Arterial blood gases in the differential diagnosis of hypoxemia

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BACKGROUND

Investigation of hypoxemia (low PaO_2) invariably benefits from a structured physiological approach based on a careful interpretation of arterial blood gas (ABG) analysis. Determining the underlying mechanism(s) might be particularly challenging when there are multiple potential causes changing over time, either spontaneously or secondary to treatment.

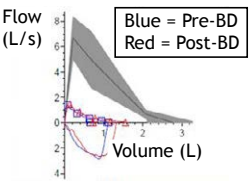
OVERVIEW

A 71 year-old woman with severe COPD (Figure 1A), GOLD classification B, and modified Medical Research Council scale score 2, presented to the emergency department with worsening dyspnea, productive cough, and abdominal pain. She was confused, lethargic, and hypoxemic (SpO_2 = 88% on room air), and presented with mild leukocytosis (12.6 x 10^3 cells/μL). Inhaled short-acting bronchodilators were optimized, and O_2 was administered by nasal cannula (2 L/min). Owing to an unremarkable chest X-ray in the supine position (as per the current pandemic precautions) plus a widened alveolar-arterial O_2 pressure gradient [$P(A\text{-}a)O_2$]—Figure 1B—a CT pulmonary angiogram was requested. Despite the absence of pulmonary embolism, an extensive retrocardiac consolidation was observed (Figure 1C). After 7 days of antibiotic therapy, she was discharged on O_2 at 1 L/min aiming at a $SpO_2 \approx$ 90-91%. Twenty days later, she returned to the emergency department presenting again with confusion and somnolence; however, her SpO_2 was 99%, O_2 flow was at 4 L/min, and ABG analysis revealed respiratory acidosis with improved $P(A\text{-}a)O_2$ (Figure 1D). After 3 days on noninvasive ventilation plus O_2 at 1 L/min, she was discharged after marked improvement in respiratory acidosis and neurological status.

If PaO_2 is substantially lower than alveolar O_2 tension (PAO_2)—i.e., widened $P(A\text{-}a)O_2$—there are a number of disorders of the lung structure reducing the efficiency of O_2 transfer, e.g., diffusion, limitation across the alveolar-capillary membrane (rarely), ventilation-perfusion (V/Q) mismatch, or shunt. In these circumstances, $PaCO_2$ is usually low. Conversely, if PaO_2 is reduced in tandem with PAO_2 (i.e., normal $P(A\text{-}a)O_2$), PAO_2 is low due to reduced inspired PO_2 (e.g. altitude) and/or alveolar CO_2 tension is increased, suggesting respiratory depression (alveolar hypoventilation).[1,2] The high $P(A\text{-}a)O_2$ in the first ABG analysis (Figure 1B) was secondary to a common cause of V/Q mismatch: an infectious pneumonic consolidation[3]

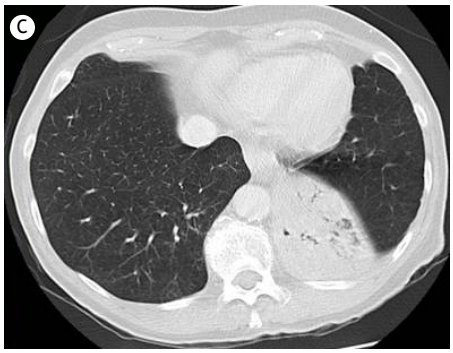
(A)

	Pre-BD	%predicted	Post-BD	%predicted
FVC	1.12	40	1.56	56
FEV_1	0.65	30	0.73	33
FEV_1/FVC	0.58		0.47	



(B)

	1st ED Visit
pH	7.48
$PaCO_2$ (mmHg)	44.4
HCO_3 (mmol/L)	32.9
PaO_2 (mmHg)	73.5
SaO_2 (%)	95.7
O_2 flow (L/min)	2
$P(A\text{-}a)O_2$ (mmHg)	67.4



(D)

2nd ED Visit
7.35
72.5
39.7
124.0
98.9
4
27.1

Figure 1. Baseline spirometry (in A) of a 71-year-old woman with a previous diagnosis of COPD who presented at the emergency department with worsening dyspnea and hypoxemia (baseline blood gas analysis in B). A CT pulmonary angiogram revealed pneumonia in the left lower lobe (Figure 1C), which explained an increased alveolar-arterial O_2 pressure gradient (expected value, 2.5 + [0.21 × age] = 17.4 mmHg). A few days after the resolution of pneumonia, a second arterial blood gas analysis showed lower alveolar-arterial O_2 pressure gradient and hypercapnia, as well as respiratory acidosis induced by the currently excessive high offer of O_2 at 4 L/min (in D). BD: bronchodilator; ED: emergency department; HCO_3: bicarbonate; and $P(A\text{-}a)O_2$: alveolar-arterial O_2 pressure gradient.

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(Figure 1C); in fact, the patient's hypoxemia responded well to a relatively low FiO_2, which is not consistent with shunt. ABG analysis also revealed increased bicarbonate levels: when a patient with chronic hypercapnia and showing compensatory bicarbonate accumulation is exposed to a source of a high ventilatory drive (e.g. hypoxemia), $PaCO_2$ may drop down to the normal range; thus, metabolic alkalosis may emerge (Figure 1B).[1] The second ABG analysis showed a different scenario (Figure 1D): at that point in time, the extra source of V/Q mismatch was no longer present, i.e., pneumonia had been resolved. Consequentially, excessively high inspired O_2 flows for the improved $P(A\text{-}a)O_2$ increased O_2 tension in the alveoli, causing low level of ventilation and inhibiting hypoxic pulmonary vasoconstriction, a well-known cause of hypercapnia (Figure 1D).[4,5]

CLINICAL MESSAGE

Interpretation of ABG analysis in a hypoxemic patient should consider the clinical history, ongoing treatment, and recent/current inspired O_2 flows. The information provided by $P(A\text{-}a)O_2$ should be considered in association with $PaCO_2$ (and pH). A normal $P(A\text{-}a)O_2$ in the presence of hypoxemia signals reduced ambient oxygen or alveolar hypoventilation, shown by elevated $PaCO_2$.

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