ABG Interpretation:
A Respirologist’s approach

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Outline

• A quick review of acid-base physiology

• The 8 steps to ABG interpretation

• Discuss the causes of hypoxemia and hypercapnea
CO2 and Carbonic Acid

\[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \]

Carbonic Acid

Bicarbonate

- These reactions are very fast, so consider them to always be in equilibrium.
What use is an ABG?

- Assess acid-base balance
- Assess adequacy of ventilation
- Assess oxygenation
Acid-Base Disturbances

- Acidosis = process that makes the blood acidic
- Alkalosis = process that makes the blood alkaline
  - This is a diagnosis
  - Multiple disorders can exist simultaneously
Acid-Base Disturbances

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  - This is a diagnosis
  - Multiple disorders can exist simultaneously

- Acidemia = blood pH below 7.35
- Alkalemia = blood pH above 7.45
  - This is a sign
  - Net result of all concurrent disorders
Acid-Base Disturbances

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  – Net result of all concurrent disorders

Two kinds of pH disorders
1. “Respiratory” = 1° abnormality in ventilation (CO2)
2. “Metabolic” = 1° abnormality in any other acid or base
Acid-Base Disturbances

• When acidosis or alkalosis occurs, the body tries to normalize pH by “compensating” using buffers

  – If the primary process is metabolic,
    • We use lungs to increase or decrease ventilation to alter $p_a \text{CO}_2$
    • This “respiratory compensation” takes minutes

  – If the primary process is respiratory,
    • We use kidneys to excrete either acid (NH4) or base (NaHCO3)
    • This “metabolic compensation” takes hours or days
Acid-Base Disturbances

- When acidosis or alkalosis occurs, the body tries to normalize pH by “compensating” using buffers
  - If the primary process is metabolic,
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  - If the primary process is respiratory,
    - We use kidneys to excrete either acid (NH4) or base (NaHCO3)
    - This “metabolic compensation” takes hours or days
- Compensation is always in the same direction as the primary problem
  - If $p_aCO_2$ rises, appropriate compensation increases HCO3-
  - If $p_aCO_2$ falls, appropriate compensation decreases HCO3-
  - If HCO3- rises, appropriate compensation increases $p_aCO_2$
  - If HCO3- falls, appropriate compensation decreases $p_aCO_2$
Alveolar Ventilation

• CO2 is normally tightly regulated
  – Small changes to CO2 alter ventilation

• Carotid body is essential to this regulation
  – This is a cluster of chemoceptors in the carotid artery
  – Detects levels of [O2], [CO2] and [H+]
  – Sends signals to the brain
  – Alters ventilation in response to [CO2] and [H+]
Alveolar Ventilation

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• Carotid body response:
  – When patient has acidemia (low pH)
    • Carotid body makes you more sensitive to [CO2] = ↑ ventilation
  – When patient has alkalemia (high pH)
    • Carotid body makes you less sensitive to [CO2] = ↓ ventilation
Respiratory Acidosis

\[ \text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{HCO}_3^- \]

\[ [\text{H}^+] = \frac{24 \times p_a\text{CO}_2}{[\text{HCO}_3^-]} \]
Respiratory Acidosis

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\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}^+ + \text{HCO}_3^-
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- Hypoventilation

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  - Acutely (10:1)
    - For each 10 mm Hg rise in \( p_a \text{CO}_2 \), \( \text{HCO}_3^- \) should increase by 1 mEq/L
    - This is due to equilibrium shift (buffering)

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– Chronically (10:3)
  • For each 10 mm Hg rise in \( p_a\text{CO}_2 \), \( \text{HCO}_3^- \) should increase by 3 mEq/L
  • This is due to renal compensation (excretion of \( \text{H}^+ \))

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- Common causes
  - Lung disease
  - Neuromuscular disease
  - Sedative drugs
  - Adaptation to extreme obesity and sleep apnea

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- Common causes
  - Anxiety / panic (including panic attacks)
  - Pregnancy
  - Early sepsis
  - Drugs (one component of ASA toxicity)
  - Mechanical ventilation at excessive rate or volumes

