

What does an ABG look like?

- pH : 7.40 (7.35 – 7.45)
- PO₂ : 80 – 104 mm Hg
- PCO₂ : 40 mm Hg (35 – 45)
- HCO₃ (act) : 24 ± 2 m Eq/L
- HCO₃ (std) : 24 ± 2 m Eq/L
- BE : ± 2
- O₂ sat : 96% - 98%
- A-a DO₂ :

What does an ABG look like?

(Contd.)

- Na^+ : 135 – 148 m mol / L
- K^+ : 3.5 – 5.5 m mol / L
- Ca^{++} : 1.13 – 1.32 m mol / L
- Cl^- : 98 – 106 m mol / L
- Anion gap :

What is pH?

- It is the negative logarithm of H^+ ion concentration in the extracellular fluid.
- As it is the negative algorithm – pH decreases as H^+ conc. increases

pH > 7.45 Alkalemia / Alkalosis

pH < 7.35 Acidosis / Acidemia

Henderson-Hasselbalch Equation

$$\text{pH} = 6.1 + \log \frac{(\text{HCO}_3)}{(0.03) \times (\text{PCO}_2)}$$

Oxygenation (Adult & Child)

- Normal PO_2 : 80 – 104 mm Hg on room air
< 80 mm Hg is Hypoxaemia
- Age: For every year of age above 60 yrs
acceptable PO_2 ↓ es by 1 mm Hg below 80
- New born: Acceptable range :– 40 – 70 mm Hg

Relationship between FiO_2 And PaO_2

- $\% \text{ of O}_2 \times 5 = \text{Predicted minimum PaO}_2$
($21\% \times 5 = 105 \text{ mm Hg}$)
- $(P_B - P_{H_2O}) \text{ FiO}_2 - \text{PaCO}_2 / RQ$
- $\text{PaO}_2 / \text{FiO}_2$ ratio: $105 / 0.21 = 500$
 - > 500 is normal
 - >300 – 500 some degree of oxygenation problem
 - 200 – 300 Acute lung injury
 - < 200 ARDS

Respiratory acidosis (Res Acid)

- Primary change is ↑ed $\text{PaCO}_2 \rightarrow$ ↓ed pH
- For each 10 mm Hg ↑ed in PaCO_2 – pH ↓es by 0.05
- COMPENSATION FOR ACUTE Res Acid:
 HCO_3^- ↑es by 1 mEq/L for each 10 mm Hg ↑ in PaCO_2
- COMPENSATION FOR CHRONIC Res Acid:
 HCO_3^- ↑es by 3 – 3.5 mEq/L for each 10 mm Hg ↑ in PaCO_2

Causes of Respiratory Acidosis

- SEVERE ACUTE ASTHMA
- COPD
- ALVEOLAR HYPOVENTILATION –
Patient on ventilator
- CNS DEPRESSION
- THORACIC CAGE RESTRICTION

Respiratory Alkalosis (Res Alk)

- Primary change is ↓ed PaCO₂ → ↑ed pH
- For each 10 mm Hg ↓ PaCO₂ → pH ↑es by 0.1
- COMPENSATION FOR ACUTE Res Alk:
HCO₃ ↓es 2 mmol /L for every 10 mm Hg ↓ PaCO₂
- COMPENSATION FOR CHRONIC Res Alk:
HCO₃ ↓es 4 – 5 m mol/ L for every 10 mm Hg ↓PaCO₂

Causes of Respiratory Alkalosis

- HYPOXAEMIA
- CENTRAL CAUSES
- FEVER
- ANXIETY
- HORMONES – Catechol, progesteron
- DRUGS – Salicylates, analeptics
- SEPSIS

Causes of Respiratory Alkalosis (contd)

- HYPERTHYROIDISM
- PREGNANCY
- CIRRHOSIS
- PULMONARY OEDEMA
- PULMONARY EMBOLISM
- PNEUMONIA
- VENTILATOR INDUCED

Metabolic Acidosis (Met Acid)

- Primary change is ↓ed HCO_3^- / ↑ed H^+ → ↓ed pH
- For each ↓ in HCO_3^- of 7 – 7.5 m mol/ L pH ↓es by 0.1

COMPENSATORY CHANGE IS ↓ed PaCO_2

- Expected $\text{PaCO}_2 = 1.5 \times \text{HCO}_3^- + 8 (\pm 2)$

Anion Gap

- It is an acid base parameter that is used to evaluate pts. with a metabolic acidosis to determine whether the problem is due to accumulation of H^+ ions (eg. Lactic acidosis) or due to loss of HCO_3 ions(eg. Diarrhea)

