SpO$_2$/FiO$_2$ Ratio as an oxygenation parameter in pediatric acute respiratory distress syndrome

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ABSTRACT

Background: Acute respiratory distress syndrome (ARDS) diagnosis requires an invasive arterial blood sampling to reveal the PaO$_2$ and calculate the PaO$_2$/FiO$_2$ ratio. SpO$_2$/FiO$_2$ ratio has been proposed as a non-invasive alternative to identify oxygenation parameter in pediatric patients with ARDS.

Objective: To evaluate sensitivity and specificity of SpO$_2$/FiO$_2$ as an oxygenation parameter to detect ARDS.

Methods: We conducted a cross-sectional at the Pediatric Emergency and Intensive Care Department, Sanglah General Hospital, Denpasar, Bali. The inclusion criteria were 1 month to 12 years old patient admitted to our PICU and diagnosed with mild or moderate to severe ARDS based on blood gas analysis which fulfilled Berlin definition (ESICM 2012). The exclusion criteria were patient with a chronic lung disease and or a cyanotic heart disease. We collected SpO$_2$/FiO$_2$ ratio and calculated its sensitivity and specificity in detecting ARDS.

Results: There were 124 patients enrolled. The most common diagnosis was diseases in respiratory system (62.1%). Based on ROC analysis to determine SpO$_2$/FiO$_2$ ratio needed to detect moderate to severe ARDS, the AUC was 0.76 (95%CI 0.677-0.843) and the cut-off point for SpO$_2$/FiO$_2$ ratio was <196. The sensitivity was 88.5% (95%CI 77.8-95.3) and specificity 44.4% (95%CI 31.9-57.5).

Conclusion: SpO$_2$/FiO$_2$ ratio can be used as an oxygenation parameter in ARDS patients.

Keywords: SpO$_2$/FiO$_2$ ratio, acute respiratory distress syndrome, pediatric ARDS


INTRODUCTION

Acute respiratory distress syndrome (ARDS) is the most frequent complication causing a high morbidity and mortality in Pediatric Intensive Care Unit (PICU). However, the diagnostic and intervention study concerning ARDS are still lacking. ARDS has sophisticated diagnostic criteria that require an invasive blood gas analysis.

ARDS was reported to occur between 17 and 34 cases every 100,000 patients a year. This illness was also accounted for causing 16% of ventilator usage in intensive care unit. In pediatric population, the incidence rate was reported to be between 2.2 and 12.8 patient per 100,000 patient a year, with 2.2-2.6% of ARDS patients being admitted to PICU. In Brazil, 2013, when categorized based on the 2012 Berlin definition, 16% of them suffered from the mild form of the disease, with 37% and 47% suffered from moderate and severe case of ARDS, respectively. In PICU of Sanglah General Hospital, Bali, acute lung injury (ALI) and ARDS constituted 18% of the diagnosis between 2013 and 2014.

The presence of an acute onset of hypoxemia is one of the diagnostic criteria for diagnosing both ALI and ARDS, commended by the 1994 American-European Consensus Conference (AECC). Hypoxemia is defined as the ratio between arterial oxygen partial pressure to inspired oxygen fraction (PaO$_2$/FiO$_2$). A patient is diagnosed with ALI when the value is between 200 to 300 mmHg and diagnosed with ARDS when the value was less than or equal to 200 mmHg.

In 2012, a new consensus called Berlin definition was released by the European Society of Intensive Care Medicine (ESICM) and ratified by the American Thoracic Society and the Society of Critical Care Medicine to diagnose ARDS. This diagnosis criteria are the presence of bilateral infiltrate on chest x-ray consistent with pulmonary edema which must not be attributed to heart failure or fluid overload, development of symptoms within 1 week or less, and oxygenation disturbance with PaO$_2$/FiO$_2$ ratio of less than 300 mmHg with a minimum of 5 cmH$_2$O positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP). Additionally, ARDS is further classified into the mild, moderate, and severe case based on the PaO$_2$/FiO$_2$ ratio on PEEP or CPAP of ≥ 5 cm H$_2$O. It is mild when the PaO$_2$/FiO$_2$ ratio more than 200 mmHg but less or equal to 300 mmHg, moderate when the ratio more than or equal to 100 mmHg but less or equal to 200 mmHg, and
severe when less than 100 mmHg. The new definition is claimed to have a better predictive validity to determine mortality and disease severity.\(^7\)

\(\text{PaO}_2\) value is obtained from a blood gas analysis from an arterial blood which sample collection method is an invasive procedure. In contrast, the \(\text{SpO}_2\) value can be obtained by using a pulse oximeter. A pulse oximeter is a simple, noninvasive device to evaluate an approximation of arterial oxygenation. Indeed, it has been widely used in clinical settings.