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Metabolic Alkalosis

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- Increase in HCO3-

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- Increase in HCO3- shifts equilibrium to the left
  - $p_a$CO2 increases
  - Alkalemia makes the carotid body less sensitive to [CO2]
  - We “allow” the $p_a$CO2 to stay elevated (maximum ~ 50 mmHg)

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- Compensation (1:0.7)
  - For every 1 mEq rise in HCO3-, \( p_a \text{CO}_2 \) increases by 0.7 mmHg

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- Causes
  - Volume depletion (“contraction alkalosis”)
  - Nasogastric suction
  - Diuretics
  - Hyperaldosteronism

\[ [\text{H}^+] = \frac{24 \times p_a \text{CO}_2}{\text{HCO}_3^-} \]
Metabolic Acidosis

• Two possible mechanisms of onset
  – Loss of HCO3-
  – Gain of H+

• Mechanisms of compensation are a bit more complex
Metabolic Acidosis – Bicarb Loss

\[ \text{CO}_2 + \text{H}_2\text{O} \iff \text{H}^+ + \text{HCO}_3^- \]

• Loss of bicarbonate (ie. diarrhea) creates an acidemia (a relative increase in \([\text{H}^+]\))

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  – Acidemia makes the carotid body more sensitive to [CO2] leading to increased ventilation

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- Compensation (1:1)
  - For every drop of 1 mEq of HCO$_3^-$, $p_a\text{CO}_2$ falls by 1 mmHg

$$[\text{H}^+] = \frac{24 \times p_a\text{CO}_2}{[\text{HCO}_3^-]}$$
Metabolic Acidosis – Acid Gain

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]

- Some acid gets added to the body (ie. excercising muscle makes lactate)

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Metabolic Acidosis – Acid Gain

CO$_2$ + H$_2$O $\xleftarrow{\uparrow}$ H$^+$ + HCO$_3^-$

- Some acid gets added to the body (ie. excercising muscle makes lactate), the equilibrium gets shifted to the left (which lowers HCO$_3^-$ and H$^+$)

$$[H^+] = \frac{24 \times p_a CO2}{[HCO3]}$$
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$\uparrow CO_2 + H_2O \leftrightarrow \uparrow H^+ + \downarrow HCO_3^-$

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  - This causes a transient rise in $[CO_2]$
Metabolic Acidosis – Acid Gain

Some acid gets added to the body (ie. exercising muscle makes lactate), the equilibrium gets shifted to the left (which lowers HCO₃⁻ and H+):

- This causes a transient rise in [CO₂]
- Excess CO₂ is quickly exhaled
- [CO₂] falls even lower than baseline, because acidemia makes the carotid body more sensitive to [CO₂] leading to increased ventilation

\[ \uparrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \uparrow \text{H}^+ + \downarrow \text{HCO}_3^- \]

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• Compensation
  – For every drop of 1 mEq of HCO3-, \( p_a \text{CO}_2 \) falls by 1 mmHg

• Examples of metabolic acidosis
  – Diarrhea/GI losses (loss of HCO3)
  – lactic acidosis (lactic acid)
  – renal failure (metabolic acids and loss of HCO3)
  – diabetic ketoacidosis (acetic acid)
  – ASA (acetylsalicylic acid)

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ABG Interpretation

“ABG’s in 8 steps”
A Case

• You get a call from your clinical clerk…
  – “I need your input on Ms. K. She is a 65 year old woman who is here for a small bowel obstruction. Med consults is following her for long standing back pain and they are working her up for possible cancer.”

• ABG (pH / PaCO2 / PaO2 / HCO3-)

  7.30 / 80 / 45 / 38

  3.6

  140 | 3.9 /

  100 | 35 \ 85
A Case

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• ABG (pH / PaCO2 / PaO2 / HCO3-)

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  Please interpret this ABG
Step 1

- **Step 1: Obtain ABG and electrolytes**
  - If you don’t perform the test, you’ll never know what is going on with the patient
  - An ABG and a lactate are the 2 best tests to help you get a sick patient to the ICU

• 7.30 / 80 / 45 / 38
Step 2

• Step 1: Obtain ABG and electrolytes
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Step 2

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  – If you don’t perform the test, you’ll never know what is going on with the patient
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• **Step 2: Determine the primary process:**
  – Is it an acidosis or an alkalosis?
  – Is the primary problem respiratory or metabolic?