Concept of Anion Gap

- To achieve electrochemical balance, ionic elements in ECF must have a net zero charge

So Anions must balance Cations -

$$(\text{Na}^+) + (\text{U Cations}) = (\text{Cl} + \text{HCO}_3) + (\text{U Anions})$$

$$\Rightarrow (\text{U Cations} - \text{U Anions}) = \text{Na}^+ - (\text{Cl} + \text{HCO}_3)$$

Concept of Anion Gap (contd)

- Unmeasured Anions (UA): Proteins + organic acids + Phosphates + Sulphates \Rightarrow 23 mEq / L
- Unmeasured Cations (UC): Calcium + Potassium + Magnesium \Rightarrow 11 mEq / L
- Normal Anion Gap = 12 mEq / L
- When organic acids like Lactic acids , Ketoacids, Ethanol \uparrow , they cause \uparrow ed anion gap

Causes of High Anion Gap Acidosis (H⁺ accumulation)

- Lactic acidosis due to tissue hypoxia
- Diabetic Ketoacidosis
- Alcoholic Ketoacidosis
- End Stage Renal Failure

Causes of Normal Anion Gap Acidosis

- GI LOSS OF BICARB
 1. Diarrhea
 2. Uretero sigmoidostomy
- RENAL BICARB LOSS (Proximal RTA)
 1. Fanconi's syndrome
 2. Carbonic Anhydrase inhibitors
 3. Ileal bladder

Causes of Normal Anion Gap Acidosis(contd.)

- REDUCED RENAL H⁺ SECRETION

I - DISTAL RTA

Familial, Hypercalcemia/Hypercalciuric states, Sjogren's syndrome, Autoimmune diseases, amphotericin, Renal Transplant

II – TYPE IV RTA

1. Hyporeninemic – Hypoaldosteronism , DM, NSAIDS
2. Defective Mineralo-corticoid synthesis – Addison's Disease, chronic heparin therapy

(contd.)

- 3 – Inadequate renal response to mineralocorticoids – SLE, K⁺ sparing diuretics
- 4 – Early Uremia

HCL/HCL PRECURSOR INGESTION:

HCl, NH₄Cl, NaCl, Arginine HCl

OTHERS:

- 1 - Post Chronic hyperventilation
- 2 - Recovery from DKA
- 3 – Toluene Inhalation

Metabolic Alkalosis

- Primary change is ↑ed HCO_3^- / or ↓ed H^+ - ↑ed pH
- For each ↑ in HCO_3^- of 7-7.5 mEq/L - pH ↑es by 0.1

RESPIRATORY COMPENSATION - ↑ed PaCO_2
(Not very common)

- Expected PaCO_2 in Metabolic Alkalosis:
⇒ $0.7 \times \text{HCO}_3^- + 21 (\pm 2)$

Classification of Metabolic Alkalosis

- Chloride Responsive:

Urinary chloride < 15m Eq/L

- 1 – Loss of gastric acid – vomiting/NG Tube
- 2 – Diuretics (long term use)
- 3 – Volume depletion
- 4 – Chloride losing diarrhea
- 5 – Post - hypercapnia

- Chloride Unresponsive:

Urinary chloride > 25m Eq/L

1 – Potassium depletion

2 – Diuretics (Recent use)

3 – Mineralocorticoid Excess

4 – Primary hyper aldosteronism

5 – Cushing's disease

6 – Ectopic ACTH

7 – Barrter Syndrome

CORRECTION

- Saline infusion for Cl⁻ responsive alkalosis
- Chloride deficit (mEq) = $0.3 \times \text{WT. (kg)} \times (100 - \text{Plasma Cl}^-)$
- Volume of Isotonic Saline (L):
Chloride deficit / 154

How to read an ABG?

