60 mmHg. Minor changes in PaO_2 will lead to major changes in SpO_2. The other line describes the relationship between SpO_2 and PaO_2, with the value of PaO_2 above 60 mmHg, forming an almost straight line. As such, major changes in PaO_2 will lead to minor changes in SpO_2.[7]

A prospective, multicenter study in the United States compared SpO_2 and PaO_2 in 137 ALI patients with 1,116 blood gas analysis results. The mean PaO_2 and SpO_2 values were 70 mmHg and 95%, respectively. These values indicated a strong correlation between S/F ratio and P/F ratio.[9] Another study in California showed the mean PaO_2 and SpO_2 values of 69 mmHg and 94%, respectively.[6] These two studies showed good results and in accordance with the principle of oxyhemoglobin dissociation curve.

The projected equation from this study was S/F ratio = 129.67 + 0.11 (P / F ratio). Using this formula, the S/F ratio is expected to increase by 0.11 for every 1 point increase in P/F ratio. The S/F ratio of 162.67 and 151.67 correlated with P/F ratio of 300 and 200, respectively. Another study compared S/F ratio with P/F ratio to predict ALI/ARDS in children. Rice *et al.* reported the equation S/F = 76 + 0.62 (P/F), where S/F ratio values of 263 and 201 correlated with P/F ratio values of 300 and 200, respectively.[8]

In Berlin (2012), improved criteria for ARDS was announced as "*The Berlin Definition*" according to the studies and data in adults. The validity of the definition for use in children was considered quite good, especially for the severe category of ARDS.[10,11] The ALI criteria in this study were based on "*The Berlin Definition,*" including mild ARDS criteria. Further study on the relationship of S/F and P/F ratios for severe ARDS in children based on "*The Berlin Definition*" is needed. A 2014 retrospective study on the relationship between ARDS according to Berlin criteria and mortality risk in children for 4 years concluded that using S/F ratio calculation to predict mortality resulted in a 2-fold higher mortality risk than using P/F ratio.[12]

The limitation of this study was that most PaO_2 values were above 100 mmHg. The PaO_2 values could exceed 100 mmHg, while SpO_2 values were limited to 100%. Hence, a comparison of these values would not yield a meaningful result. The mean PaO_2 value in this study was 100 mmHg, and only 3 subjects had PaO_2 values below 100 mmHg. According to the oxyhemoglobin curve, PaO_2 values >100 mm Hg cannot be used to determine a corresponding SpO_2 value. In conclusion, S/F ratio has a weak correlation with P/F ratio for ALI in children (r= 0.2).

Conflict of interest

None declared.

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