• 7.30 / 80 / 45 / 38
Step 2: What is the primary process?

A. Look at the pH.
   - Is it normal, acidemic or alkalemic?
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A. Look at the pH.
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B. Look at $p_a\text{CO}_2$—is it “concordant” with pH change?
   (i.e. CO2 is an acid… So, is $\Delta\text{CO}_2$ in the direction that would cause pH change?)
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A. Look at the pH.
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B. Look at $p_a$CO$_2$— is it “concordant” with pH change? (i.e. CO$_2$ is an acid… So, is $\Delta$CO$_2$ in the direction that would cause pH change?)
   • If concordant, the primary problem is respiratory
     • Low pH and high $p_a$CO$_2$ indicates respiratory acidosis
     • High pH and low $p_a$CO$_2$ indicates respiratory alkalosis
   • If not concordant, the primary problem is metabolic
     • Low pH and low $p_a$CO$_2$ indicates metabolic acidosis
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Step 3: What is the compensation?

- 7.30 / 80 / 45 / 38
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• Then look at HCO$_3^-$
  • Has it changed by the expected amount?
    • It doesn’t have to be “perfect”
  • Change in HCO$_3^-$ can tell you
    • if the disorder is acute or chronic
    • Whether multiple disorders are present

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<td>↑ 10</td>
<td>↑ 3</td>
</tr>
<tr>
<td>Chronic Respiratory Alkalosis</td>
<td>↓ 10</td>
<td>↓ 4</td>
</tr>
<tr>
<td>Metabolic Alkalosis</td>
<td>↑ 0.7</td>
<td>↑ 1</td>
</tr>
<tr>
<td>Metabolic Acidosis</td>
<td>↓ 1</td>
<td>↓ 1</td>
</tr>
</tbody>
</table>

• 7.30 / 80 / 45 / 38
Step 3: What is the compensation?

- If compensation is “right”, there is one process

- If compensation doesn’t “fit”, there may be more than one process going on

<table>
<thead>
<tr>
<th>Condition</th>
<th>Δ $p_a$CO2</th>
<th>Δ HCO3-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Respiratory Acidosis</td>
<td>↑ 10</td>
<td>↑ 1</td>
</tr>
<tr>
<td>Acute Respiratory Alkalosis</td>
<td>↓ 10</td>
<td>↓ 2</td>
</tr>
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<td>Chronic Respiratory Acidosis</td>
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</tbody>
</table>

• 7.30 / 80 / 45 / 38
Step 4:

- 7.30 / 80 / 45 / 38
Step 4: Determine the Anion Gap

\[
\begin{array}{c|c}
3.6 \\
140 / \\
100 | 35 \\
\end{array}
\]

\[
\begin{array}{c|c}
 & 85 \\
\end{array}
\]

•7.30 / 80 / 45 / 38
Step 4: Determine the Anion Gap

3.6

\[
\begin{array}{c|c}
140 & \_ \\
100 & 35 \\
\end{array}
\]

\[
\begin{array}{c}
85
\end{array}
\]

Anion Gap = Na\(^+\) - Cl\(^-\) - HCO\(_3^\-\)

= 140 - 100 - 35

= 5 (normal is < 12)

7.30 / 80 / 45 / 38
Anion Gap

• What is the anion gap?
• What is the anion gap?

All the cations in the body
(Na+)
Anion Gap

• What is the anion gap?

All the cations in the body
(Na+)

\[ \begin{align*}
\text{+} & \quad \text{HCO}_3^- \\
\text{-} & \quad \text{Cl}^- 
\end{align*} \]
Anion Gap

• What is the anion gap?

- All the cations in the body (Na+)
- ???
- HCO3-
- Cl-

Diagram: Yellow box represents ??? between Na+ and HCO3-.
Anion Gap

• What is the anion gap?

All the cations in the body (Na+)

Phosphate, Pyruvate, Sulfate, Lactate

Albumin

HCO3-

Cl-
Anion Gap

• What causes an increased anion gap?

