CASE BASED DISCUSSION ON ACID BASE BALANCE

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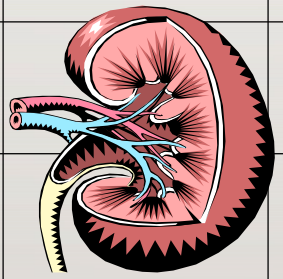
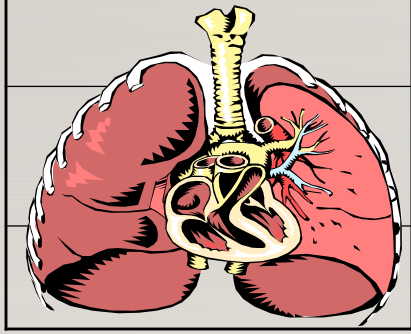
After a pulse is found, a blood sample is taken from the artery

INTRODUCTION

- Aim of acid-base balance is to maintain the normal **pH** (7.35 to 7.45) of the arterial blood.
- Pathologic changes in **PCO_2** or **HCO_3** that typically produce abnormal arterial pH .
- Accurate interpretation of acid-base disorders is critical for understanding pathophysiology, making a diagnosis, planning effective treatment and monitoring progress.

ACID-BASE DISORDERS(ABD)

			Primary Change	Compensatory response
Metabolic	Acidosis		$\downarrow HCO_3$	$\downarrow PCO_2$
	Alkalosis		$\uparrow HCO_3$	$\uparrow PCO_2$
Respiratory	Acidosis	Acute	$\uparrow PCO_2$	$\uparrow HCO_3$
		Chronic	$\uparrow PCO_2$	$\uparrow HCO_3$
	Alkalosis	Acute	$\downarrow PCO_2$	$\downarrow HCO_3$
		Chronic	$\downarrow PCO_2$	$\downarrow HCO_3$

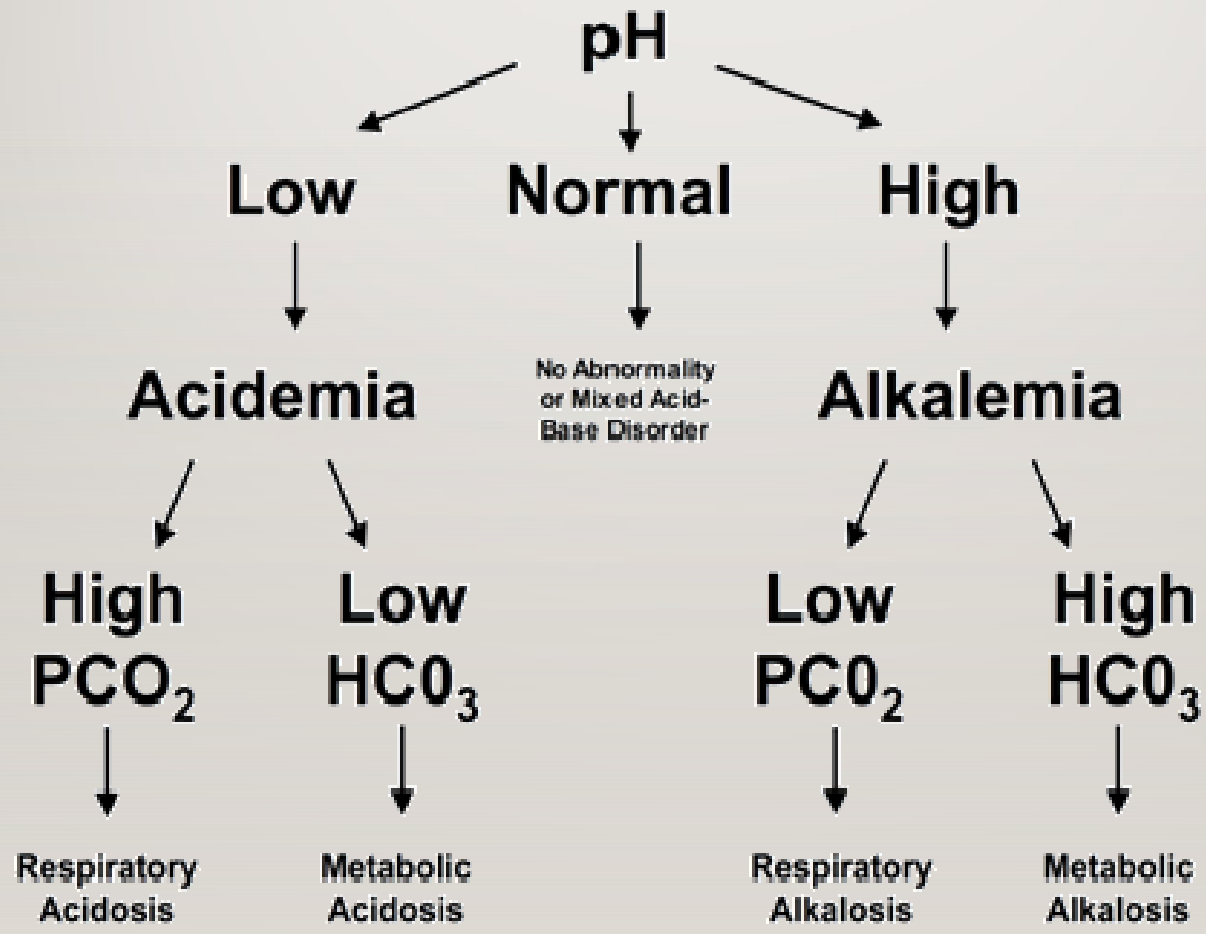
NORMAL VALUES

- pH : 7.35 – 7.45
- PCO_2 : 35 – 45 mm Hg
- HCO_3 : 22 -26 m Eq /L
- BE : -2 to +2 m Eq /L
- PO_2 : 80 - 100 mm Hg
- SaO_2 : 92 -100 %
- AG : 8 – 16 m Eq /L

