Approach to Acid-Base Disorder

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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 [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: 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

Determine what is being mixed

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

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

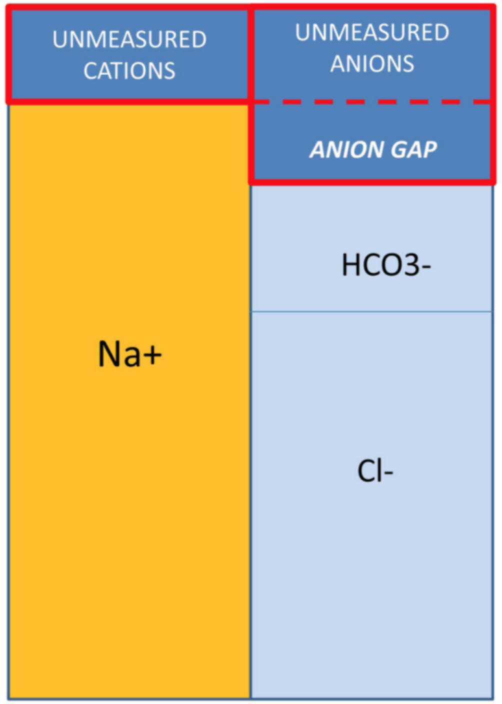
Compensation calculations

Primary Disorder	*Expected Compensation*
Metabolic Acidosis	$\downarrow PaCO_2 = 1.2 \times \Delta HCO_3$ or $PaCO_2 = 1.5 \times HCO_3 + 8 \pm 2$ or $PaCO_2$ ~ 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 $\downarrow pH = 0.003 \times \Delta PaCO_2$
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

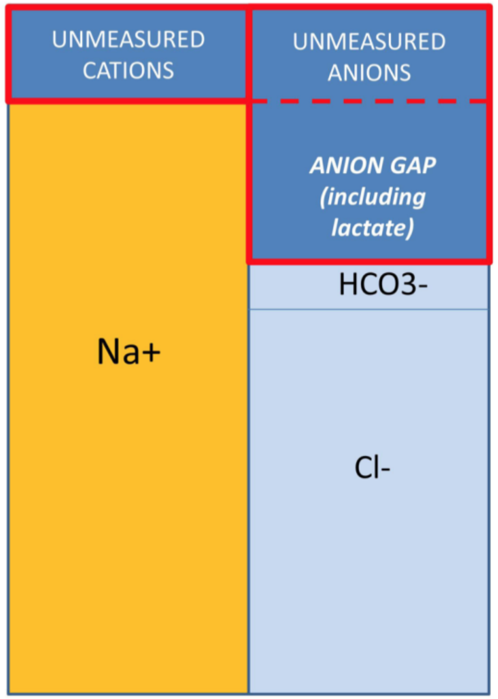
Albumin is the main unmeasured anion
To overcome the effects of the hypoalbuminemia on the AG, the corrected AG can be used which is AG + (0.25 X (40-albumin) expressed in g/L

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



The Anion Gap contains unmeasured anions

$[Na^+] - [Cl^-] + [HCO_3^-] =$ Anion Gap



In a High Anion Gap Metabolic Acidosis (HAGMA), e.g. lactic acidosis, the anion gap will increase following addition of "new" anions (lactate) with a corresponding fall in bicarbonate as it is used to buffer the additional acid (H^+)

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 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.