Arterial Blood Gas Interpretation

OBJECTIVES

- ABG Sampling
- Interpretation of ABG
  - Oxygenation status
  - Acid Base status
- Case Scenarios

ABG – Procedure and Precautions

- Site- (Ideally) Radial Artery
  Brachial Artery
  Femoral Artery

- Ideally - Pre-heparinised ABG syringes
  - Syringe should be **FLUSHED** with 0.5ml of 1:1000 Heparin solution and emptied.

DO NOT LEAVE EXCESSIVE HEPARIN IN THE SYRINGE

↑ HEPARIN ⟹ ↑ DILUTIONAL EFFECT ⟹ ↓ HCO_3, ↓ PCO_2

- ✓ Only small 0.5ml Heparin for flushing and discard it
- ✓ Syringes must have > 50% blood. Use only 2ml or less syringe.

- Ensure No Air Bubbles. Syringe must be sealed immediately after withdrawing sample.
  - **Contact with AIR BUBBLES**

Air bubble = PO_2 150 mm Hg , PCO_2 0 mm Hg

Air Bubble + Blood = ↑ PO_2 ↓ PCO_2

- ABG Syringe must be transported at the earliest to the laboratory for **EARLY** analysis via **COLD CHAIN**

CHANGE IN VALUES EVERY 10 MINUTES	UNICED SAMPLE 37°C	ICED SAMPLE 4°C
pH	0.01	0.001
PCO_2	1 mm Hg	0.1 mm Hg
PO_2	0.1 %	0.01 %

- Patients **Body Temperature** affects the values of PCO_2 and HCO_3.
  - ABG Analyser is controlled for Normal Body temperatures
  - Any change in body temp at the time of sampling leads to alteration in values detected by the electrodes

- ↑ Cell count ↓ in PO_2

- ABG Sample should always be sent with relevant information regarding O_2, FiO_2 status and Temp .

ABG ELECTRODES

A. pH (Sanz Electrode)

- Measures H+ ion concentration of sample against a known pH in a reference electrode, hence potential difference. Calibration with solutions of known pH (6.384 to 7.384)

B. P CO_2 (Severinghaus Electrode)

- CO_2 reacts with solution to produce H+

  higher $C0_2$-→ more H+ → higher P CO_2 measured

C. P 0_2 (Clark Electrode)

- 0_2 diffuses across membrane producing an electrical current measured as P 0_2.