The \(\text{SpO}_2\) of a child without ARDS are expected to be 92% to 100%. The \(\text{SpO}_2\) of a child with ARDS is expected to be around 88% to 95%. Based on oxyhemoglobin dissociation curve, \(\text{SpO}_2\) between 80% and 97% creates a nearly straight line. Thus, it could be assumed that \(\text{SpO}_2\) might potentially replace \(\text{PaO}_2\) to identify ARDS.\(^8\) Pulse oximeter is primarily used to monitor patients with respiratory dysfunction as it may detect symptoms of hypoxemia. It has been proven effective in monitoring oxygenation therapy in both adult and pediatric patients.\(^9\)

The objective of this study is to diagnose ARDS by determining \(\text{SpO}_2/\text{FiO}_2\) ratio using a pulse oximeter. Research concerning means to noninvasively diagnose ARDS has been done in many countries. But, the in Indonesia it is still lacking.

METHODS

A cross-sectional study was conducted between June 2014 and May 2016 at the Pediatric Emergency and Intensive Care Department, Sanglah General Hospital, Bali. The sample size was calculated using the formula for diagnostic study with area under curve (AUC) result. AUC 1 for ARDS based on literatures was 0.85, with AUC 2 was expected to be 0.95; meanwhile, AUC 1 for ALI was 0.80 and the expected AUC 2 was 0.90. On two-tailed hypothesis, the type I error was 5% and type II error was set at 20%. As a result, the sample size was 124 children. This study has been approved by the Ethical Committee of Udayana University’s Faculty of Medicine. The data was collected from July 2014 to June 2016. The samples were recruited consecutively.

The inclusion criteria were patient admitted PICU of Sanglah General Hospital, aged 1 month to 12 years by the time of admission, diagnosed with mild ARDS and moderate to severe ARDS based on blood gas analysis result that fulfilled the Berlin definition, the parents were willing to participate in the study, and the parents signed the informed consent form (ICF). The exclusion criteria were patient with chronic lung disease (e.g., pulmonary tuberculosis) and cyanotic heart disease.

The study was done by direct observation by measuring the \(\text{PaO}_2/\text{FiO}_2\) to get the severity of ARDS based on Berlin definition. The patient blood for blood gas analysis was drawn by a laboratory assistant. The subjects were using either CPAP or a ventilator. The subjects were also checked for \(\text{SpO}_2\) using a pulse oximeter to get the \(\text{SpO}_2/\text{FiO}_2\) ratio.

The eligible patients were later categorised based the severity of the ARDS based on Berlin definition. On mild cases, the \(\text{PaO}_2/\text{FiO}_2\) ratio is ≤ 300 mmHg; on moderate cases, the ratio is ≥ 100 mmHg and up to ≤ 200 mmHg; and finally, severe ARDS is when the \(\text{PaO}_2/\text{FiO}_2\) ratio is < 100 mmHg. On severe ARDS, severe hypoxemia is bound to happen, which in turn will require the patient to be put on high mean airway pressure through ventilator or CPAP and be admitted to the pediatric intensive care unit.

Age is time unit measured from the date, month, and year a child was born. The anthropometric measurement was done using a standard procedure from pediatrics department of Sanglah Hospital by measuring the weight and height of a child using stadiometer. If the patient is unable to mobilize, weight measurement was done using bed scale and height measurement was done using a measuring tape. Nutrition status was determined based on weight-for-length/weight-for-height indicator using WHO Anthro and WHO AnthroPlus software, which are based on WHO growth standard issued in 2006.\(^10\) Categorization of nutritional status into severely wasted, wasted, normal, overweight, and obese was based on WHO criteria which were adapted by Pediatric Nutrition Care, a recommendation issued by Indonesian Pediatrics Society in 2011.\(^11\)

The data was analyzed with a computer program. We did a descriptive analysis of the study variables, ROC analysis to determine the cut-off value. We also calculated the sensitivity (Sn) and specificity (Sp) based on the best cut-off value, positive predictive value (PPV), negative predictive value (NPV), accuracy (Ac), positive likelihood ratio (PLR), and negative likelihood ratio (NLR) compared to the gold standard.