- STEP – 1 : First look at the pH
 - * Acidemia - ↓ed pH
 - * Alkalemia - ↑ed pH
 - * Normal - \Leftrightarrow pH
- STEP – 2 : If acidemia is there – Check PaCO₂
 - * Normal – Metabolic acidosis
 - * Low – Metabolic acidosis
 - * High – Primary respiratory acidosis

How to read an ABG? (Contd)

- If pH is Acidemic and PaCO₂ is Normal OR Low :
 - * Then calculate the difference between measured and expected PaCO₂
- If pH is Acidemic and PaCO₂ is High:
 - * Then determine the change in pH & HCO₃ to decide whether Chronic or Acute , and if there is any other superimposed problem

How to read an ABG? (Contd)

- STEP – 3 : If Alkalemia is there – Check PaCO₂

* If pH is Alkalemic and PaCO₂ is Normal or High

It indicates Primary Metabolic Alkalosis

Then compare measured and expected PaCO₂ to identify any associated Respiratory disorder

How to read an ABG? (Contd)

- STEP – 3 (contd)

* If pH is Alkalemic and PaCO₂ is Low

It indicates Primary Respiratory Alkalosis

Then we determine the change in pH & HCO₃ to decide whether Acute or Chronic, and for any other superimposed problem

How to read an ABG? (Contd)

- STEP – 4 :

If Normal pH – Check PaCO₂, can be High or Low

- * High PaCO₂ indicates a Mixed Respiratory Acidosis – Metabolic Alkalosis
- * Low PaCO₂ indicates a Mixed Respiratory Alkalosis – Metabolic Acidosis

How to read an ABG? (Contd)

- STEP – 5 :
- If Metabolic Acidosis is diagnosed – Check Anion Gap

SOME EXAMPLES

- pH = 7.54
 - $PO_2 = 105$ mm Hg
 - BE = - 2
 - $Na^+ = 138$ m mol / L
 - $Cl^- = 104$ m mol / L
- $PCO_2 = 26$ mm Hg
 - $HCO_3 = 22$ m
 - $SaO_2 = 99\%$
 - $K^+ = 3.8$ m mol / L
 - Anion Gap = 12

Examples

- pH = 7.3
- $\text{PCO}_2 = 60 \text{ mm Hg}$
- $\text{PO}_2 = 60 \text{ mm Hg}$
- $\text{HCO}_3 = 26 \text{ m mol / L}$
- $\text{BE} = + 3$
- $\text{SaO}_2 = 89 \%$
- $\text{Na}^+ = 140 \text{ m mol / L}$
- $\text{K}^+ = 4 \text{ m mol / L}$
- $\text{Cl}^- = 100 \text{ m mol / L}$

Examples

- $\text{pH} = 7.44$
- $\text{PCO}_2 = 29 \text{ mm Hg}$
- $\text{PO}_2 = 100 \text{ mm Hg}$
- $\text{HCO}_3 = 19 \text{ m mol / L}$
- $\text{BE} = -5$
- $\text{SaO}_2 = 98 \%$
- $\text{Na}^+ = 137 \text{ m mol / L}$
- $\text{K}^+ = 3.7 \text{ m mol / L}$
- $\text{Cl}^- = 108 \text{ m mol / L}$

Examples

- $\text{pH} = 7.35$
- $\text{PCO}_2 = 70 \text{ mm Hg}$
- $\text{PO}_2 = 62 \text{ mm Hg}$
- $\text{HCO}_3 = 32 \text{ m mol / L}$
- $\text{BE} = +8$
- $\text{SaO}_2 = 90 \%$
- $\text{Na}^+ = 136 \text{ m mol / L}$
- $\text{K}^+ = 3.5 \text{ m mol / L}$
- $\text{Cl}^- = 96 \text{ m mol / L}$

Examples

- pH = 7.30
 - $\text{PO}_2 = 80 \text{ mm Hg}$
 - BE = - 14
 - $\text{Na}^+ = 139 \text{ m mol / L}$
 - $\text{Cl}^- = 100 \text{ m mol / L}$
 - Expected PaCO_2 :
 - $(\text{HCO}_3) \times 1.5 + 8 (\pm 2) = 10 \times 1.5 + 8 (\pm 2)$
 - = 21 – 25 mm Hg
- $\text{PCO}_2 = 30 \text{ mm Hg}$
 - $\text{HCO}_3 = 10 \text{ mmol / L}$
 - $\text{SaO}_2 = 95 \%$
 - $\text{K}^+ = 4.1 \text{ m mol / L}$
 - Anion Gap = 29

Examples

- $\text{pH} = 7.50$
- $\text{PCO}_2 = 50 \text{ mm Hg}$
- $\text{PO}_2 = 75 \text{ mm Hg}$
- $\text{HCO}_3 = 40 \text{ m mol / L}$
- $\text{BE} = + 16$
- $\text{SaO}_2 = 95 \%$
- $\text{Na}^+ = 132 \text{ m mol / L}$
- $\text{K}^+ = 3.1 \text{ m mol / L}$
- $\text{Cl}^- = 88 \text{ m mol / L}$
- $\text{Anion Gap} = 4$