Interpretation of ABG

- OXYGENATION
- ACID BASE

OXYGENATION

➢ Determination of PaO_2

PaO_2 is dependant upon ⟹ Age, FiO_2, P_{atm}

As **Age** ⬆ the expected **PaO_2** ⬇

- $PaO_2 = 109 - 0.4 (Age)$

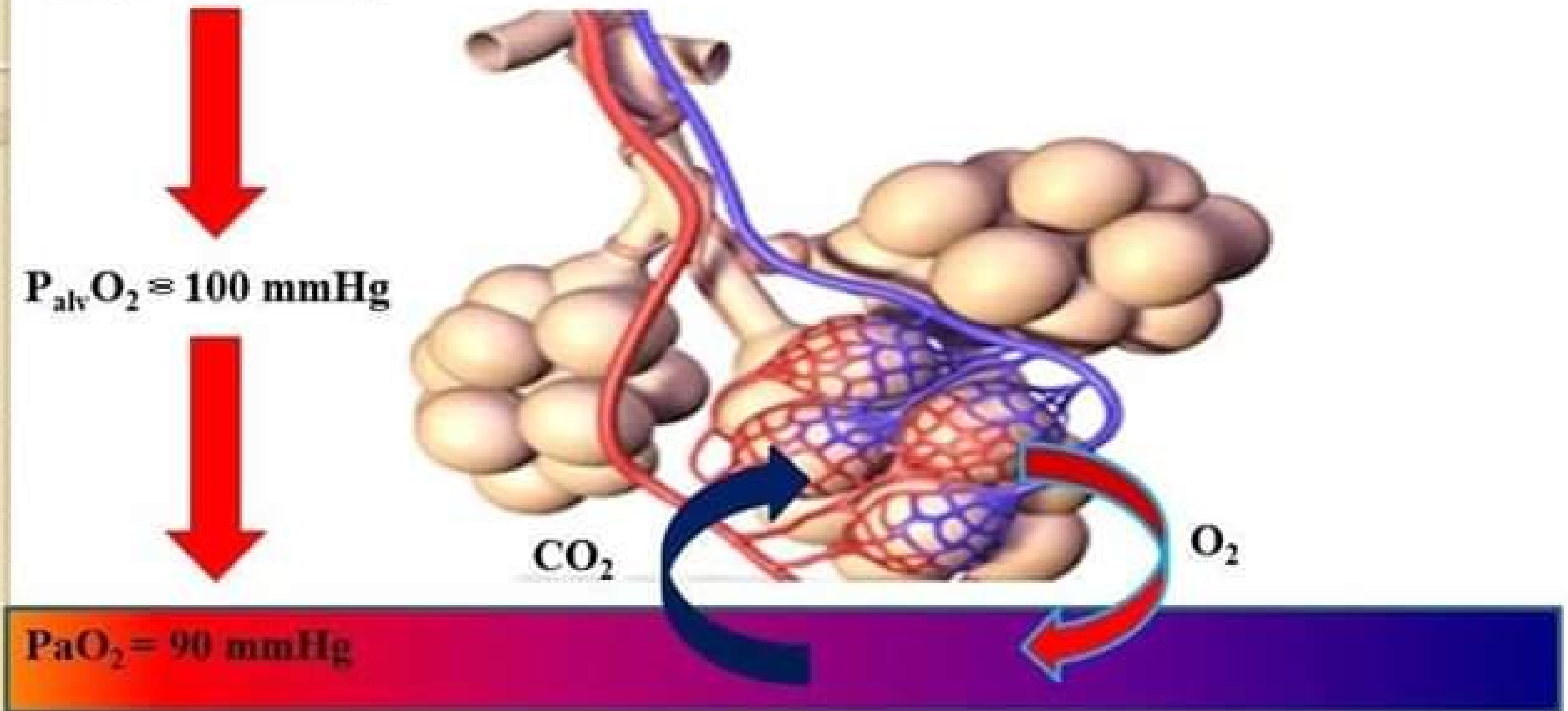
As **FiO_2** ⬆ the expected **PaO_2** ⬆

- Alveolar Gas Equation:
  - $P_AO_2 = (P_B - P_{h2o}) \times FiO_2 - pCO_2/R$

P_AO_2 = partial pressure of oxygen in alveolar gas, **P_B** = barometric pressure (760mmHg), **P_{h2o}** = water vapor pressure (47 mm Hg), **FiO_2** = fraction of inspired oxygen, **PCO_2** = partial pressure of CO_2 in the ABG, **R** = respiratory quotient (0.8)

Determination of the PaO2 / FiO2 ratio

Inspired Air $FiO_2 = 21\%$
$PiO_2 = 150$ mmHg



PiO_2 / FiO_2 Ratio	Inference
476	Normal
< 300	Acute Lung Injury
< 200	ARDS (along with other criteria)

PO_2/ FiO_2 ratio (P:F Ratio)

- Gives understanding that the patients OXYGENATION with respect to OXYGEN delivered is more important than simply the PO_2 value.

Example,

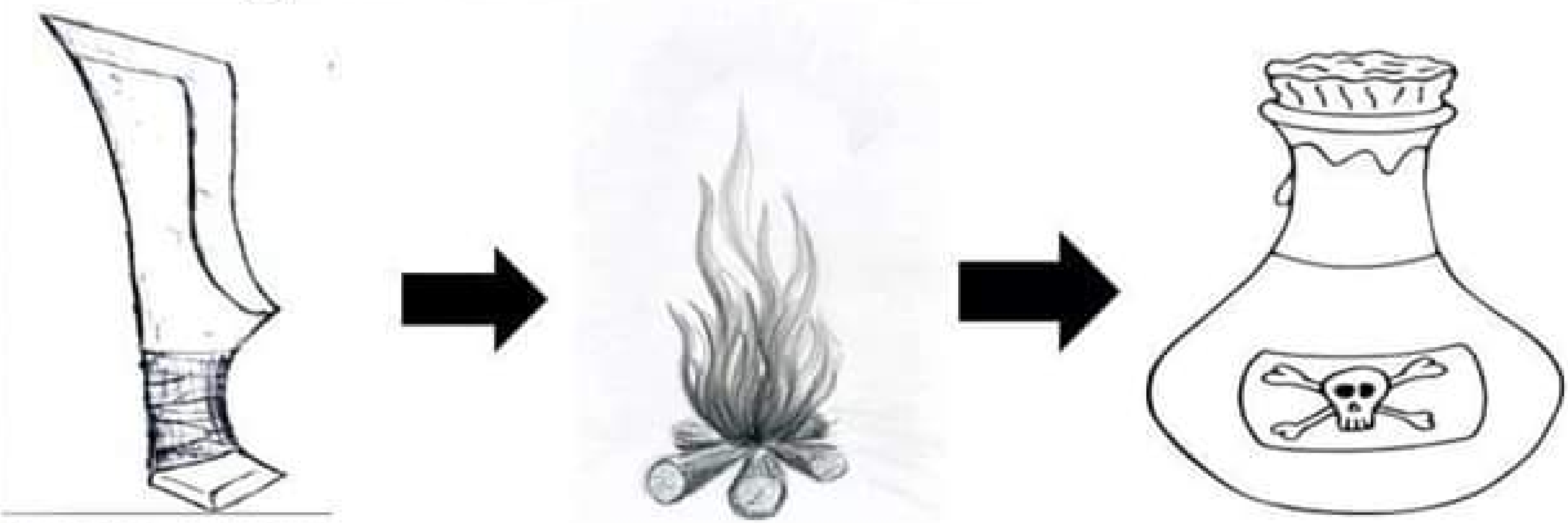
	Patient 1 On Room Air	Patient 2 On MV
PO2	60	90
FiO2	21% (0.21)	50% (0.50)
P:F Ratio	↑ 285	180 ↓

