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An Introduction to Blood Gas Analysis

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Things You Can Know Without Performing a Blood Gas Analysis

- Historical
  - Is the patient having difficulty breathing?
  - Is the patient having a change in symptoms over time?

- Physical
  - Is the patient working to breathe?
  - Is the patient wheezing?
  - Does the patient have rales?

- Noninvasive Measurement
  - Is the patient sufficiently oxygenated (SaO_2)?

Pulse Oximetry ‘The 5th Vital Sign’

- Non-invasive
- Instantaneous
- Ubiquitous
- SaO_2 < 95% the usual cutoff for normal versus ‘abnormal’
- Limitations:
  - Patient must have pulse
  - Detects only significant decreases in PO_2
  - Does not comment on content

 Roger W. Stevens (Wikipedia)

Reasons to Sample Arterial Blood

- Firmly establish the severity of an oxygenation abnormality
- To evaluate hyper- or hypoventilation
  - Currently no convenient noninvasive way of evaluating pCO_2
- To determine acid-base status, particularly in patients with metabolic acidosis (e.g., diabetic ketoacidosis)
- To track the application of mechanical ventilation in a critically ill patient

Most Dyspneic Patients Don’t Require ABG Analysis

- When cause of dyspnea is established
  - Asthma, CHF, restrictive lung disease, etc.
- When cause of dyspnea is suspected and patient is not especially ill
  - E.g., a child with new-onset wheezing in January
- When dyspnea is so severe as to warrant immediate mechanical ventilation
  - The decision to intubate and mechanically ventilate is almost always one based on clinical, not laboratory, grounds

Limitations of ABGs

- ABGs measure gas partial pressures (tensions)
  - Remember: PO_2 is not the same as content! A severely anemic patient may have an oxygen content reduced by half while maintaining perfectly acceptable gas exchange and therefore maintaining pO_2
- Technical issues
  - They hurt
  - Sampling from a vein by mistake
  - Finding an arterial pulse can be difficult in very hypotensive patients
  - Complications such as arterial thrombosis are possible, but awfully rare

PD-INCL Pemed www.pemed.com/lab/labanalz/labanalz.htm

ABGs: What You Get

- Arterial PO_2
- Arterial PCO_2
- Arterial pH
- Some electrolytes (e.g., Na^+, K^+, Ca^{++})
- Lactate

Measured. The real meat of the sample

- $[HCO_3^-]$
- SaO_2
- Other assorted calculated results

An Organized Approach to ABG Interpretation

- Determining oxygenation abnormalities
- Determining acid-base status and evaluating adequacy of ventilation

Evaluating Oxygenation

- What is a ‘normal’ PO_2?
  - Oxygenation gradually deteriorates during life
  - Several calculations available for determining ‘normal’ based on patient age.

$$P_aO_2 = 104.2 - (0.27 \times age)$$

i.e., 30 year old ~ 95 mmHg
60 year old ~ 88 mmHg

  - Note: Some patients with previous (and now resolved) severe pulmonary diseases may never recover their full lung function, so any sense of ‘normal’ needs to be tempered with historical information

Oxygenation: Two Key Questions Addressed with an ABG

Is the patient hypoxic?

Is the hypoxia due to:

- Hypoventilation
- One of the 3 other causes
- Or a combination of both

Importantly, an ABG alone cannot differentiate diffusion block, V/Q inequality, and shunt!

Looking at the PO_2 versus Calculating the A-a gradient

- In a comfortable patient breathing room air, glancing at the PO_2 will allow a cursory interpretation of oxygenation
- However, most ABGs are performed in sick patients
  - Supplemental oxygen may be present
  - Importantly, the patient may be compensating for an oxygenation defect by hyperventilating, hiding the abnormal oxygenation

