Technical note

A nomogram for obtaining the partial pressure of oxygen in alveolar air

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The relation between the arterial and the alveolar partial pressure of oxygen (P_{O_2}) is used for estimation of venous admixture in critically ill patients,^{1,2} for adjusting the inspired oxygen concentration to obtain the required arterial P_{O_2} in patients having mechanical ventilation,³⁻⁵ as a basis for deciding whether to wean a patient from mechanical ventilation,⁶ for calculating intrapulmonary shunting,⁷ and for predicting the extent of hypoxaemia during an air flight in patients with chronic obstructive lung disease.⁸ Whereas the arterial P_{O_2} is estimated by blood gas analysis, the partial pressure of oxygen in alveolar gas (PAO_2) is obtained from the alveolar gas equation^{9,10}:

$$PAO_2 = (PB - PH_2O) \times FIO_2 - \frac{PaCO_2}{R}$$

where PB is the barometric pressure in mm Hg, PH_2O is the water vapour pressure

(which at 37°C is 47 mm Hg), FIO_2 is the fraction of oxygen in inspired air, $PaCO_2$ is the partial pressure of carbon dioxide in arterial blood, and R is the respiratory quotient. To avoid the tedious task of repeatedly calculating PAO_2 by solving the alveolar gas equation, we attempted to produce a nomogram that takes all these variables into account.

The nomogram

The nomogram was drawn on the basis of the alveolar gas equation on the assumption that the value of R is 0.8. The barometric pressure (PB) is selected on the scale at the bottom of the left hand portion of the nomogram. A vertical line is plotted upwards from this PB until it intersects the desired FIO_2 line. For values of FIO_2 that lie between two drawn FIO_2 lines a measured or approximate point is selected. From this point a horizontal line is

Nomogram based on the alveolar gas equation for obtaining the alveolar partial pressure of oxygen (PAO_2). P_{IO_2} —partial pressure of oxygen in inspired air; P_{aCO_2} —partial pressure of carbon dioxide in arterial blood. Correction for the respiratory quotient (R): The correction factor is obtained by rounding off $PaCO_2$ in kPa to the nearest whole number and then dividing this by 10, or by dividing $PaCO_2$ in mm Hg by 10 and rounding this off to the nearest whole number. If $R = 0.8$, no change in PAO_2 is required; if $R = 0.7$, 1.5 times the correction factor is subtracted from the PAO_2 ; if $R = 0.9$, 1.5 times the correction factor is added to PAO_2 ; if $R = 1$, twice the correction factor is added to the PAO_2 .

plotted, extending rightwards across the vertical scale for the partial pressure of oxygen in inspired air (P_{iO_2} , kPa) into the right hand portion of the nomogram. The P_{iO_2} value may be read off this vertical (kPa) scale or off the vertical scale on the right in mm Hg if desired, but is not essential for obtaining the PAO_2 . The horizontal line that is being plotted is extended until it intersects the desired P_{aCO_2} line. A vertical line through this point of intersection, drawn upwards (if the horizontal line is in the upper half of the nomogram) or downwards (if the horizontal line is in the lower half of the nomogram) will give the PAO_2 value in kPa and mm Hg.

In most clinical circumstances the respiratory quotient is assumed to be 0.8³⁷; we therefore assumed this value when preparing the nomogram. If, however, in a particular patient the respiratory quotient is measured and is not 0.8, a correction is provided (see legend below figure).

Validation

After some practice in using the nomogram and a non-programmable pocket calculator, 20 resident doctors were given 10 problems; in each case values were provided for P_B , F_{iO_2} , and P_{aCO_2} , from which the PAO_2 had to be derived first with the calculator and then with the nomogram. In problems 1–5 there was a constant P_B of 760 mm Hg, so these values could be plotted on the vertical line already drawn on the nomogram at 760 mm Hg. In problems 6–10 the P_B varied from 500 to 800 mm Hg. These doctors took an average of 13 seconds (95% CI 8.07–18.03 seconds) longer over each problem with the nomogram than with the calculator. The mean of the residuals (difference between actual and

nomogram values) was 7.4 mm Hg or 1 kPa (95% CI 6.1–8.7 mm Hg or 0.8–1.2 kPa).

The nomogram is suitable for use up to an altitude of 11 000 feet (3353 metres). We recommend that users draw a vertical line corresponding to the barometric pressure at the altitude at which they are working. The line for use at sea level is the one already drawn at 760 mm Hg. Plotting values on a line that is already drawn increased accuracy.

Our nomogram therefore gives fairly accurate values of PAO_2 within a reasonable time. Moreover, its ease of use makes it a convenient alternative to a pocket calculator.

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