A
C
I
D

B
A
S
E

Acid Base Balance

- H^+ ion concentration in the body is precisely regulated
- The body understands the importance of H^+ and hence devised DEFENCES against any change in its concentration-



BICARBONATE BUFFER SYSTEM
Acts in few seconds

RESPIRATORY REGULATION
Acts in few minutes

RENAL REGULATION
Acts in hours to days

Regulation of Acid Base

- **Bicarbonate Buffer System**

$$CO_2 + H_2O \xleftrightarrow{carbonic\,anhydrase} H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

In Acidosis - Acid = H^+

$$\uparrow H^+ + HCO_3 \longrightarrow H_2CO_3 \longrightarrow CO_2 + H_2O$$

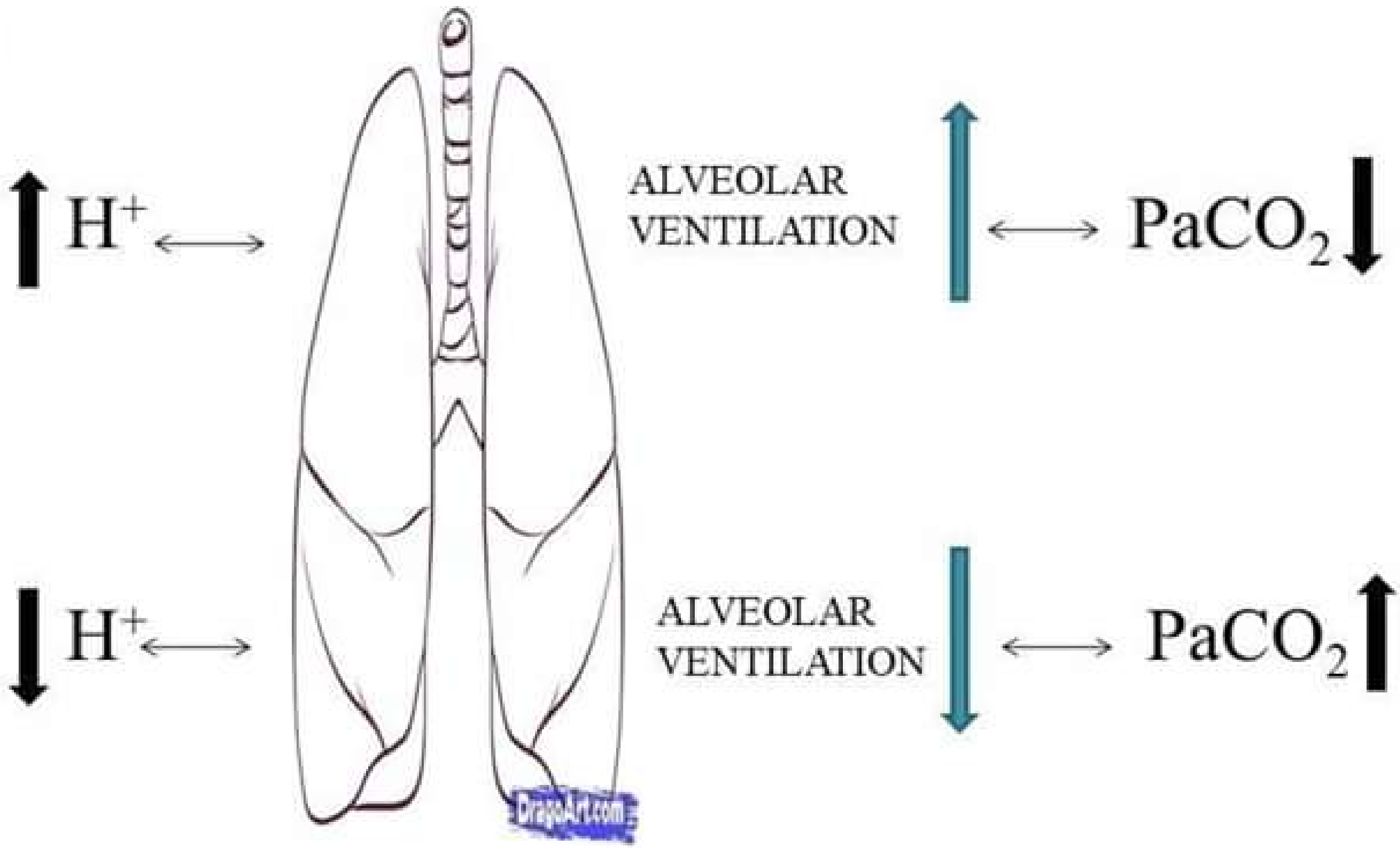
In Alkalosis - Alkali + Weak Acid = H_2CO_3

