# Approach to Acid-Base Disorder

Dr. Talal Alfaadhel

2018/10/28

# Objectives

- Develop an approach to acid base problems
- Identify the primary acid base disturbance
- Solve simple acid base cases

# Introduction

- The assessment of acid base abnormalities is typically done using arterial blood gases (ABG)
- Given the ease of obtaining venous blood gases (VBG) and capillary blood gases (CBG) these are often used in clinical practice

**Normal pH value ranges for arterial blood are 7.35 - 7.45, while normal pH of venous blood is 7.31-7.41**

**Always check the reference range in your local laboratory**

# Definitions

| | |
|---|---|
| **Metabolic acidosis** | **loss of [$HCO_3$] or addition of [H+]** |
| **Metabolic alkalosis** | **loss of [H+] or addition of [$HCO_3$]** |
| **Respiratory acidosis** | **increase in $pCO_2$** |
| **Respiratory alkalosis** | **decrease in $pCO_2$** |

| | |
|---|---|
| Metabolic acidosis | Process that primarily reduces bicarbonate:<br>Excessive $H^+$ formation e.g. lactic acidosis, ketoacidosis<br>Reduced $H^+$ excretion e.g. renal failure<br>Excessive $HCO_3^-$ loss e.g. diarrhoea |
| Metabolic alkalosis | Process that primarily raises bicarbonate:<br>Extracellular fluid volume loss e.g. due to vomiting or diuretics<br>Excessive potassium loss with subsequent hyperaldosteronism |
| Respiratory acidosis | Process that primarily causes elevation in $PaCO_2$:<br>Reduced effective ventilation e.g. many chronic respiratory diseases or drugs depressing the respiratory centre |
| Respiratory alkalosis | Process that primarily causes reduction in $PaCO_2$:<br>Increased ventilation e.g. in response to hypoxia or secondary to a metabolic acidosis |

# Step 1.

- Take a thorough history and physical examination, look for clues that may lead to the abnormalities in pH
  - Vomiting
  - Diarrhea
  - Hypoventilation
  - Respiratory disease
  - Medications (laxatives, diuretics, etc)
  - Diabetes
  - etc

**Vomiting for example, causes loss of acid and gastric contents, which suggests development of alkalosis**

# Step 2

- Look at the pH:
- Determine if this is
  - Normal 7.35 – 7.45 (No abnormality or mixed acidosis and alkalosis)
  - Low <7.35 (acidemic)
  - High >7.45 (alkalemic)

# Step 3 - a

- Determine the primary abnormality that is causing the abnormal pH

- If the pH is acidemic (<7.35), then look for
  - Low $HCO_3$ (Metabolic) or High $PCO_2$ (Respiratory)

- If the pH is alkalemic (>7.45), then look for
  - High $HCO_3$ (Metabolic) or Low $PCO_2$ (Respiratory)

# Step 3 - b

- If pH is normal, rule out mixed acidosis and alkalosis
  - Look for high or low $PCO_2$
  - Look for high or low $HCO_3$

- **Low** PCO2 suggests **respiratory alkalosis**
- **High** PCO2 suggests **respiratory acidosis**
- **Low** $HCO_3$ suggests **metabolic acidosis**
- **High** $HCO_3$ suggests **metabolic alkalosis**

**Determine what is being mixed**

# Step 4

- After determining the primary abnormality, check for compensation
- Compensation is the mechanism by which the body adapts to either acidosis or alkalosis, it will fully correct the abnormality
- For example
  - A patient has diabetic ketoacidosis, pH is 7.29, $HCO_3$ is 15
  - Expected $PCO_2$ by using Winter's formula
  - $PCO_2 = 1.5 \times HCO_3 + 8 \ (\pm 2)$

    $= 1.5 \times 15 + 8 = 30.5$

  So you expect the $PCO_2$ in this patient to be in the range of 28.5– 32.5

  - If the $PCO_2$ in this patient is higher than 32.5 → consider additional respiratory acidosis
  - If the $PCO_2$ in the patient is lower than 28.5 → consider additional respiratory alkalosis

