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RESEARCH LETTER

Classifying Acute Respiratory Distress Syndrome Severity: Correcting the Arterial Oxygen Partial Pressure to Fractional Inspired Oxygen at Altitude

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BACKGROUND

In the well-known Berlin definition of acute respiratory distress syndrome (ARDS)[1], there is a recommended adjustment for arterial oxygen partial pressure to fractional inspired oxygen (PaO_2/FIO_2) at altitude, but without a reference as to how it was derived. At the same shunt, PaO_2/FIO_2 decreases with altitude[2], impairing a proper comparison of individuals with similar lung damage if they reside at different altitudes and if the shunt is not directly measured, as is the case in most patients. It is then very important in multicenter studies to correct the PaO_2/FIO_2 by altitude or barometric pressure (i.e. raise the value of PaO_2/FIO_2 obtained at altitude), but unfortunately, the adjustment is not a simple function of altitude or barometric pressure[2]. The correction suggested by the working group does the opposite of what is needed because it requests a multiplication by a fraction: barometric pressure (Pbar)/760. If, instead of multiplying by Pbar/760, we divide by the ratio (to set, for example, varying limits for ARDS severity at different altitudes), the resulting PaO_2/FIO_2 is closer to that expected at sea level for lower shunts (and high PaO_2/FIO_2), but overcorrects at higher shunts and of course does not take into account changes in PaO_2/FIO_2 due to modifications of FIO_2[3]. Our aim was to develop an equation able to take into account the impact of altitude on PaO_2/FIO_2 so that patients from different altitudes could be compared at a more homogeneous degree of lung damage.

METHODS

Computational lung models of gas exchange provide a better understanding of the problem. We performed a computer simulation changing FIO_2 from 0.21 to 1.0, altitude from sea level to 3,000 m, barometric pressure from 537 to 760 mmHg, and shunt from 5 to 50% of cardiac output, maintaining constant hemoglobin, carboxyhemoglobin, p50, 2,3-diphosphoglycerate (2-3DPG), cardiac output, and acid-base status and without incorporating into the model ventilation/perfusion (V/Q) inequalities[4]. Calculated values at varying altitudes were incorporated into a database

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Table 1. Classification of acute respiratory distress syndrome severity in 173 patients admitted to the intensive care unit at an altitude of 2,240 m

ARDS severity by level of PaO$_2$/FIO$_2$	Without adjustment n (%)	With the Berlin definition adjustment n (%)	With suggested adjustment (lung models) n (%)
Mild	34 (19.7)	8 (4.6)	71 (41.0)
Moderate	104 (60.1)	97 (56.1)	97 (56.1)
Severe	35 (20.2)	68 (39.3)	5 (2.9)

ARDS: acute respiratory distress syndrome; PaO$_2$/FIO$_2$ arterial oxygen partial pressure to fractional inspired oxygen.

and then simpler linear multiple regression equations of sea level-adjusted PaO$_2$/FIO$_2$ were obtained as a function of FIO$_2$, altitude above sea level (or barometric pressure), and measured PaO$_2$/FIO$_2$, all with an $R^2 > 0.99$. The impact of the proposed adjustment on the severity of ARDS classification was tested on a group of patients with ARDS secondary to pneumonia admitted during 2014-2015 to the intensive care unit of a referral center for respiratory diseases in the metropolitan area of Mexico City (altitude 2,240 m above sea level).

RESULTS

Using altitude in meters to estimate PaO$_2$/FIO$_2$ at sea level (PaO$_2$/FIO$_2$SL):

$$PaO_2/FIO_2SL = (PaO_2/FIO_2*1.245) + (FIO_2*51.51) + (0.0307*altitude) - 88$$

Using mean Pbar in mmHg:

$$PaO_2/FIO_2SL = 224.46 + (PaO_2/FIO_2*1.245) - (Pbar*0.413389) + (FIO_2*51.55)$$

Table 1 shows the severity of ARDS with the original classification and after the proposed adjustment, duplicating the percentage of patients with mild ARDS.

DISCUSSION

These proposed adjustments appropriately raise the PaO$_2$/FIO$_2$ measured at altitude, so that the same sea level cut-point limits to classify ARDS severity can be utilized when comparing patients living at different altitudes above sea level. Empirical testing of estimations is necessary although rather complicated because several factors that are maintained constant in the computer simulation regularly have variations in critical patients.

The adjustments are important as is evidenced by the shift in severity classification of a group of patients with ARDS (Table 1), displaced towards milder stages, as expected, because part of the decreased PaO$_2$/FIO$_2$ observed in Mexico City was due to altitude and not to lung damage. Classifications by saturation of oxygen (SaO$_2$/FIO$_2$, not shown) had a similar tendency.

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