$$CO_2 + H_20 \longrightarrow H_2CO_3 \longrightarrow \uparrow HCO_3^- + H^+$$

+

ALKALI

Respiratory Regulation of Acid Base Balance-

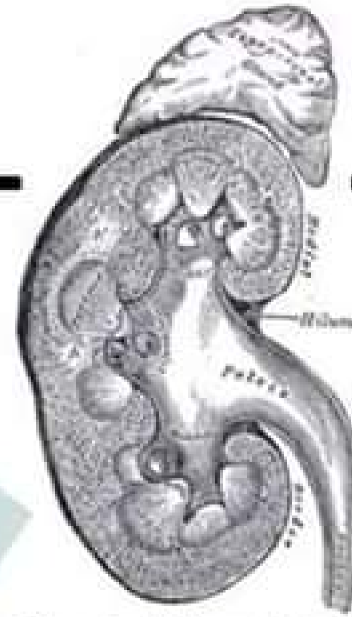


➢ **Renal Regulation** of Acid Base Balance

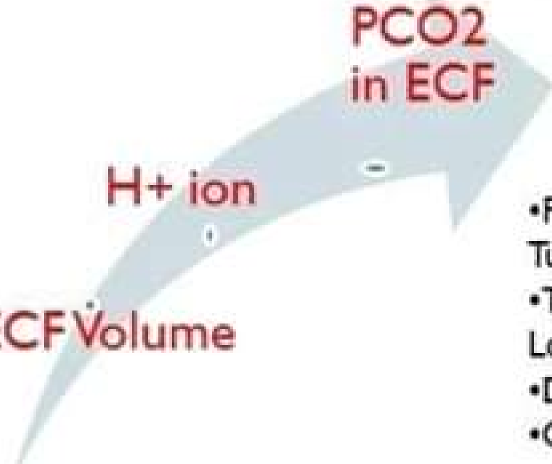
Kidneys control the acid-base balance by excreting either an acidic or a basic urine,