# Step 4

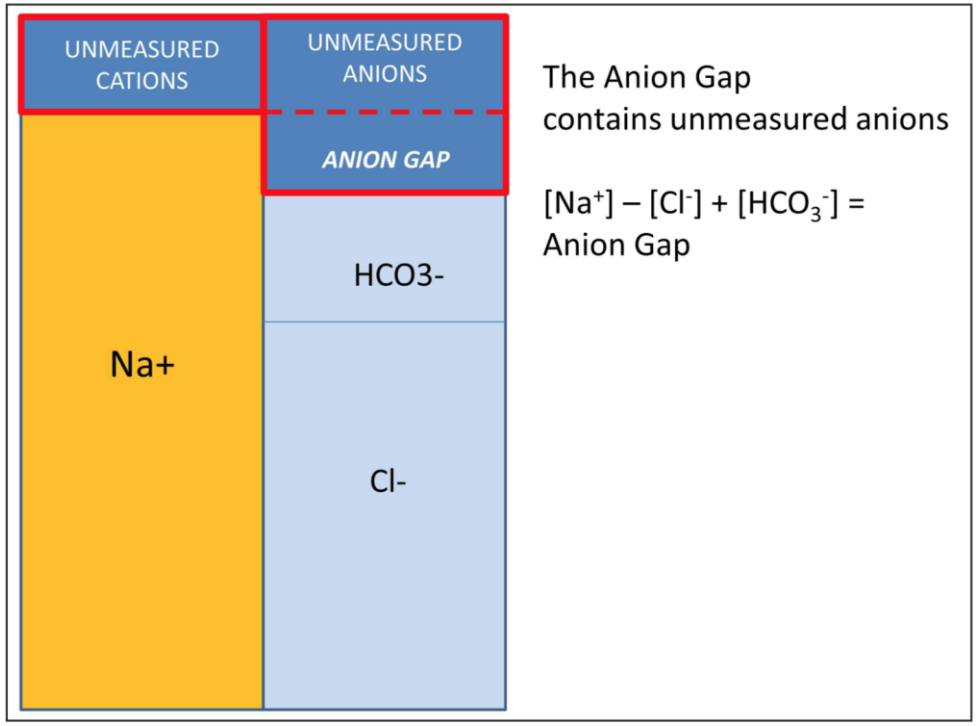
**Compensation calculations**

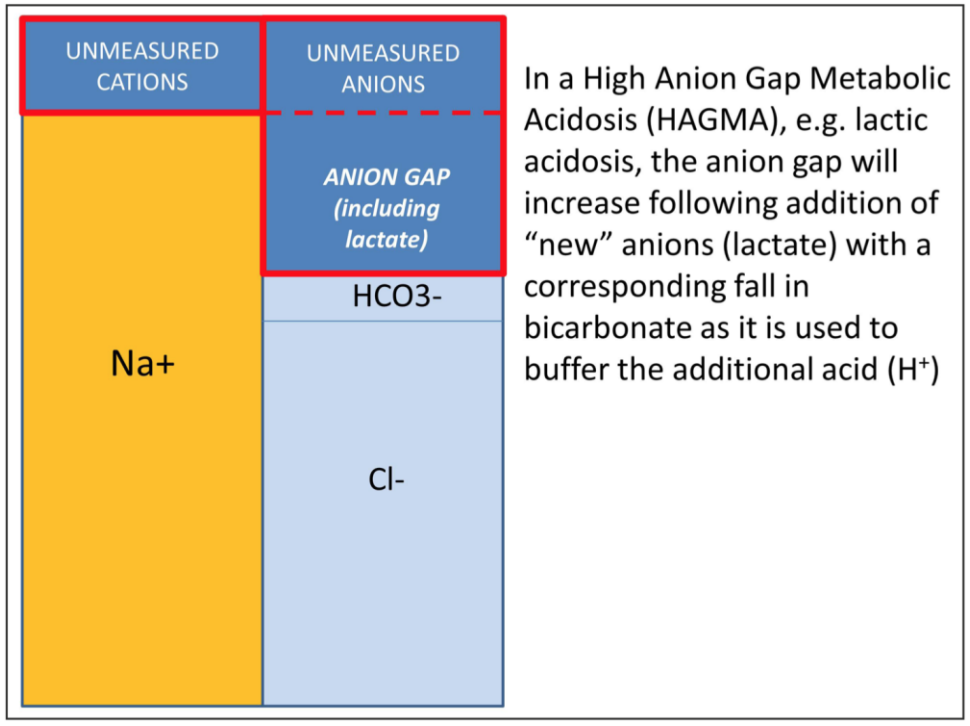
| *Primary Disorder* | *Expected Compensation* |
| --- | --- |
| Metabolic Acidosis | $\downarrow PaCO_2 = 1.2 \times \Delta HCO_3$ or<br>$PaCO_2 = 1.5 \times HCO_3 + 8 \pm 2$ or<br>$PaCO_2$ ~ last two digits of pH. |
| Metabolic Alkalosis | $\uparrow PaCO_2 = 0.7 \times \Delta HCO_3$ |
| Acute Respiratory Acidosis | $\uparrow HCO_3 = 0.1 \times \Delta PaCO_2$ |
| Chronic Respiratory Acidosis | $\uparrow HCO_3 = 0.35 \times \Delta PaCO_2$ also<br>$\downarrow pH = 0.003 \times \Delta PaCO_2$ |
| Acute Respiratory Alkalosis | $\downarrow HCO_3 = 0.2 \times \Delta PaCO_2$ |
| Chronic Repsiratory Alkalosis | $\downarrow HCO_3 = 0.4 \times \Delta PaCO_2$ |