An extra unmeasured anion

All the cations in the body (Na+)

+ Phosphate, Pyruvate, Sulfate, Lactate
  Albumin
  HCO₃⁻

- Cl⁻
Anion Gap – DDx

• Medical student answer
  – MUDPILES

• Real life answer…
Anion Gap – DDx

• Medical student answer
  – MUDPILES

• Real life answer...
  – Lactic acidosis
  – Ketosis (DKA, starvation, alcohol)
  – Renal failure
  – Poison (alcohols, ASA, cyanide)
Step 5

• Step 1: Get the ABG
• Step 2: Determine primary abnormality
• Step 3: What is the compensation
• Step 4: Assess the anion gap
• Step 5:

7.30 / 80 / 45 / 38
Step 5: If an Anion Gap is present, is it the only process?

• How do you determine if AG is the only process?

• 7.30 / 80 / 45 / 38
Step 5: If an Anion Gap is present, is it the only process?

- Each molecule of unmeasured anion (ie. Lactate) donates a H+ which binds to HCO3-

- \( \text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{O} \text{ and CO2} \)
Step 5: If an Anion Gap is present, is it the only process?

- Each molecule of unmeasured anion (ie. Lactate) donates a H+ which binds to HCO3-

- $H^+ + HCO_3^- \rightarrow H_2O$ and CO2

- Therefore, if there is only one process,
  - Amount of added acid = the increase in $H^+$ = the fall in HCO3-
  - The amount of added acid is measured using the anion gap
  - So, the change in Anion Gap should equal the change in HCO3-
Step 5: If an Anion Gap is present, is it the only process?

- Calculate $\Delta AG/\Delta HCO_3^-$ ratio

  $\Delta AG = \text{measured AG} - 12$

  $\Delta HCO_3^- = 24 - \text{measured HCO}_3^-$

- 7.30 / 80 / 45 / 38
Step 5: If an Anion Gap is present, is it the only process?

- Calculate $\Delta AG/\Delta HCO_3$- ratio

- If $\Delta AG/\Delta HCO_3$- ratio = 1 $\rightarrow$ no other process
  - Ratio $>1$, HCO$_3$ is too low $\rightarrow$ concomitant non-AG acidosis
  - Ratio $<1$, HCO$_3$ is too high $\rightarrow$ concomitant alkalosis

- 7.30 / 80 / 45 / 38
Step 6

• Step 1: Get the ABG
• Step 2: Determine primary abnormality
• Step 3: What is the compensation
• Step 4: Assess the anion gap
• Step 5: Is the anion gap the only process
• Step 6:
Step 6: Determine the Osmolar (OSM) Gap

• How do you calculate the osmolar gap?
Step 6: Determine the Osmolar (OSM) Gap

• OSM gap = measured OSM - calculated OSM
  
  – Measured OSM: given by the lab

  – Calculated OSM = \( (2 \times \text{Na}^+) + \text{BG} + \text{BUN} \)
    • “Two salts and a sugar bun.”

• Normal Osmolar gap < 10
Step 6: Determine the Osmolar (OSM) Gap

• DDx of a high osmolar gap
  – Methanol*
  – Ethylene glycol*
  – Ethanol
  – Mannitol
  – Acetone
  – Isopropyl alcohol
  – Others...

* Anion gap AND osmolar gap
Step 7

- Step 1: Get the ABG
- Step 2: Determine primary abnormality
- Step 3: What is the compensation
- Step 4: Assess the anion gap
- Step 5: Is the anion gap the only process
- Step 6: Calculate the osmolar gap
- Step 7:
Step 7: Calculate the A-a gradient

- Calculate the A-a gradient in this patient

7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

• A-a gradient = PAO2 – PaO2

• PAO2 = [(Pbar – PH20) x FiO2] – [PaCO2/RQ]
  = [(713) x FiO2] – [PaCO2/RQ]

• PaO2 = measured with ABG

7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

- \( \text{PAO2} = [(P_{\text{bar}} - P_{H20}) \times \text{FiO2}] - [\text{PaCO2/RQ}] \)

- \( A-a = \text{PAO2} - \text{PaO2} \)
Step 7: Calculate the A-a gradient

- \( \text{PAO2} = [(P_{\text{bar}} - PH_{20}) \times FiO2] - [\text{PaCO2}/RQ] \)

- \( \text{A-a} = \text{PAO2} - \text{PaO2} \)
- \( \text{A-a} = [(P_{\text{bar}} - PH_{20}) \times FiO2] - [\text{PaCO2}/RQ] - \text{PaO2} \)