This is achieved in the following ways-

Reabsorption of HCO_3 in blood ⟵

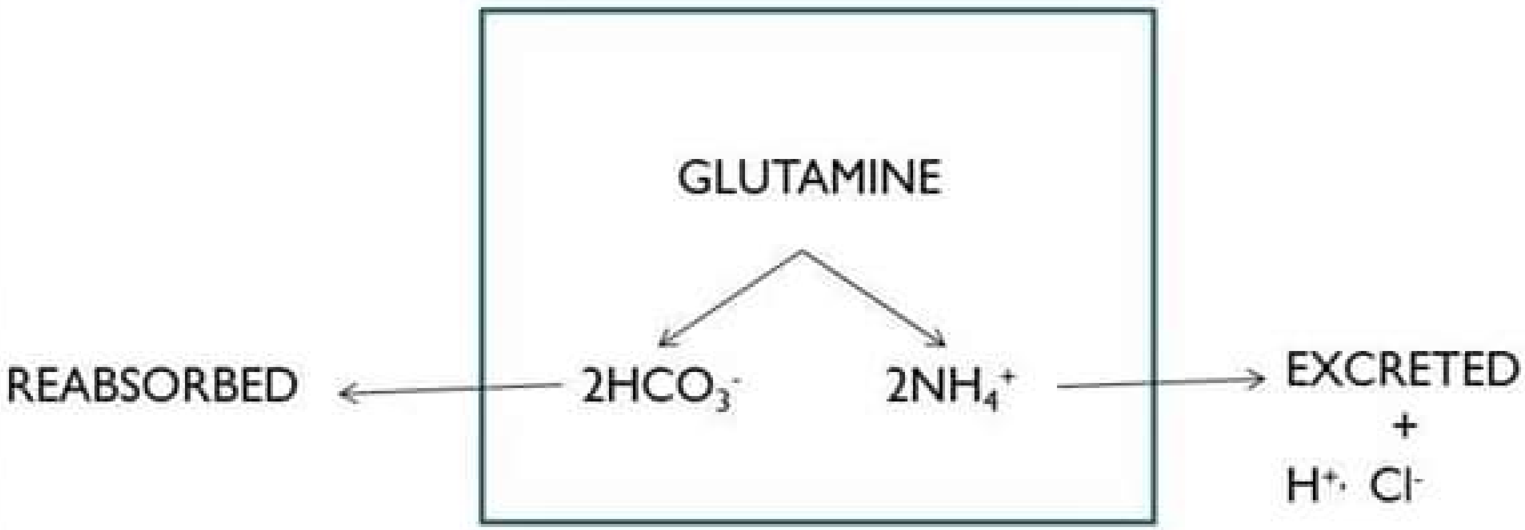


⟶ Secretion of H^+ ions in tubules and excretion



- Proximal Convulated Tubules (85%)
- Thick Ascending Limb of Loop of Henle (10%)
- Distal Convulated Tubule
- Collecting Tubules(5%)

- Another mechanism by which the kidney controls the acid base balance is by the **Combination of excess H+ ions in urine with AMMONIA and other buffers- A mechanism for generating NEW Bicarbonate ions**



- In **CKD,** the **dominant mechanism** by which acid is eliminated by the Kidneys is **excretion of NH4+**

Assessment of ACID BASE Balance

- Definitions and Terminology

- **ACIDOSIS** – presence of a process which tends to ↓ pH by virtue of gain of H^+ or loss of HCO_3^-
- **ALKALOSIS** – presence of a process which tends to ↑ pH by virtue of loss of H^+ or gain of HCO_3^-

If these changes, change pH, suffix 'emia' is added

- **ACIDEMIA** – reduction in arterial pH (pH<7.35)
- **ALKALEMIA** – increase in arterial pH (pH>7.45)

- **Simple Acid Base Disorder/ Primary Acid Base disorder** – a single primary process of acidosis or alkalosis due to an initial change in PCO_2 and HCO_3.

- **Compensation** - The normal response of the respiratory system or kidneys to change in pH induced by a primary acid-base disorder

✓ The Compensatory responses to a primary Acid Base disturbance are never enough to correct the change in pH , they only act to reduce the severity.

- **Mixed Acid Base Disorder** – Presence of more than one acid base disorder simultaneously .

Characteristics of Primary ACID BASE Disorders

PRIMARY DISORDER	PRIMARY RESPONSES			COMPENSATORY RESPONSES
	H+ ion Conc.	pH	Primary Defect	
Metabolic Acidosis	↑ H^+	↓ pH	↓ HCO_3	↓ PCO_2 Alveolar Hyperventilation

Compensation

Metabolic Disorders – Compensation in these disorders leads to a change in PCO_2

METABOLIC ACIDOSIS

- **$PCO_2 = (1.5 \times [HCO_3^-]) + 8 \pm 2$**
- $PCO_2 = [HCO_3-] + 15$
- For every 1mmol/l ↓in HCO_3 the PCO_2 ↓falls by 1.25 mm Hg

METABOLIC ALKALOSIS

- **$PCO_2 = (0.7 \times [HCO_3^-]) + 21 \pm 2$**
- $PCO_2 = [HCO_3^-] + 15$
- For every 1mol/l ↑in HCO_3 the PCO_2 ↑ by 0.75 mm Hg

In **Respiratory Disorders**

↑↓ PCO2 ⟶ Kidney ⟶ ↑↓ HCO3 Reabsorption

Compensation begins to appear in 6 – 12 hrs and is fully developed only after a few days.

1.ACUTE

Before the onset of compensation

Resp. acidosis – **1mmHg ↑ in PCO2 ⟶ HCO3 ↑ by 0.1meq/l**

Resp. alkalosis – **1mmHg ↓ in PCO2 ⟶ HCO3 ↓ by 0.2 meq/l**

2.CHRONIC (>24 hrs)

After compensation is fully developed

Resp. acidosis – **1mmHg ↑ in PCO2 ⟶ HCO3 ↑ by 0.4meq/l**

Resp. alkalosis – **1mmHg ↓ in PCO2 ⟶ HCO3 ↓ by 0.4meq/l**

Respiratory Disorders – Compensation in these disorders leads to a change in HCO_3.