Evaluating Oxygenation with ABGs

- Step 1. Determine the A-a gradient

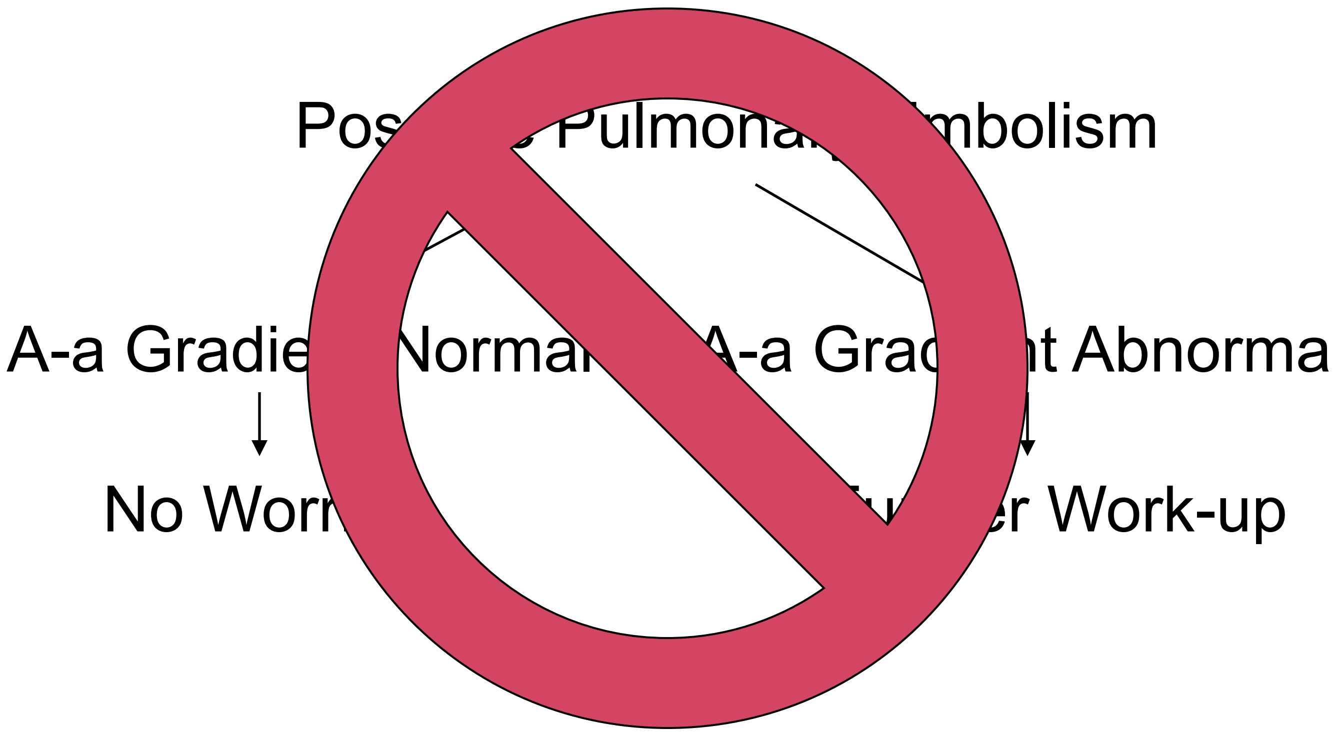
A-a Gradient =

$$[(P_{atm} - P_{H2O}) \times FiO_2] - (P_{CO2}/RQ) - P_aO_2$$

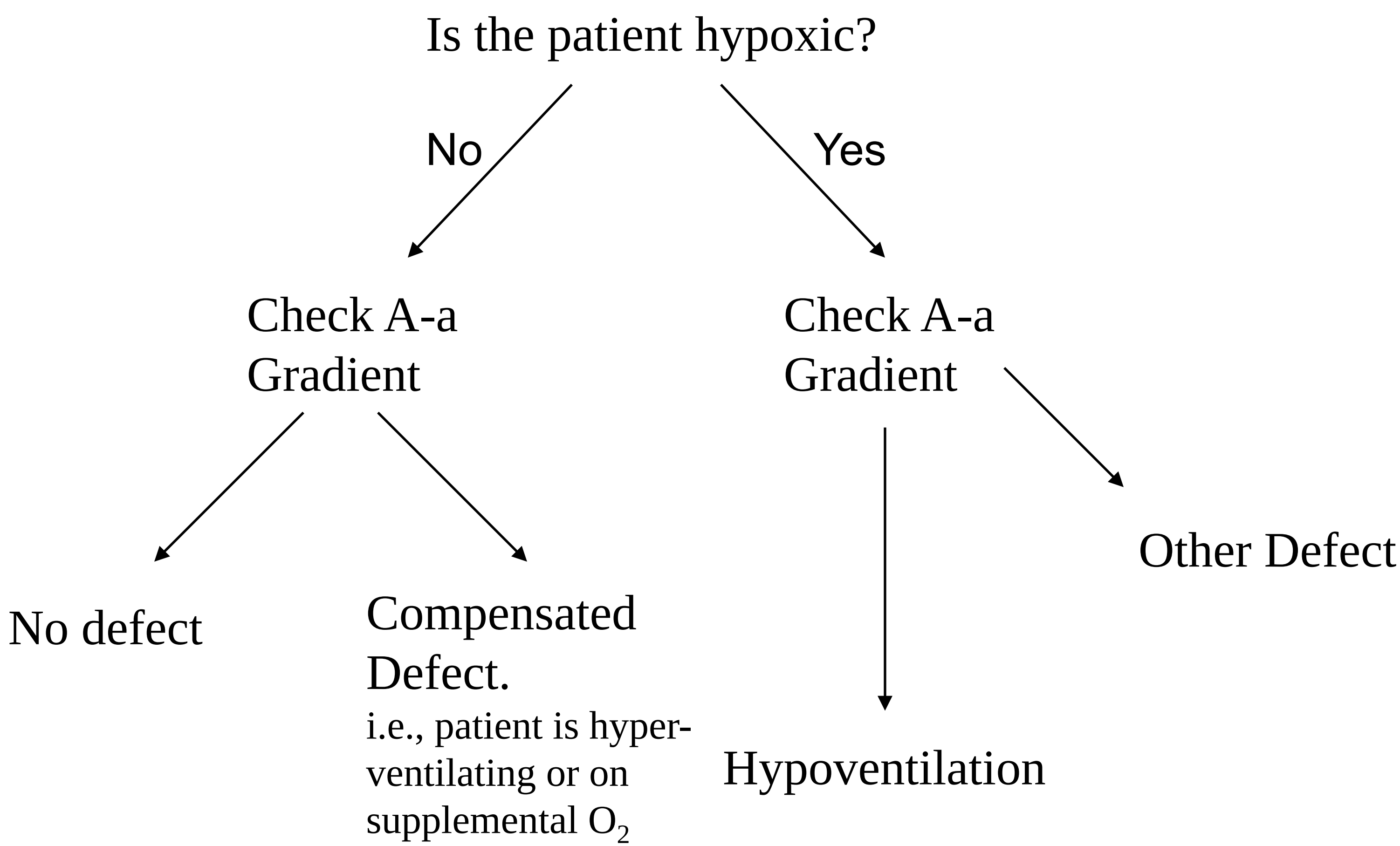
P_{atm} = 760 mmHg
P_{H2O} = 47 mmHg
FiO_2 = 0.21 on room air at sea level
P_{CO2} is taken from the blood gas measurement
RQ can be assumed to be 1 (possible range from 0.7 to 1.0)

Why do details like RQ matter?

- ABGs occasionally used as dichotomous results, prompting changes in management



Evaluating Oxygenation with ABGs



Evaluating Acid-Base Status

- Both metabolic and respiratory abnormalities can alter pH
- Respiratory and renal function strive to keep pH = 7.4.
  - Minute ventilation can respond very quickly to metabolic acid-base problems
  - Renal excretion or retention of bicarbonate takes days to compensate for respiratory acid-base problems
- For our purposes, 3 questions:
  - Is the abnormality respiratory or metabolic?
  - If respiratory, is it acute or chronic?
  - If metabolic, is the respiratory system responding appropriately?

Evaluation of Acid-Base Status:
Is the patient acidemic or alkalemic?

What is the pH?

< 7.38	>7.42
↓	↓
Acidemic	Alkalemic

Evaluation of Acid-Base Status: Is the disorder respiratory or metabolic?

If acidemic (pH < 7.38)

What is the PCO_2?

> 40 mmHg → Respiratory acidosis

< 40 mmHg → Metabolic acidosis

Evaluation of Acid-Base Status: Is the disorder respiratory or metabolic?