- 7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

- $PAO2 = [(Pbar - PH20) \times FiO2] - [PaCO2/RQ]$

- $A-a = PAO2 - PaO2$
- $A-a = [(760 - 47) \times 0.21] - [PaCO2 / 0.8] - PaO2$
- $7.30 / 80 / 45 / 38$
Step 7: Calculate the A-a gradient


- A-a = PAO2 – PaO2
- A-a = [(760 – 47) x 0.21] – [PaCO2 / 0.8] – PaO2

\[\text{7.30 / 80 / 45 / 38}\]
Step 7: Calculate the A-a gradient

- \( \text{PAO}_2 = [(\text{Pbar} - \text{PH}_20) \times \text{FiO}_2] – [\text{PaCO}_2 / \text{RQ}] \)
- \( \text{A-a} = \text{PAO}_2 – \text{PaO}_2 \)
- \( \text{A-a} = [(\text{Pbar} - \text{PH}_20) \times \text{FiO}_2] – [\text{PaCO}_2 / \text{RQ}] – \text{PaO}_2 \)
- \( \text{A-a} = [(760 - 47) \times 0.21] – [\text{PaCO}_2 / 0.8] – \text{PaO}_2 \)
- \( \text{A-a} = [(760 - 47) \times 0.21] – [1.25 \times \text{PaCO}_2] – \text{PaO}_2 \)
- \( \text{A-a} = [(713) \times 0.21] – [1.25 \times \text{PaCO}_2] – \text{PaO}_2 \)
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- $\text{7.30 / 80 / 45 / 38}$
Step 7: Calculate the A-a gradient

- **PAO2** = \[(P_{bar} - PH20) \times FiO2\] – [PaCO2/RQ]

- A-a = PAO2 – PaO2
- A-a = [(760 – 47) \times 0.21] – [PaCO2 / 0.8] – PaO2
- A-a = [(713) \times 0.21] – [1.25 \times PaCO2] – PaO2
- **A-a** = [150] – [1.25 \times PaCO2] – PaO2 - Simplified version for pt on R/A

7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

- \( PAO2 = [(Pbar - PH20) \times FiO2] - [PaCO2/RQ] \)
- \( A-a = PAO2 - PaO2 \)
- \( A-a = [(Pbar - PH20) \times FiO2] - [PaCO2/RQ] - PaO2 \)
- \( A-a = [(760 - 47) \times 0.21] - [PaCO2 / 0.8] - PaO2 \)
- \( A-a = [(760 - 47) \times 0.21] - [1.25 \times PaCO2] - PaO2 \)
- \( A-a = [(713) \times 0.21] - [1.25 \times PaCO2] - PaO2 \)
- \( A-a = [150] - [1.25 \times PaCO2] - PaO2 \)
- 7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient


- A-a = PAO2 – PaO2
- A-a = [(760 – 47) x 0.21] – [PaCO2 / 0.8] – PaO2

- 7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient


- A-a = PAO2 – PaO2
- A-a = [(760 – 47) x 0.21] – [PaCO2 / 0.8] – PaO2

- 7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

- \( \text{PAO2} = [(P_{\text{bar}} - PH20) \times FiO2] - [\text{PaCO2/RQ}] \)

- \( A-a = \text{PAO2} - \text{PaO2} \)
- \( A-a = [(P_{\text{bar}} - PH20) \times FiO2] - [\text{PaCO2/RQ}] - \text{PaO2} \)
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- \( A-a = [(713) \times 0.21] - [1.25 \times \text{PaCO2}] - \text{PaO2} \)
- \( A-a = [150] - [1.25 \times \text{PaCO2}] - \text{PaO2} \)
- \( A-a = [150] - [1.25 \times 80] - \text{PaO2} \)
- \( A-a = [150] - [100] - \text{PaO2} \)
- \( A-a = 50 - \text{PaO2} \)

- \( 7.30 / 80 / 45 / 38 \)
Step 7: Calculate the A-a gradient


- A-a = PAO2 – PaO2
- A-a = [(760 – 47) x 0.21] – [PaCO2 / 0.8] – PaO2
- A-a = 50 – PaO2
- A-a = 50 – 45