- Expected PaCO_2 :
- $(\text{HCO}_3) \times 0.7 + 21 (\pm 2) = 40 \times 0.7 + 21 (\pm 2)$
- $= 47 - 51 \text{ mm Hg}$

MIXED ACID BASE DISORDERS

- MIXED METABOLIC ACIDOSIS AND METABOLIC ALKALOSIS:
- Essential clue to mixed disorders is the Anion gap-- HCO₃ Relationship
 $\Delta AG / \Delta HCO_3$ ---- Called gap-gap
- AG excess/ HCO₃ deficit
- $(AG - 12/24 - HCO_3)$
- For Anion Gap acidosis ---
 $\Delta AG / \Delta HCO_3 \approx 1$
- For Hyperchloremic (normal) AG acidosis -- $\Delta AG / \Delta HCO_3 \approx 0$

- For metabolic acidosis with metabolic alkalosis --- $\Delta\text{AG}/\Delta\text{HCO}_3 \geq 1.5$
- i.e. Change in AG excess is greater than change in HCO_3 deficit
- TRIPLE DISORDERS:
- Combination of metabolic acidosis and metabolic alkalosis combined with either respiratory acidosis or respiratory alkalosis

EXAMPLES OF MIXED DISORDERS

- pH : 7.55
- PCO₂ : 30 mm Hg
- PO₂ : 104 mm Hg
- HCO₃ : 29mmol/L
- BE : +5
- Sats : 99%
- Na⁺ : 135mmol/L
- K⁺ : 3.5mmol/L
- Cl⁻ : 95mmol/L
- Anion Gap: 11

- pH : 7.25
- PCO₂ : 50 mm Hg
- PO₂ : 104 mm Hg
- HCO₃ : 15mmol/L
- BE : -8
- Sats : 95%
- Na⁺ : 140mmol/L
- K⁺ : 4.5mmol/L
- Cl⁻ : 105mmol/L
- Anion Gap: 20

- pH : 7.36
- PCO₂ : 34 mm Hg
- PO₂ : 100 mm Hg
- HCO₃ : 16mmol/L
- BE : -8
- Sats : 98%
- Na⁺ : 140mmol/L
- K⁺ : 3.5mmol/L
- Cl⁻ : 98mmol/L
- Anion Gap : 26

- pH : 7.40
- PCO₂ : 28 mm Hg
- PO₂ : 60 mm Hg
- HCO₃ : 15mmol/L
- BE : -9mmol/L
- Sats : 90%
- Na⁺ : 140mmol/L
- K⁺ : 3.5mmol/L
- Cl⁻ : 98mmol/L
- Anion Gap : 27

- pH : 7.46
- PCO₂ : 54 mm Hg
- PO₂ : 90 mm Hg
- HCO₃ : 34mmol/L
- BE : +10
- Sats : 98%
- Na⁺ : 135mmol/L
- K⁺ : 3.5mmol/L
- Cl⁻ : 90mmol/L
- Anion Gap : 11

- pH : 7.45
- PCO₂ : 15 mm Hg
- PO₂ : 244 mm Hg
- HCO₃ : 10mmol/L
- BE : -14mmol/L
- Sats : 99%
- Na⁺ : 104mmol/L
- K⁺ : 2.10mmol/L
- Cl⁻ : 60mmol/L
- Anion Gap : 34

Method of obtaining an ABG

- SITES:
 - 1) Radial artery
 - 2) Brachial artery
 - 3) Femoral artery
- PRECAUTIONS:----- Modified Allen's Test

Method of obtaining an ABG (contd.)

- **CLEANING:**

- 1) 70% Alcohol
- 2) Tincture Benzoin

- **HEPARINATION:**

Flush syringe with heparin

Leave approx. 0.2 ml in the hub of syringe

Method of obtaining an ABG (contd.)

- **SAMPLING:**

To be done within 10 mins or else O_2 is consumed by WBC's at the rate of 0.1 ml of O_2 /100 ml blood in 10 mins

OR

Cool the sample in refrigerator/ice pack to decrease O_2 consumption by WBC's

Method of obtaining an ABG (contd.)

- **RADIAL ARTERY PUNCTURE:**
 1. Modified Allen's Test-
 2. Palpate the radial artery against the head of the radius
 3. Direct the needle at 45 to the perpendicular – use 22 G needle
 4. Put slight negative suction on the syringe
 5. Put rubber or plastic block on the syringe
 6. No large air bubble should be in there in the sample

All the best..