RESPIRATORY ACIDOSIS

- **ACUTE** $pH = 7.40 - 0.008(PCO_2 - 40)$
- **CHRONIC** $pH = 7.40 - 0.003(PCO_2 - 40)$

RESPIRATORY ALKALOSIS

- **ACUTE** $pH = 7.40 + 0.008(40 - PCO_2)$
- **CHRONIC** $pH = 7.40 + 0.003(40 - PCO_2)$

STEP WISE APPROACH
to
Interpretation Of
ABG reports

Six steps logical approach originally proposed by Narins and Emmett (1980) and modified by Morganroth in 1991

Normal Values

ANALYTE	Normal Value	Units
pH	7.35 - 7.45	
PCO2	35 - 45	mm Hg
PO2	72 – 104	mm Hg`
[HCO3]	22 – 30	meq/L
SaO2	95-100	%
Anion Gap	12 $\pm$ 4	meq/L
ΔHCO3	+2 to -2	meq/L

STEP 0	• Is this ABG Authentic?
STEP 1	• ACIDEMIA or ALKALEMIA?
STEP 2	• RESPIRATORY or METABOLIC?
STEP 3	• If Respiratory – ACUTE or CHRONIC?
STEP 4	• Is COMPENSATION adequate?
STEP 5	• If METABOLIC – ANION GAP?
STEP 6	• If High gap Metabolic Acidosis– GAP GAP?

Is this ABG authentic ?

- $pH = -\log [H^+]$

Henderson-Hasselbalch equation

$$pH = 6.1 + \log \frac{HCO_3^-}{0.03 \times PCO_2}$$

The [HCO3-] mentioned on the ABG is actually calculated using this equation from measured values of PCO_2 nd pH

- $[H+]$ **neq/l** $= 24 \times (PCO_2 / HCO_3)$

- $pH = -\log [H^+]$

$pH_{expected} = pH_{measured}$ = ABG is **authentic**

ABG ELECTRODES

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STEP 1 **ACIDEMIA OR ALKALEMIA?**

- Look at pH

  <7.35 - acidemia

  >7.45 – alkalemia

- RULE – An acid base abnormality is present even if either the pH or PCO2 are Normal.

STEP 2 **RESPIRATORY or METABOLIC?**

IS PRIMARY DISTURBANCE RESPIRATORY OR METABOLIC?

- pH ⬆ PCO_2 ⬆ or pH ⬇ PCO_2 ⬇ ⟹ METABOLIC
- pH ⬆ PCO_2 ⬇ or pH ⬇ PCO_2 ⬆ ⟹ RESPIRATORY

❖ RULE- If either the pH or PCO_2 is Normal, there is a mixed metabolic and respiratory acid base disorder.

STEP 3 RESPIRATORY- **ACUTE/CHRONIC?**

IF RESPIRATORY, IS IT ACUTE OR CHRONIC?

- Acute respiratory disorder - $\Delta \mathbf{pH_{(e\text{-}acute)}} = \mathbf{0.008x}\ \Delta \mathbf{Pco_2}$
- Chronic respiratory disorder - $\Delta \mathbf{pH_{(e\text{-}chronic)}} = \mathbf{0.003x}\ \Delta \mathbf{pCO_2}$

- Compare, $pH_{measured}$ (pH_m) v/s $pH_{expected}$ (pH_e)

$\mathbf{pH_{(m)} = pH_{(e\text{-}acute)}}$	$\mathbf{pH_{(m)}}$ = between $\mathbf{pH_{(e\text{-}acute)}}$ & $\mathbf{pH_{(e\text{-}chronic)}}$	$\mathbf{pH_{(m)} = pH_{(e\text{-}chronic)}}$
ACUTE RESPIRATORY DISORDER	PARTIALLY COMPENSATED	CHRONIC RESPIRATORY DISORDER

STEP 4 **ADEQUATE COMPENSATION?**

IS THE COMPENSATORY RESPONSE ADEQUATE OR NOT?