RESULTS

There were 679 infants and children admitted to PICU between June 2014 and June 2016. Only 186 patients met the inclusion criteria. As many as 56 patients were excluded based on the exclusion criteria. We analyzed a total of 124. The demographic characteristics are presented in Table 1.

The sample comprises of 55.6% male. The median age was 5 month (IQR 2-19). Most subjects (57.3%)
has normal nutritional status. The diagnosis was grouped based on which organ system dysfunction causing an admission to our hospital, which 62.1% had a respiratory system dysfunction. The mean PaO$_2$ was 123.5 (SD 45.9), mean PaCO$_2$ 49.7 (SD 20.9), and mean FiO$_2$ 0.68 (SD 0.2). Additionally, the mean PaO$_2$/FiO$_2$ ratio was 192 (SD 65.8) and SpO$_2$/FiO$_2$ 157.8 (SD 59.7). The most duration from the onset of symptoms until the development of ARDS was 3-7 days (70.2%). Based on the severity, 50.8% suffered from mild ARDS. Most chest x-ray interpretation of subjects came out as pneumonia (74.2%). The respiratory support used by most subjects was ventilator with PEEP ≥ 5cmH$_2$O (60.5%).

The curve shown in Figure 1 showed that SpO$_2$/FiO$_2$ ratio has a good ability to predict mild ARDS. Best cut-off point for SpO$_2$/FiO$_2$ ratio lies under 196. Based on that cut-off point, sensitivity and specificity are calculated (validity test).

According to the calculation result for sensitivity, specificity, PPV, and NPV of SpO$_2$/FiO$_2$, it was found that sensitivity of SpO$_2$/FiO$_2$ ratio in predicting moderate to severe ARDS is 88.5% and its specificity is 44.4% (See Table 3).

**DISCUSSION**

Our sample age median was 5 month (IQR 2-19) and most of them were male (55%). It is similar to another study showing the incidence of ARDS among patients admitted to PICU was 2.6%, with the majority of the subjects was under 1 year old and male. A different study had a mean age of 3 years, with the male as the majority of patients. ARDS incidence varies between studies. One of the factors causing the variation is the difference in the
definition used in determining ARDS. This study applied the Berlin definition issued by the ESICM in 2012.

Most ARDS in this study was the result of respiratory system disturbance (62.1%), with pneumonia as the dominating cause. A similar result was observed in a study by Bauer, et.al. in 2006, in which they found that the onset of symptoms was considered the most common cause of ARDS. Additionally, the onset of symptoms was found to be supported by other studies, which was 3-7 days. Similarly, Barreira, et al., found that the median of time from the onset of symptom until development of ARDS was 3 days (IQR 2-5).

In predicting moderate to severe ARDS, SpO2/FiO2 ratio has a sensitivity of 88.5% and specificity 44.4%. It is important to find out which Berlin definition's category and at what PaO2/FiO2 ratio value does the SpO2/FiO2 ratio correspond to. In our study, SpO2/FiO2 ratio of < 196 is equal to PaO2/FiO2 ratio of < 200 in moderate to severe ARDS case. It shows that SpO2/FiO2 ratio can be used as an oxygenation parameter for ARDS. This finding is similar to a study by Khemani, et al, where the sensitivity and specificity for the SpO2/FiO2 ratio of 201 to determine ARDS were 84% and 78%, respectively. Whereas Bilan, et al., found that SpO2/FiO2 ratio of 181 has a sensitivity of 71% and a specificity of 82% to detect ARDS.

STUDY LIMITATION

The limitation of this study was that it did not consider conditions that might shift the oxyhemoglobin dissociation curve. Additionally, this study did not consider any slight variation in SpO2 estimation between the device of different brand and calibration status.

CONCLUSION

The SpO2/FiO2 ratio can be used as an oxygenation parameter in ARDS patients.

REFERENCES


