Interpretation of Mixed Acid Base Disorders - No Da Vinci Code

by

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PNS SHIFA
ARTERIAL BLOOD GASES

- Measured on a Blood Gas Analyser.
- Sample of whole blood is directly injected into the analyser without delay
Site for Sample Collection

• Best site?

• Why?

• No vein adjacent to Radial Artery
<table>
<thead>
<tr>
<th></th>
<th>Arterial Blood</th>
<th>Venous Blood</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td>7.35-7.45</td>
<td>7.31-7.40</td>
<td>7.27</td>
</tr>
<tr>
<td><strong>PCO2</strong></td>
<td>35-45 mmHg</td>
<td>41-51 mmHg</td>
<td>54 mmHg</td>
</tr>
<tr>
<td></td>
<td>(4.7-6.0 kPa)</td>
<td>(5.5-6.8 kPa)</td>
<td></td>
</tr>
<tr>
<td><strong>HCO3</strong>-</td>
<td>22-28 mmol/l</td>
<td>25-29 mmol/l</td>
<td>31 mmol/l</td>
</tr>
<tr>
<td><strong>PO2</strong></td>
<td>&gt;80 mmHg</td>
<td>38-42 mmHg</td>
<td>40 mmHg</td>
</tr>
<tr>
<td></td>
<td>(&gt;10.6 kPa)</td>
<td>(5.1-5.6 kPa)</td>
<td></td>
</tr>
</tbody>
</table>
Solution?

Mention site on Lab Form
**Measured and Calculated Tests**

**Measured parameters:**
- pH
- *Partial Pressure of Carbon dioxide* (*PCO₂*)
- *Partial Pressure of oxygen* (*PO₂*)

**Calculated parameters:**
- $\text{HCO}_3^-$ using Henderson Hasselbalch equation
- Base Excess (BE)
ABG measurement – Some unique things

- Samples to reach lab within 15 minutes
- No incubation or reagent mixing
- Instant results
- Invalid if result delayed
- “bedside use” with some precautions
ABG measurement – An expensive test

- Quite expensive investigation
- Under-utilized
- Cost of even one test per day is also very high
- Proper interpretation is required for optimum use
ABG measurement – High diagnostic yield

- 95% diagnostic yield
- ABGs: 25%
- CBC: 15%
- Electrolytes: 10%
- Urinalysis: 5%
Types of Acid Base Disorders

- Single (simple) disorders
- Double (mixed) disorders
- Triple (mixed) disorders
Simple (Single) Disorders

- Metabolic Acidosis
- Metabolic Alkalosis
- Respiratory Acidosis
- Respiratory Alkalosis
Double Disorders

- Metabolic and Respiratory Acidosis
- Metabolic and Respiratory Alkalosis
- Metabolic Alkalosis and Respiratory Acidosis
- Metabolic Acidosis and Metabolic Alkalosis
Triple Disorders

Metabolic Acidosis, Metabolic Alkalosis and Respiratory Alkalosis:

beyond “salicylate poisoning”

Any high anion gap acidosis complicated by vomiting and hyperventilation can cause this disorder
Pattern of ABG results from CCU, ICU and NICU in 45 days (n=114)

- Simple Disorders: 48%
- Mixed Disorders: 46%
- Normal Results: 6%
Distribution of Mixed Acid Base Disorders in a Critical Care Units (PNS SHIFA) in 45 days (n=67)

- 34% Metabolic Acidosis + Respiratory Alkalosis
- 56% Double Acidity
- 10% Opposing disorders
- 66% Metabolic Alkalosis + Respiratory Acidosis

Legend:
- Double Acidity
- Double Alkalosis
- Opposing disorders

- Metabolic Acidosis + Respiratory Alkalosis
- Metabolic Alkalosis + Respiratory Acidosis
Analysing ABG Reports

- Clinical features
- Results of other investigations e.g. electrolytes etc
- ABG result necessary for confirmation of diagnosis
- Biochemical opinion may be given even with meagre information
Treatment Principles of Acid-Base Disturbances

The 3-Cs

Correct analysis
(always be alert to the presence of mixed disturbances)

Correct disturbance
(buy time, don’t over do)

Correct disease
(a MUST if possible)
Decoding an ABG Report
Look at pH

- **Low pH**-----Acidosis
- **High pH**-----Alkalosis
- **Normal pH**--- A normal pH does not rule out existence of an acid base disorder (see below)
If pH is abnormal Examine PCO2 and HCO3 relationship

• If PCO2 and HCO3 change in the same direction, it is a **single disorder**.