- METABOLIC DISORDER ⟶ $\mathbf{PCO_{2expected}}$

$\mathbf{PCO_2 measured \neq PCO_2 expected}$ ⟶ MIXED DISORDER

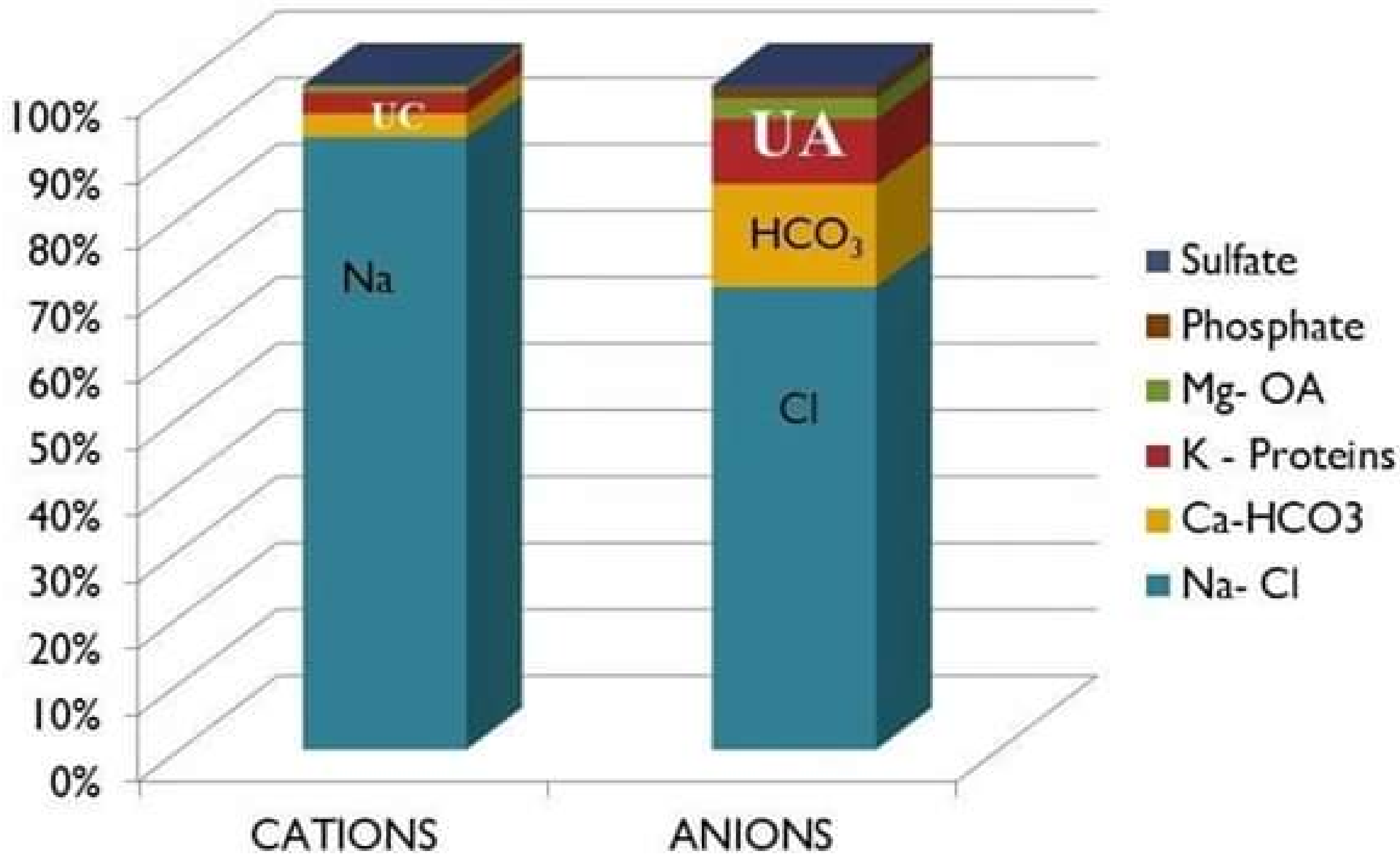
- RESPIRATORY DISORDER ⟶ $\mathbf{pH_{expected\ acute\text{-}chronic}}$

$\mathbf{pH_m \neq pH_e}$ **range** ⟶ MIXED DISORDER

STEP 5

- If METABOLIC – ANION GAP?

Electrochemical Balance in Blood



Anion Gap

AG based on principle of electroneutrality:

- Total Serum Cations = Total Serum Anions
- M cations + U cations = M anions + U anions
- Na + (K + Ca + Mg) = HCO_3 + Cl + (PO4 + SO4 + Protein + Organic Acids)
- Na + ***UC*** = HCO_3 + Cl + ***UA***
- But in Blood there is a relative abundance of Anions, hence

  Anions > Cations
- Na – (HCO_3 + Cl) = ***UA – UC***
- Na – (HCO_3 + Cl) = ***Anion Gap***

STEP 5 — METABOLIC ACIDOSIS- **ANION GAP?**

IN METABOLIC ACIDOSIS WHAT IS THE ANION GAP?

