MAKING SENSE OF ARTERIAL BLOOD GASES

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Core medical trainee
Case 1

You are asked to see a 60 years woman on the orthopaedic ward who had a Right hip replacement 2 weeks ago. She has become breathless. Her arterial blood gas is as follows

- pH: 7.48
- P02: 9kPa
- PC02: 3.1kPa
- HCO3-: 24mmol/L

What is the acid-base disturbance?
Case 2

You see an 18 yr old male in A&E. He feels unwell and has been vomiting for the last 24hrs. His arterial blood gas is as follows;

- pH: 7.50
- PO2: 12.7kPa
- PCO2: 5.0 kPa
- HCO3-: 32mmol/L

What is the acid-base disturbance?
Case 3

- A 20 years old man suffers from abdominal pain. He is thirsty and drinking lots of fluids. His arterial blood gas is as follows;

- pH: 7.32
- P02: 11.8 kPa
- PC02: 3.2 kPa
- HCO3-: 18mmol/L
- Glucose: 25mmol/L
- Na+: 148 mmol/L
- K+: 3.1 mmol/L
- Cl- : 100mmol/L

What is the acid-base disturbance?
Case 4

A 44 yr old patient with ulcerative colitis has been suffering with bloody diarrhea for the last 48hrs. Arterial blood gas is as follows;

- pH: 7.31
- P02: 12.5 kPa
- PC02: 4.0 kPa
- HCO3-: 14 mmol/L
- Na+: 135 mmol/L
- K+: 3.1 mmol/L
- Cl-: 113 mmol/L
- Urea: 17 mmol/L
- Creatinine: 200 mmol/L

What is the acid-base disturbance?
Case 5

- A 60 year woman with history of depression takes an overdose of benzodiazepine. Her arterial blood gas is as follows;

- pH 7.2
- P02 12 kPa
- PC02 7.8 kPa
- HCO3- 25mmol/L

What is the acid-base disturbance?
Normal Values

- pH  7.35-7.45
- PO2  10-13 kPa
- PCO2  4.6-6.0 kPa
- HCO3-  21-28 mmol/l
- Base excess  -2 to +2
- O2 saturation  95-100%
Control of blood pH

Three mechanisms

- Intracellular and extracellular buffers (hemoglobin, carbonic acid and bicarbonate)
- Regulation by the kidneys
- Regulation by the lungs
The Bicarbonate buffer

• Effective

The lungs regulate the PC02 by adjusting the rate of alveolar ventilation.

The kidneys regulate the concentration of HCO3- by adjusting the renal excretion of carbonic acid and reabsorption of bicarbonate.
Handerson- Hasselbalch Equation

\[
pH = (6.1) + \log \frac{[\text{HCO}_3^-]}{(0.03) \times \text{pCO}_2}
\]

\[
pH \sim \frac{\text{HCO}_3^-}{\text{pCO}_2}
\]
Interpretation of Blood gases

1- Is it an Acidosis or alkalosis?
2- Is it Respiratory or metabolic?
3- Is there any compensation?
4- For metabolic acidosis, what is the anion gap?
Points to remember

• Primary changes in CO2 are respiratory
• CO2 is an acidic gas
• Primary changes in HCO3- are metabolic
• HCO3- is alkaline

The change that explains the pH is your primary change
Identifying the Primary Process

- **Low pH**: Acidosis
  - Low PCO₂: Respiratory Acidosis
  - Low HCO₃: Metabolic Acidosis
- **Normal pH**: No Abnormality or fully compensated
- **High pH**: Alkalosis
  - Low PCO₂: Respiratory Alkalosis
  - High HCO₃: Metabolic Alkalosis
Step 1- Look at the pH

Is the pH normal?

• <7.35 – acidosis
• >7.45- alkalosis
Step 2-Look at the pCO2

- Step 2- Is the pCO2 abnormal? If so, is the change in keeping with the pH?

CO2 is an acidic gas
Raised in acidosis and lowered in alkalosis
If so, it is in keeping with the pH and thus caused by a respiratory problem
Step 3- Look at the bicarbonate

Is the bicarbonate abnormal?
If so, is the change in keeping with the pH?

Bicarbonate is alkaline
Raised with an alkalosis and lowered with an acidosis
If so, the problem is a metabolic one.
A 21 year old female presents acutely sweating and short of breath. She has her final university exams in 3 days. Her patient's blood gas shows

- pH 7.52
- pCO2 2.5kPa
- HCO3- 23mmol/L

There is an alkalosis. The pCO2 is low and explains the alkalosis, thus this is the primary change. HCO3- is normal. This is a Respiratory alkalosis.
Step 4- Is there compensation?