# Step 5

- Calculate the anion gap (AG)
  - AG = Na – (Cl + $HCO_3$)

Albumin is the main unmeasured anion
To overcome the effects of the hypoalbuminemia on the AG, the corrected AG can be used which is AG + (0.25 X (40-albumin) expressed in g/L



# Step 5

Causes of High Anion Gap Metabolic Acidosis (MUD PILES)

- **M**ethanol
- **U**remia
- **D**KA
- **P**ropylene glycol (not paraldehyde)
- **I**NH (impaired hepatic clearance of lactate)
- **L**actic acidosis
- **E**thanol/Ethylene  Glycol
- **S**alicylates

# Step 5

- Metabolic acidosis with normal anion gap suggests

| **Normal anion gap** |
| --- |
| Gastrointestinal losses of bicarbonate |
| Renal tubular acidosis |
| Treatment with carbonic anhydrase inhibitors |
| Urinary diversion procedures |
| Excessive administration of 0.9% saline |

# Case 1

**Normal reference range**
pH (7.35-7.45), PCO2 (35-45 mmHg), PO2 (82-105 mmHg), HCO3 (22-26 mmol/L), AG (8-12)
Creatinine (40-110 umol/L), Urea (2.5-7.8 mmol/L), Na (136-145 mmol/L), K (3.5-5 mmol/L)

- A 75 year old man is admitted with septic shock. Shortly after admission, blood tests reveal the following:
- pH 7.18, $PO_2$= 150 mmHg, $PaCO_2$= 16 mmHg, $HCO_3$ 7 mmol/L
- Na 138 mmol/L, K 3.9 mmol/L, Cl 95 mmol/L, Urea 8.2 mmol/L, Creatinine 102 µmol/L

- Please identify the acid base disturbance
- Please indicate what is causing the acid base disturbance.

# Case 2

**Normal reference range**
pH (7.35-7.45), PCO2 (35-45 mmHg), PO2 (82-105 mmHg), HCO3 (22-26 mmol/L), AG (8-12)
Creatinine (40-110 umol/L), Urea (2.5-7.8 mmol/L), Na (136-145 mmol/L), K (3.5-5 mmol/L)

- A 68 year old woman is being treated for congestive heart failure in the coronary care unit. After several days of treatment, the following results are returned:
- pH 7.49, PO2= 86 mmHg, PaCO2= 48.5 mmHg, HCO3 39 mmol/L
- Na 142 mmol/L, K 3.0 mmol/L, Cl 85 mmol/L, Urea 9.3 mmol/L, Creatinine 84 µmol/L

- Please identify the acid base disturbance
- Please indicate what is causing the acid base disturbance.

# Case 3

**Normal reference range**
pH (7.35-7.45), PCO2 (35-45 mmHg), PO2 (82-105 mmHg), HCO3 (22-26 mmol/L), AG (8-12)
Creatinine (40-110 umol/L), Urea (2.5-7.8 mmol/L), Na (136-145 mmol/L), K (3.5-5 mmol/L)

- A 70 year old man with chronic obstructive pulmonary disease (COPD) is admitted with increasing confusion. Shortly after admission, blood tests reveal the following:
- pH 7.21, PO 61.5 mmHg, PaCO2 83 mmHg, HCO3 34 mmol/L
- Na 140 mmol/L, K 4.7 mmol/L, Cl 94 mmol/L Urea 8.2 mmol/L, Creatinine 66 µmol/L

- Please identify the acid base disturbance
- Please indicate what is causing the acid base disturbance.

# Case 4

**Normal reference range**
pH (7.35-7.45), PCO2 (35-45 mmHg), PO2 (82-105 mmHg), HCO3 (22-26 mmol/L), AG (8-12)
Creatinine (40-110 umol/L), Urea (2.5-7.8 mmol/L), Na (136-145 mmol/L), K (3.5-5 mmol/L)

- An 40 year old man developed profuse diarrhoea following antibiotic treatment of a chest infection. He is thirsty and light headed. Shortly after admission, blood tests reveal the following:
- pH 7.25, PO 101 mmHg, PaCO2 31.5 mmHg, HCO3 17 mmol/L
- Na 134 mmol/L, K 3.4 mmol/L, Cl 104 mmol/L, Urea 9.3 mmol/L, Creatinine 102 µmol/L

- Please identify the acid base disturbance
- Please indicate what is causing the acid base disturbance.