What does an ABG look like?

- pH : 7.40 (7.35 – 7.45)
- PO_2 : 80 – 104 mm Hg
- PCO_2 : 40 mm Hg (35 – 45)
- HCO_3 (act) : 24 ± 2 m Eq/L
- HCO_3 (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

$$pH = 6.1 + \log \frac{(HCO_3)}{(0.03) \times (PCO_2)}$$

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

- % of $O_2 \times 5$ = Predicted minimum PaO_2

  (21% × 5= 105 mm Hg)

- $(P_B - P_{H_2O})\ FiO_2 - PaCO_2 / RQ$

- PaO_2 / 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 $PaCO_2$ → ↓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 $PaCO_2$ → ↑ed pH
- For each 10 mm Hg ↓ $PaCO_2$ → pH ↑es by 0.1

- COMPENSATION FOR ACUTE Res Alk:

HCO_3 ↓es 2 mmol /L for every 10 mm Hg ↓ $PaCO_2$

- COMPENSATION FOR CHRONIC Res Alk:

HCO_3 ↓es 4 – 5 m mol/ L for every 10 mm Hg ↓$PaCO_2$

Causes of Respiratory Alkalosis

- HYPOXAEMIA
- CENTRAL CAUSES
- FEVER
- ANXIETY
- HORMONES – Catechol, progestron
- 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 PaCO2 = $1.5 \times HCO_3 + 8 (\pm 2)$

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 -

(Na^+) + (U Cations) = (Cl + HCO_3) + (U Anions)

$\Rightarrow$(U Cations – U Anions) = Na^+ – (Cl + 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 ↑, they cause ↑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

<u>HCL/HCL PRECURSOR INGESTION</u>:

HCl, NH_4Cl, $NaCl$, Arginine HCl

<u>OTHERS:</u>

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 PaCO2 in Metabolic Alkalosis:

$\Rightarrow 0.7 \times HCO3 + 21\ (\pm 2)$

Classification of Metabolic Alkalosis

- <u>Chloride Responsive:</u>

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

- <u>Chloride Unresponsive:</u>

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 X WT. (kg) x (100 – Plasma Cl^-)
- Volume of Isotonic Saline (L): Chloride deficit / 154

How to read an ABG?

- STEP – 1 : First look at the pH
  - * Acidemia - $\downarrow$ed pH
  - * Alkalemia - $\uparrow$ed pH
  - * Normal - $\Leftrightarrow$ pH

- STEP – 2 : If acidemia is there – Check $PaCO_2$
  - * Normal – Metabolic acidosis
  - * Low – Metabolic acidosis
  - * High – Primary respiratory acidosis

How to read an ABG? (Contd)

- If pH is Acidemic and $PaCO_2$ is Normal OR Low :

* Then calculate the difference between measured and expected $PaCO_2$

- If pH is Acidemic and $PaCO_2$ is High:

* Then determine the change in pH & HCO_3 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 $PaCO_2$

  * If pH is Alkalemic and $PaCO_2$ is Normal or High

  It indicates Primary Metabolic Alkalosis

  Then compare measured and expected $PaCO_2$ to identify any associated Respiratory disorder

How to read an ABG? (Contd)

- STEP – 3 (contd)

* If pH is Alkalemic and $PaCO_2$ is Low

It indicates Primary Respiratory Alkalosis

Then we determine the change in pH & HCO_3 to decide whether Acute or Chronic, and for any other superimposed problem

How to read an ABG? (Contd)

- STEP – 4 :

If Normal pH – Check $PaCO_2$, can be High or Low

* High $PaCO_2$ indicates a Mixed Respiratory Acidosis – Metabolic Alkalosis

* Low $PaCO_2$ 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 PCO$_2$ = 26 mm Hg
- PO$_2$ = 105 mm Hg HCO$_3$ = 22 m mol / L
- BE = - 2 SaO$_2$ = 99%
- Na$^+$ = 138 m mol / L K$^+$ = 3.8 m mol / L
- Cl$^-$ = 104 m mol / L Anion Gap = 12

Examples

- pH = 7.3 PCO_2 = 60 mm Hg
- PO_2 = 60 mm Hg HCO_3 = 26 m mol / L
- BE = + 3 SaO_2 = 89 %
- Na^+ = 140 m mol / L K^+ = 4 m mol / L
- Cl^- = 100 m mol / L

Examples

- pH = 7.44
- PO_2 = 100 mm Hg
- BE = - 5
- Na^+ = 137 m mol / L
- Cl^- = 108 m mol / L

PCO_2 = 29 mm Hg

HCO_3 = 19 m mol / L

SaO_2 = 98 %

K^+ = 3.7 m mol / L

Examples

- pH = 7.35 PCO_2 = 70 mm Hg
- PO_2 = 62 mm Hg HCO_3 = 32 m mol / L
- BE = + 8 SaO_2 = 90 %
- Na^+ = 136 m mol / L K^+ = 3.5 m mol / L
- Cl^- = 96 m mol / L

Examples

- pH = 7.30
- PO_2 = 80 mm Hg
- BE = - 14
- Na^+ = 139 m mol / L
- Cl^- = 100 m mol / L

PCO_2 = 30 mm Hg

HCO_3 = 10 mmol / L

SaO_2 = 95 %

K^+ = 4.1 m mol / L

Anion Gap = 29

- Expected $PaCO_2$:
- $(HCO_3) \times 1.5 + 8\ (\pm 2) = 10 \times 1.5 + 8\ (\pm 2)$
- = 21 – 25 mm Hg

Examples

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

- Expected PaCO$_2$:
- (HCO$_3$) $\times$ 0.7 + 21 ($\pm$2) = 40 $\times$ 0.7 + 21 ($\pm$2)
- = 47 – 51 mm Hg

MIXED ACID BASE DISORDERS

- MIXED METABOLIC ACIDOSIS AND METABOLIC ALKALOSIS:
- Essential clue to mixed disorders is the Anion gap-- HCO_3 Relationship

  Δ AG/ Δ HCO_3 ---- Called gap-gap
- AG excess/ HCO_3 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 ---$\Delta AG/\Delta HCO_3 \geq 1.5$
- i.e. Change in AG excess is greater than change in HCO_3 deficit

- <u>TRIPLE DISORDERS:</u>
- 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
- PCO_2 : 28 mm Hg
- PO_2 : 60 mm Hg
- HCO_3 : 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
• PCO_2	:	15 mm Hg
• PO_2	:	244 mm Hg
• HCO_3	:	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..