- 7.30 / 80 / 45 / 38
Step 7: Calculate the A-a gradient

- $PAO_2 = [(P_{bar} - PH_20) \times FiO_2] - [PaCO_2/RQ]$

- $A-a = PAO_2 - PaO_2$
- $A-a = [(P_{bar} - PH_20) \times FiO_2] - [PaCO_2/RQ] - PaO_2$
- $A-a = [(760 - 47) \times 0.21] - [PaCO_2 / 0.8] - PaO_2$
- $A-a = [(760 - 47) \times 0.21] - [1.25 \times PaCO_2] - PaO_2$
- $A-a = [(713) \times 0.21] - [1.25 \times PaCO_2] - PaO_2$
- $A-a = [150] - [1.25 \times PaCO_2] - PaO_2$
- $A-a = [150] - [1.25 \times 80] - PaO_2$
- $A-a = [150] - [100] - PaO_2$
- $A-a = 50 - PaO_2$
- $A-a = 50 - 45$
- $A-a = 5$

$7.30 / 80 / 45 / 38$
Step 7: Calculate the A-a gradient

• What is a normal A-a gradient?
Step 7: Calculate the A-a gradient

• Normal A-a gradient
  – A-a gradient < 10 is normal
  – A-a gradient is higher in elderly (up to 20)
Step 8: Causes of hypoxemia

- List the 5 major causes of hypoxemia
- Which have a normal A-a gradient?
- Which have a high A-a gradient?
Step 8: Causes of hypoxemia

1. Low inspired O2 content (low FiO2 or low PiO2)
2. Hypoventilation

3. V/Q mismatch
   - Asthma, COPD, Alveolar filling (fluid, blood, pus), pHTN
4. Shunt
   - Physiologic shunt
   - Intra-cardiac (ASD, PFO or VSD)
   - Intra-pulmonary
     - With normal capillaries: atelectasis or consolidation
     - With abnormal capillaries: pAVM’s or HPS
5. Diffusion abnormality
   - Severe ILD, severe COPD, etc…
Summarize this ABG

- Step 1: Get the ABG
- Step 2: Determine primary abnormality
- Step 3: What is the compensation
- Step 4: Assess the anion gap
- Step 5: Is the anion gap the only process
- Step 6: Calculate the osmolar gap
- Step 7: Calculate the A-a gradient
- Step 8: Cause of hypoxemia

7.30 / 80 / 45 / 38
140 | 3.6
100 | 35 \ 85
Summarize this ABG

• Step 1: done
• Step 2: chronic respiratory acidosis
• Step 3: compensated appropriately (10:3.5)
• Step 4: anion gap = 5 (normal)
• Step 5: no anion gap present
• Step 6: osmolar gap (can’t do)
• Step 7: A-a gradient = 5 (normal)
• Step 8: hypoxemia due to hypoV

<p>| | | | |</p>
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<td></td>
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Causes of Hypercapnia

• What are the determinants of PaCO2?
Causes of Hypercapnia

• What are the determinants of PaCO2?

• \[ \text{PaCO2} = \frac{\text{VCO2}}{\text{RR} \ (\text{Vt-Vd}) \times K} \]
  – CO2 production
  – Respiratory rate
  – Tidal volume
  – Dead space volume
Causes of Hypercapnia

\[ \text{PaCO}_2 = \frac{(VCO_2)}{\text{RR} \ (V_t-V_d)} \times K \]

- High VCO2
Causes of Hypercapnia

PaCO2 = \frac{(VCO2)}{RR (Vt-Vd)} x K

- High VCO2
  - fever, sepsis, seizures
Causes of Hypercapnia

\[ \text{PaCO2} = \frac{\text{VCO2}}{\text{RR} \times (\text{Vt-Vd}) \times K} \]

- High VCO2
  - fever, sepsis, seizures

- Low RR
Causes of Hypercapnia

\[ \text{PaCO}_2 = \frac{(\text{VCO}_2)}{\text{RR}} \times (\text{Vt-Vd}) \times K \]

- **High VCO2**
  - fever, sepsis, seizures

- **Low RR**
  - drugs, brainstem lesions, hypothyroid
Causes of Hypercapnia

\[ \text{PaCO2} = \frac{(\text{VCO2})}{\text{RR}} (\text{Vt-Vd}) \times K \]