• If a change is opposite to the pH, the change is compensatory

Maybe fully or partially compensated
Worked example

• Your patients blood gas shows
  
• pH 7.25
• PCO2 2.0kPa
• HCO3- 8.0mmol/L

There is an acidosis. The CO2 is low and thus compensatory change. The HCO3- is also low but explains the low pH so this is the primary change ie, a metabolic acidosis (partially compensated)
<table>
<thead>
<tr>
<th>Acid-Base Disorder</th>
<th>Initial Chemical Change</th>
<th>Compensatory Response</th>
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<tr>
<td>Respiratory acidosis</td>
<td>$pCO_2$</td>
<td>$HCO_3$</td>
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<td>Respiratory alkalosis</td>
<td>$pCO_2$</td>
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• Lungs compensate for metabolic disorders- Respiratory compensation takes hours.
• Kidneys compensate for respiratory disorders- Renal compensation takes days.
• Neither can overcompensate
• The compensation is always in the same direction as the initial change (to maintain the ratio of bicarbonate concentration to PC02)
Worked example

A patient in the community is being assessed for home oxygen. His blood gas is as follows

- pH 7.36
- PCO2 6.7kPa
- HCO3- 33mmol/l

pH is normal (acidic). PCO2 is high (explains the pH) . Bicarbonate is also high. Kidney takes longer to compensate- Fully compensated chronic respiratory acidosis
Step 5 - Calculating Anion gap

Estimates unmeasured plasma anions (fixed or organic acids) such as phosphate, ketones or lactate which are hard to measure directly. Implies to metabolic acidosis

\[(\text{Na}^+ + \text{k}^+) - (\text{HCO}_3^- + \text{Cl}^-) = \text{Anion gap}\]

Normal 10-18 mmol/L
High anion gap Metabolic acidosis

Accumulation of unmeasured anions

• **Ketoacidosis** (diabetes, starvation, alcohol)
• **Lactic acidosis** (shock, infection, ischemia)
• **Exogenous acids** (methanol, ethylene glycol, aspirin)
• **Chronic renal failure**
Normal Anion gap Metabolic acidosis

Due to loss of bicarbonate mainly

- Diarrhoea
- Ileostomy
- Pancreatic fistula
- Drugs (Acetazolamide)
- Renal tubular acidosis
Respiratory Acidosis

-Central depression of respiratory drive (Drugs; opioids, benzodiazepines, CNS lesions)

-Neuromuscular disorders (MND, Guillain-Barre syndrome, B/L diaphragmatic paralysis, MS)

-Chest wall/thoracic cage abnormality (Obesity Hypoventilation syndrome, Kyphoscoliosis, Flail chest)

-Disorders affecting gas exchange (COPD, Severe Asthma)

-Airway obstruction (obstructive sleep apnea)
Respiratory Alkalosis

• **Hypoxia** - High altitude, severe anemia

• **Hyperventilation** due to pain or anxiety

• **Pulmonary disease** (Pulmonary embolism, Acute asthma, Pneumonia, Pulmonary edema, Interstitial lung disease, Pneumothorax)

• **Drugs** - Respiratory stimulants (salicylates, aminophylline)
Metabolic alkalosis

• GI losses- Vomiting and Nasogastric suction
• Renal- Loop or thiazide diuretics, Mineralocorticoid excess
• Ingestion of base
Base excess

• The amount of base needed to restore the pH to the normal range.
• Base excess $>+2$, patient has excess base present (alkalosis)
• Base excess $<-2$, patient has insufficient base present (acidosis)
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What is the acid-base disturbance?
Answer: Respiratory Alkalosis
No compensatory change
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You see an 18 yr old male in A&E. He has been vomiting for the last 24hrs having had a chinese take away. His arterial blood gas is as follows;

- pH: 7.50
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What is the acid-base disturbance?
Answer: Metabolic Alkalosis
No compensatory change
Case 3

- A 20 years old man feels extremely unwell complaining of abdominal pain. He is thirsty and drinking lots of fluids. His arterial blood gas is as follows:
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What is the acid-base disturbance?
• Answer: High anion gap Metabolic acidosis-
Partially compensated
Case 4

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- pH: 7.31
- P02: 12.5 kPa
- PC02: 4.0 kPa
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- Na⁺: 135 mmol/L
- K⁺: 3.1 mmol/L
- Cl⁻: 113 mmol/L
- Urea: 17 mmol/L
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What is the acid-base disturbance?
• Answer: Normal Anion gap Metabolic acidosis-Partially compensated
Case 5

- A 60 year woman with history of depression is admitted drowsy and unresponsive. She has taken an overdose of benzodiazepines. Her arterial blood gas is as follows;
  - pH 7.2
  - P02 12 kPa
  - PC02 7.8 kPa
  - HCO3- 25mmol/L

What is the acid-base disturbance?
• Answer: Respiratory Acidosis- Uncompensated
Thank You