**Example:**

• *in Metabolic Acidosis (i.e. decreased HCO3)*, PCO2 should decrease. If it is decreased, consider *Metabolic Acidosis with Respiratory Compensation (Single Disorder)*
If pH is abnormal Examine PCO2 and HCO3 relationship (Cont)

- If PCO2 and HCO3 change in the opposite direction, it is a double disorder

**Example:**

- in Metabolic Acidosis (i.e. decreased HCO3), PCO2 should decrease. If it is increased, consider Metabolic Acidosis with Respiratory Acidosis (Double Disorder)
Examine pH and HCO3 relationship (For single disorders)

If pH and HCO3 change in the same direction primary abnormality is metabolic

- **Examples:**
  - *in metabolic acidosis both pH and HCO3 decrease*
  - *in metabolic alkalosis both pH and HCO3 increase*
Examine pH and HCO3 relationship (For single disorders) (Cont)

If pH and HCO3 change in the opposite direction primary abnormality is respiratory

- **Examples:**
  - in respiratory acidosis pH decreases and HCO3 increases
  - in respiratory alkalosis pH increases and HCO3 decreases
If pH is normal Examine PCO2 and HCO3 relationship again

If PCO2 and HCO3 **grossly** change in the same direction, it is also a **double disorder**

**Examples:**

- **in Metabolic Acidosis** (i.e. decreased HCO3), PCO2 should decrease to a certain extent. If it is decreased too much, consider Metabolic Acidosis with Respiratory Alkalosis (Double Disorder)

- **in Respiratory Acidosis** (i.e. increased PCO2), HCO3 should increase to a certain extent. If it is increased too much, consider Respiratory Acidosis with Metabolic Alkalosis (Double Disorder)
If pH, PCO2 and HCO3 all are normal

Normal Acid Base Status !!

(----but please be careful of values on the extreme of reference ranges, which may be due to a fully compensated disorder like Chronic Respiratory Alkalosis or mild double disorders)
ANION GAP

• It is a measure of anions other than HCO$_3^-$ and Chloride
• Biochemical Basis:
Always:

\[
\text{CATIONS} = \text{ANIONS}
\]
ANION GAP
(Biochemical Basis)

• Major Cat-ions:
  – Na = 140 mmol/L
  – K = 4 mmol/L
  – Ca = 4.5 mmol/L
  – Mg = 1.5 mmol/L

  TOTAL CATIONS = 150 mmol/L
ANION GAP
(Biochemical Basis)

• Major Anions:
  - Cl = 100 mmol/L
  - $\text{HCO}_3$ = 27 mmol/L
  - proteins = 15 mmol/L
  - $\text{PO}_3$ = 2 mmol/L
  - $\text{SO}_3$ = 1 mmol/L
  - Organic Acids = 5 mmol/L

TOTAL ANIONS = 150 mmol/L
Anion Gap:

- Calculated as following:
  \[(\text{Na} + \text{K}) - (\text{Cl} + \text{HCO}) = 18 \text{ mmol/L}\]
  Range: 7 – 18 mmol/L

- It is only a lab derived index

- There can *never* be an anion gap in any condition because electroneutrality is always maintained in the plasma
High Anion Gap
(Hyperkalaemic Metabolic Acidosis)

- Increased unmeasured Anions
  - Ketoacidosis
  - Lactic Acidosis
  - Renal Failure
  - Poisoning
    - Methanol
    - Ethanol
    - Salicylates
    - others
Normal Anion Gap
(Hypokalaemic Metabolic Acidosis)

- Diarrhoea:
  - Loss of HCO3
  - Loss of K
- Renal Tubular Acidosis
- Acetazolamide therapy
- Uretro-ileoal shunt
DELTA RATIO

The delta ratio is used for the determination of a mixed acid base disorder in an elevated anion gap metabolic acidosis.

- Measured anion gap – Normal anion gap
- Normal [HCO3-] – Measured [HCO3-]

or

(anion gap – 12)

(24 - [HCO3-])
## Delta Ratio Assessment Guideline

<table>
<thead>
<tr>
<th>Delta Ratio</th>
<th>Description</th>
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<tbody>
<tr>
<td>&lt; 0.4</td>
<td>Hyperchloreaemic normal anion gap acidosis</td>
</tr>
</tbody>
</table>
| 0.4 - 0.8   | - Renal failure  
             | - Combined high AG & normal AG acidosis |
| 1 to 2      | - Uncomplicated high-AG acidosis  
             | - Lactic acidosis: 1.6 (average value) |
| >2          | A pre-existing elevated HCO3 level due to:  
             |   - a concurrent metabolic alkalosis, or  
             |   - a pre-existing compensated respiratory acidosis |
Predicted HCO3

Predicted [HCO3] = 24 -[Anion Gap-12]

• If patient's [HCO3] > Predicted [HCO3]
  – Metabolic acidosis + Metabolic Alkalosis
  – Compensatory response to resp acidosis

If patient's [HCO3] = Predicted [HCO3]
  – Simple Metabolic acidosis

• If patient's [HCO3] < Predicted [HCO3]
  – Compensatory response to resp alkalosis
Other Interpretation Assistants

- Flenley’s Graph
- Electronic Calculators (*Skyscape* for desktop, ipads etc).
- Equations (or Formulas) – usually required for interpreting more subtle changes in ABGs.
Flenley’s graph

By plotting the result of the pH, HCO3, and Paco2 on the graph, a mixed ABG disturbance is present if the point falls outside the arms of the CROSS.
Learning Points

• ABG samples should be sent to the lab immediately and ask for results instantly

• Mixed disturbances are very common in critically ill patients because of multiple pathologies

• Always be on the lookout for Mixed Disturbance
Acknowledgement

Dr Humaira Ashraf
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