- **High VCO2**
  - fever, sepsis, seizures

- **Low RR**
  - drugs, brainstem lesions, hypothyroid

- **Low Vt**
Causes of Hypercapnia

\[ \text{PaCO}_2 = \frac{(\text{VCO}_2)}{\text{RR}} \times (\text{Vt-Vd}) \times K \]

- **High VCO2**
  - fever, sepsis, seizures

- **Low RR**
  - drugs, brainstem lesions, hypothyroid

- **Low Vt**
  - muscle weakness (rapid shallow breathing pattern), neuromuscular disease, low chest wall compliance
Causes of Hypercapnia

\[ \text{PaCO}_2 = \frac{\text{VCO}_2}{\text{RR} \times (\text{Vt-Vd}) \times K} \]

- **High VCO2**
  - fever, sepsis, seizures

- **Low RR**
  - drugs, brainstem lesions, hypothyroid

- **Low Vt**
  - muscle weakness (rapid shallow breathing pattern), neuromuscular disease, low chest wall compliance

- **High Vd**
Causes of Hypercapnia

PaCO2 = \((\text{VCO2}) / \text{RR} \times (\text{Vt-Vd}) \times K\)

- **High VCO2**
  - fever, sepsis, seizures

- **Low RR**
  - drugs, brainstem lesions, hypothyroid

- **Low Vt**
  - muscle weakness (rapid shallow breathing pattern), neuromuscular disease, low chest wall compliance

- **High Vd**
  - ARDS, PE, COPD
Back to the case

• You get a call from a your clinical clerk…
  – “I need your input on Ms. K. She is a 65 year old woman who is here for a small bowel obstruction. Med consults is following her for long standing back pain and they are working her up for possible cancer.”

• ABG (pH/PaCO2/PaO2/HCO3-)

  7.30 / 80 / 45 / 38
Back to the case

• You get a call from a your clinical clerk…
  – “I need your input on Ms. K. She is a 65 year old woman who is here for a small bowel obstruction. Med consults is following her for long standing back pain and they are working her up for possible cancer.”

• ABG (pH/PaCO2/PaO2/HCO3-)
  
  7.30 / 80 / 45 / 38

• You diagnose a chronic respiratory acidosis with a normal A-a gradient due to hypoventilation
  – You remove the fentanyl patch from her arm
  – You transfer her to the ICU
Back to the case

• 15 minutes later
  – Patient arrives in ICU
  – RT feels patient is worse

• ABG: 7.30 / 80 / 30 / 38
  – What happened?

Baseline ABG:
7.30 / 80 / 45 / 38
Back to the case

- ABG: 7.30 / 80 / 30 / 38
  - Acid base status unchanged
  - PaO2 fell from 45 → 30

- A-a gradient has increased
  - A-a = PAO2 – PaO2
  - A-a = [150 – (1.25 x PaCO2)] – PaO2
  - A-a = [150 – (1.25 x 80)] – 30
  - A-a = 20

- DDx?

Baseline ABG: 7.30 / 80 / 45 / 38
Back to the case:
Causes of hypoxemia

1. Low inspired O2 content (low FiO2 or low PiO2)
2. Hypoventilation

3. V/Q mismatch
   - Asthma, COPD, Alveolar filling (fluid, blood, pus), pHTN

4. Shunt
   - Physiologic shunt
   - Intra-cardiac (ASD, PFO or VSD)
   - Intra-pulmonary
     • With normal capillaries: atelectasis or consolidation
     • With abnormal capillaries: pAVM’s or HPS

5. Diffusion abnormality
   - Severe ILD, severe COPD, etc…
Back to the case:
**DDx of acute rise in A-a gradient**

- V/Q mismatch
  - Aspiration pneumomomitis
  - Flash pulmonary edema
  - Mucous plug
  - Pneumothorax
  - PE
  - (ARDS)
Review:
ABG interpretation in 8 steps

- Step 1: Get the ABG
- Step 2: Determine primary abnormality
- Step 3: What is the compensation
- Step 4: Assess the anion gap
- Step 5: Is the anion gap the only process
- Step 6: Calculate the osmolar gap
- Step 7: Calculate the A-a gradient
- Step 8: Causes of hypoxemia
Questions?