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An Introduction to Blood Gas Analysis

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Fall 2008
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 ($\text{SaO}_2$)?
Pulse Oximetry ‘The 5th Vital Sign’

- Non-invasive
- Instantaneous
- Ubiquitous
- $\text{SaO}_2 < 95\%$ the usual cutoff for normal versus ‘abnormal’

Limitations:
- Patient must have pulse
- Detects only significant decreases in $\text{PO}_2$
- Does not comment on content
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 pCO₂

• 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
ABGs: What You Get

- Arterial PO$_2$
- Arterial PCO$_2$
- Arterial pH
- Some electrolytes (e.g., Na$^+$, K$^+$, Ca$^{++}$)
- Lactate

- [HCO$_3^-$]
- SaO$_2$
- Other assorted calculated results

Measured. The real meat of the sample
An Organized Approach to ABG Interpretation

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

• What is a ‘normal’ PO₂?
  – Oxygenation gradually deteriorates during life
  – Several calculations available for determining ‘normal’ based on patient age.

\[
\text{PaO}_2 = 104.2 - (0.27 \times \text{age})
\]

  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 =

\[
(P_{atm} - P_{H2O}) \times FiO_2 - (P_{CO2}/RQ) - P_{aO2}
\]

- \(P_{atm} = 760 \text{ mmHg}\)
- \(P_{H2O} = 47 \text{ mmHg}\)
- \(FiO_2 = 0.21\) 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.

Possible Pulmonary Embolism

A-a Gradient Normal → A-a Gradient Abnormal

↑

No Worries

Further Work-up
Evaluating Oxygenation with ABGs

Is the patient hypoxic?

No

Check A-a Gradient

No defect

Yes

Check A-a Gradient

Compensated Defect.
i.e., patient is hypoventilating or on supplemental $O_2$

Hypoventilation

Other Defect
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?

\[
\begin{align*}
&< 7.38 & > 7.42 \\
\downarrow & \quad \downarrow \\
\text{Acidemic} & \quad \text{Alkalemic}
\end{align*}
\]
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  < 40 mmHg

Metabolic alkalosis  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 [(PCO₂ - 40)/10]

In acute respiratory alkalosis, the 
pH will rise by 0.08 x [(40-PCO₂)/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 $0.03 \times \frac{(PCO_2 - 40)}{10}$

In chronic respiratory alkalosis, the pH will rise by $0.03 \times \frac{(40-PCO_2)}{10}$
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 CO₂’.
Appropriateness of Respiratory Response to Metabolic Acidosis

Predicted Change in PCO$_2$ = (1.5 x 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

\[
\begin{align*}
pH &= 7.48 \\
PCO_2 &= 28 \text{ mm Hg} \\
pO_2 &= 54 \text{ mmHg}
\end{align*}
\]
pH 7.48, PCO$_2$ 28, PO$_2$ 54

What is his A-a gradient?

\[
(760-47) \times 0.21 - (28/0.08) - 54 = 61 \text{ mmHg}
\]
pH 7.48, $\text{PCO}_2$ 28, $\text{PO}_2$ 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 $0.08 \times \frac{(40 - \text{PCO}_2)}{10}$

$0.08 \times \frac{(40-28)}{10}] = 0.09$, or a pH of 7.49

If chronic, then pH change should be $0.03 \times \frac{(40-\text{PCO}_2)}{10}$

$0.03 \times \frac{(40-28)}{10}] = 0.03$, or a pH of 7.43
How would you interpret this ABG?

pH 7.48
PCO₂ 28
PO₂ 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

\[
\begin{align*}
\text{pH} & \ 7.36 \\
\text{PCO}_2 & \ 54 \text{ mmHg} \\
\text{PO}_2 & \ 62 \text{ mmHg}
\end{align*}
\]
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 $0.08 \times \frac{(PCO_2 - 40)}{10}$

$$0.08 \times \frac{(54-40)}{10} = 0.11, \text{ or a pH of 7.29}$$

If chronic, then pH change will be $0.03 \times \frac{(PCO_2 - 40)}{10}$

$$0.03 \times \frac{(54-40)}{10} = 0.04, \text{ or a pH of 7.36}$$
How would you interpret this ABG?

pH 7.36
PCO₂ 54
PO₂ 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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