

Approach to Acid-Base Disorder

Dr. Talal Alfaadhel

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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 $[\text{HCO}_3^-]$ or addition of $[\text{H}^+]$

Metabolic alkalosis

loss of $[\text{H}^+]$ or addition of $[\text{HCO}_3^-]$

Respiratory acidosis

increase in pCO_2

Respiratory alkalosis

decrease in pCO_2

Metabolic acidosis	Process that primarily reduces bicarbonate: Excessive H ⁺ formation e.g. lactic acidosis, ketoacidosis Reduced H ⁺ excretion e.g. renal failure Excessive HCO ₃ ⁻ loss e.g. diarrhoea
Metabolic alkalosis	Process that primarily raises bicarbonate: Extracellular fluid volume loss e.g. due to vomiting or diuretics Excessive potassium loss with subsequent hyperaldosteronism
Respiratory acidosis	Process that primarily causes elevation in PaCO ₂ : 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 : 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 PCO_2 suggests respiratory alkalosis**
- **High PCO_2 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, HCO₃ is 15
- Expected PCO₂ 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 PCO₂ in this patient to be in the range of 28.5– 32.5

- If the PCO₂ in this patient is higher than 32.5 → consider additional respiratory acidosis
- If the PCO₂ in the patient is lower than 28.5 → consider additional respiratory alkalosis

Step 4

Compensation calculations

Primary Disorder

Metabolic Acidosis

Expected Compensation

$$\downarrow \text{PaCO}_2 = 1.2 \times \Delta \text{HCO}_3 \quad \text{or}$$

$$\text{PaCO}_2 = 1.5 \times \text{HCO}_3 + 8 \pm 2 \quad \text{or}$$

$\text{PaCO}_2 \sim$ last two digits of pH.

Metabolic Alkalosis

$$\uparrow \text{PaCO}_2 = 0.7 \times \Delta \text{HCO}_3$$

Acute Respiratory Acidosis

$$\uparrow \text{HCO}_3 = 0.1 \times \Delta \text{PaCO}_2$$

Chronic Respiratory Acidosis

$$\uparrow \text{HCO}_3 = 0.35 \times \Delta \text{PaCO}_2 \quad \text{also}$$

$$\downarrow \text{pH} = 0.003 \times \Delta \text{PaCO}_2$$

Acute Respiratory Alkalosis

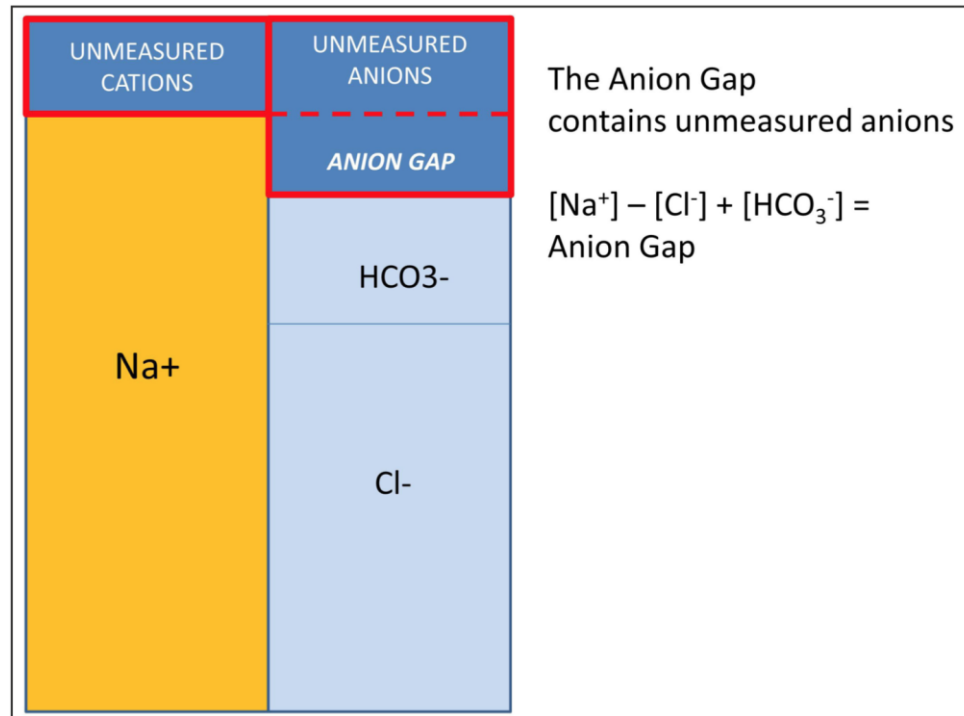
$$\downarrow \text{HCO}_3 = 0.2 \times \Delta \text{PaCO}_2$$

Chronic Respiratory Alkalosis

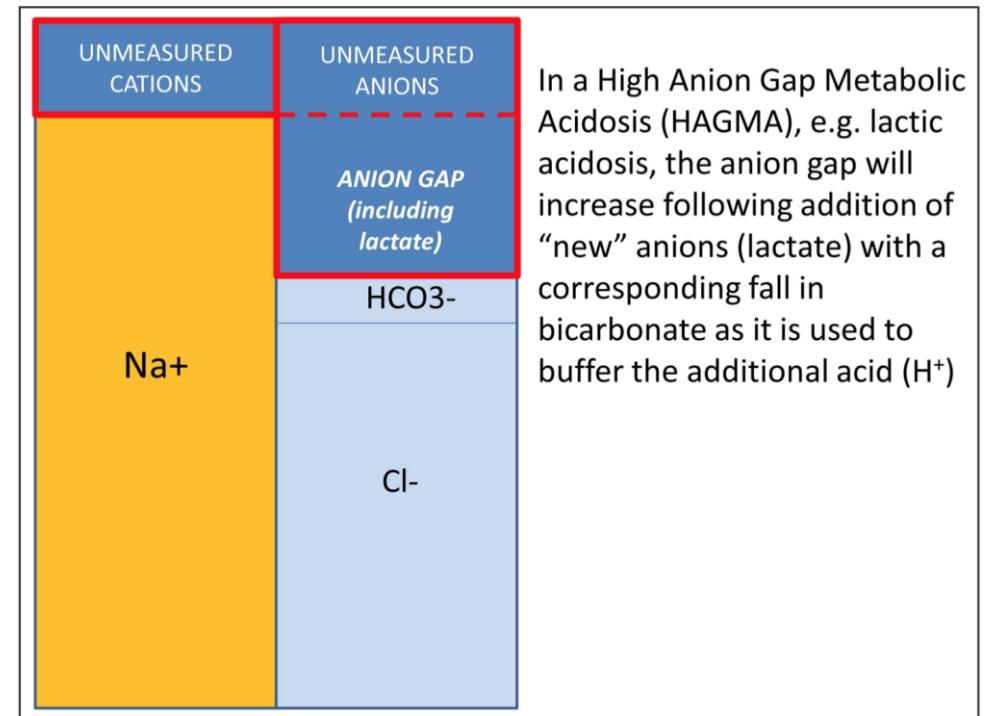
$$\downarrow \text{HCO}_3 = 0.4 \times \Delta \text{PaCO}_2$$

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 $AG + (0.25 \times (40 - \text{albumin}))$ 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 μ mol/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, PO₂= 150 mmHg, PaCO₂= 16 mmHg, HCO₃ 7 mmol/L
- Na 138 mmol/L, K 3.9 mmol/L, Cl 95 mmol/L, Urea 8.2 mmol/L, Creatinine 102 μ mol/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 μ mol/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 μ mol/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 μ mol/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 μ mol/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 µmol/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 lightheaded. 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.