- **ANION GAP(AG) = Na – (HCO_3 + Cl)**

Normal Value = 12 $\pm$ 4 (7- 16 Meq/l)

Adjusted Anion Gap = Observed AG +2.5(4.5- S.Albumin)

50% ↓ in S. Albumin ⟹ 75% ↓ in Anion Gap !!!

Metabolic Acidosis → High Anion Gap Metabolic Acidosis

Metabolic Acidosis → Normal Anion Gap Acidosis

High Anion Gap Metabolic Acidosis

M	METHANOL
U	UREMIA - ARF/CRF
D	DIABETIC KETOACIDOSIS & other KETOSIS
P	PARALDEHYDE, PROPYLENE GLYCOL
I	ISONIAZIDE, IRON
L	LACTIC ACIDOSIS
E	ETHANOL, ETHYLENE GLYCOL
S	SALICYLATE

STEP 6 CO EXISTANT METABOLIC DISORDER – "**Gap Gap**"?

C/O HGAG METABOLIC ACIDOSIS,ANOTHER DISORDER?

- Δ **Anion Gap =** Measured AG – Normal AG

  Measured AG – 12

- Δ **HCO_3 =** Normal HCO_3 – Measured HCO_3

  24 – Measured HCO_3

Ideally, ΔAnion Gap = ΔHCO_3

For each 1 meq/L increase in AG, HCO3 will fall by 1 meq/L

$\Delta AG/\Delta HCO_3^- = 1$ → Pure High AG Met Acidosis

$\Delta AG/\Delta HCO_3^- > 1$ → Assoc Metabolic Alkalosis

$\Delta AG/\Delta HCO_3^- < 1$ → Assoc N AG Met Acidosis

Clinical CASE SCENARIOS

CASE 1

Mr. Shamshuddin, 62/M,

Nagina

- k/c/o COPD
- Breathlessness, progressively increased, aggravated on exertion, 2 days
- Chronic smoker
- O/E

  RS- B/L expiratory rhonchi

22/7/11	7:30 am
pH	7.20
PCO2	92 mmHg
PO2	76 mmHg
Actual HCO3	21.00 mmol/l
SO2	89
FiO2	37%

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pH	7.20
PCO2	92 mmHg
PO2	76 mmHg
Actual HCO3	21.00 mmol/l
SO2	89
FiO2	37%

- STEP 1 – ACIDEMIA
- STEP 2 – pH ⬇ PCO_2 ⬆

  Respiratory
- STEP 3 – pH expected
  - pH acute = 7.40 – 0.008(92-40)

    7.40 – 0.008(52)

    6.984
  - pH chronic = 7.40 – 0.003(92-40)

    7.244
  - pH b/w 6.98 to 7.244
- Primary Respiratory Acidosis, partially compensated

CASE 2

Mr.Dharam Dutt, 63/M,

Bijnor

- k/c/o CRF(conservativeRx)
- Breathlessness
- Decreased Urine Otpt. 2days
- Vomiting 10-15
- O/E

  No pedal edema, dehydration+

  RS – B/L A/E Normal

31/7/11	11:30pm
pH	7.18
PCO2	21.00
PO2	90
Actual HCO3	7.80
Base Excess	-18.80
SO2	95
Na	140.6
Chloride	102
T.Protein	6
Albumin	2.4

31/7/11	11:30pm
pH	7.18
PCO2	21.00
PO2	90
Actual HCO3	7.80
Base Excess	-18.80
SO2	95
Na	140.6
Chloride	102
T.Protein	6
Albumin	2.4

- STEP 1 – ACIDEMIA
- STEP 2 – pH ↓ PCO2 ↓

  METABOLIC
- STEP 4 – PCO2expected

  PCO2exp = (1.5 x HCO3)+8$\pm$2

  (1.5X7.80)+8$\pm$2

  19.7$\pm$2= 17.7 – 21.7
- STEP5 – ANION GAP

  = Na – (HCO3 +Cl)

  = 140.6-(7.80+102)

  = 30.8

✓ AG corrected for albumin = 30.8+5.25

AG = 36.05

HIGH AG Met. Acidosis

31/7/11	11:30pm
pH	7.18
PCO2	21.00
PO2	90
Actual HCO3	7.80
Base Excess	-18.80
SO2	95
Na	140.6
Chloride	102
T.Protein	6
Albumin	2.4

- STEP 6 – GAP GAP

= (AG-12)/(24-HCO3)
= 36.05-12/24-7.80

= 24.05/16.2

= 1.48

Gap/gap > 1 = add. Metabolic alkalosis

Δsis – Primary Metabolic Acidosis

High Anion Gap, compensated

Cause- CRF

- Metabolic Alkalosis

Cause - ? Vomiting