If alkalemic (pH $>$ 7.42)

What is the PCO_2?

$>$ 40 mmHg → Metabolic alkalosis

$<$ 40 mmHg → Respiratory alkalosis

For respiratory abnormalities, is the condition acute or chronic?

Acute respiratory disturbances change **pH 0.08** units for every **10 mmHg** deviation from normal

Therefore, in acute respiratory acidosis, the pH will fall by 0.08 x [(PCO_2 - 40)/10]

In acute respiratory alkalosis, the pH will rise by 0.08 x [(40-PCO_2)/10]

For respiratory abnormalities, is the condition acute or chronic?

Chronic respiratory disturbances only change **pH 0.03** units for every **10 mmHg** deviation from normal

Therefore, in chronic respiratory acidosis,
pH will fall by 0.03 x [(PCO_2 - 40)/10]

In chronic respiratory alkalosis, the
pH will rise by 0.03 x [(40-PCO_2)/10]

Regarding Metabolic Acidosis

- It is common for patients with severe respiratory disease to at some point develop other systemic illnesses producing metabolic acidosis.
- Patients with metabolic acidosis will attempt to hyperventilate to correct their pH
- It's useful in patients with lung disease to determine how successful they are in 'blowing off their CO_2'

Appropriateness of Respiratory Response to Metabolic Acidosis

Predicted Change in $PCO_2 = (1.5 \times HCO_3) + 8$

If patient's PCO_2 is roughly this value, his or her response is appropriate

If patient's PCO_2 is higher than this value, they are failing to compensate adequately

Example 1

A 59 year old with a week of upper respiratory symptoms followed by one day of fever, chest pain, and dyspnea on exertion

pH = 7.48
PCO_2 = 28 mm Hg
pO_2 = 54 mmHg

pH 7.48, PCO_2 28, PO_2 54

What is his A-a gradient?

$$[(760-47)x0.21] - (28/0.08) - 54 = 61 \text{ mmHg}$$

pH 7.48, PCO_2 28, PO_2 54

Is this a respiratory or metabolic alkalosis?

pH 7.48, PCO_2 28, PO_2 54

Is this an acute or chronic abnormality?

If acute, then pH change should be 0.08 x $[(40 - PCO_2)/10]$

0.08 x [(40-28)/10)] = 0.09, or a pH of 7.49

If chronic, then pH change should be 0.03 x $[(40-PCO_2)/10]$

0.03 x [(40-28)/10] = 0.03, or a pH of 7.43

How would you interpret this ABG?

pH 7.48
PCO_2 28
PO_2 54

- Hypoxic
- Acute respiratory alkalosis

Example 2

A 47 year old woman with a 65 pack/year history of tobacco use is being evaluated for disability due to dyspnea

pH 7.36
PCO_2 54 mmHg
PO_2 62 mmHg

pH 7.36, PCO_2 54, PO_2 62

What is her A-a gradient?

$$[(760-47)\times 0.21] - (54/0.8) - 62 = 20 \text{ mmHg}$$

pH 7.36, PCO_2 54, PO_2 62

Is this a respiratory or metabolic acidosis?

pH 7.36, PCO_2 54, PO_2 62

Is this an acute or chronic abnormality?

If acute, then pH change should be 0.08 x [(PCO_2 - 40)/10]

0.08 x (54-40)/10 = 0.11, or a pH of 7.29

If chronic, then pH change will be 0.03 x [(PCO_2 - 40)/10]

0.03 x (54-40)/10 = 0.04, or a pH of 7.36

How would you interpret this ABG?

pH 7.36
PCO_2 54
PO_2 62

- Hypoxic, with both a hypoventilatory and primary oxygenation abnormality
- Chronic respiratory acidosis

Want more?

For more cases,

http://www.sitemaker.umich.edu/younger

For the purposes of looking sharp on the wards (and for the exam)

- Be able to do these problems
  - Practice, practice, practice
  - Take advantage of PDA-based software
- Anticipate special circumstances
  - What if the patient isn't breathing room air?
  - More than one defect at a time (i.e., both respiratory and metabolic disease simultaneously. We will graciously save that one for the renal folks)

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