DIAGNOSTIC APPROACH TO ACID BASE DISORDERS

- Clinical evaluation
- ABG analysis , serum electrolyte
- pH
- Respiratory or metabolic
- Compensated or uncompensated
- Anion gap (AG)
- Delta ratio
- Osmolar gap

Figure 1: Identifying the Primary Process



SCALES OF COMPENSATION

ABD	Expected PCO_2 / HCO_3 (after compensation)
Metabolic acidosis	PCO_2 =[40-(24 - HCO_3) X1.2] ± 2 mmHg
Metabolic alkalosis	PCO_2 =[40 + (HCO_3 -24) X .7] ± 2 mmHg
Acute respiratory acidosis	HCO_3 = 24 + (PCO_2 - 40) X .1 mmol/L
Chronic respiratory acidosis	HCO_3 = 24 + (PCO_2 - 40) X .4 mmol/L
Acute respiratory alkalosis	HCO_3 = 24 - (40 - PCO_2) X .2 mmol/L
Chronic respiratory alkalosis	HCO_3 = 24 - (40 - PCO_2) X .5 mmol/L

ANION GAP

- **Plasma anion gap** = (Na + K) – (Cl + HCO_3)
- **Normal anion gap** 8 – 16 mmol/L(<20)
- **High plasma anion gap** is a powerful clue to metabolic acidosis .
- Anion gap **within 20- 30 mmol/L** is mostly due to **metabolic acidosis** irrespective of pH and HCO_3 because HCO_3 can't be so low to make so high anion gap in respiratory alkalosis.

ANION GAP CONTD.

- Anion gap **more than 30 mmol/L** is almost certainly due to metabolic acidosis regardless of pH and HCO_3 status e.g. a. renal failure b. lactic acidosis c. keto acidosis d. intoxication (poisoning)
- ***Non AG metabolic acidosis*** happen in i.e. GI loss of HCO_3 or Renal tubular acidosis

DELTA RATIO

= Δ AG/Δ HCO_3

Tool	HAGMA (simple)	NAGMA	HAGMA+ NAGMA	HAGMA+ METABOLIC ALKALOSIS
Delta ratio	1.0	0	<1	>1 (>2 is significant)
Corrected **HCO_3**	normal	low	low	high

OSMOLAR GAP

- **Osmolar gap =** measured osmolarity – calculated osmolarity
- **Calculated plasma osmolarity =** 2 Na + Urea + Glucose
- **Normally osmolar gap** upto 12 mosm/L

Causes of high osmolar gap

- Alcohol poisoning
- Gross hyperproteinemia
- Gross hyperlipidemia
- Chronic renal failure
- Keto acidosis
- Lactic acidosis
- Mannitol infusion

IMPORTANT TIPS ON ABD

- **Serum HCO_3 <10 mmol/L** : Metabolic acidosis is the likely diagnosis .

  * Respiratory alkalosis is unlikely to cause so low HCO_3

- **Serum $HCO_3 \geq 40$ mmol/L** : Metabolic alkalosis is the likely diagnosis .

  * Respiratory acidosis is unlikely to cause so high HCO_3 .

IMPORTANT TIPS ON ABD

- **PCO_2 > 55mmHg** :Respiratory acidosis is the likely diagnosis .

*Metabolic alkalosis is unlikely to cause so high PCO_2 .

- If **HCO_3 and PCO_2 changes in same direction** : simple acid base disorder is likely
- If **HCO_3 and PCO_2 changes in opposite direction** or If one changes but other one normal : complex ABD is likely

CASE SCENARIO 1

- A 23-year-old healthy student admitted with disorientation after attending a birthday party . His vital signs were normal. Laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.2	Creatinine	1.0 mg/dl
HCO_3	18mmol/L	Urea	3.3 mmol/L
PCO_2	34 mmHg	Glucose	4.7 mmol/L
PO_2	95 mmHg	Lactic acid	1.5
Na	140 mmol/L	Urine Ketone body	negative
K	5.5 mmol/l	Plasma osmolarity	382 mosm/L
Cl	101 mmol/L		

CASE SCENARIO 1 CONTD.

- **pH is low** . So it is acidosis.
- **HCO_3 is low.** So it is metabolic acidosis as pH and HCO_3 are directly related.
- **PCO_2 is low.** Low PCO_2 cannot decrease pH. So **it isn't respiratory acidosis.**
- **Compensation :** Expected PCO_2 = [40-(24 - HCO_3) X1.2] ± 2 mmHg = [40-(24 - 18) X1.2] ± 2 mmHg = 32.8 ± 2 = **30.8 -34.8**

Patient's PCO_2 is in the range of expected PCO_2 . So it is compensated .

- **Plasma AG** = (Na +K) – (Cl + HCO_3) = (140 + 5.5) – (101 + 18) = 26.5 mmol/L (> 20 mmol/L)

So it is **high anion gap metabolic acidosis .**

CASE SCENARIO 1 CONTD.

- **Delta ratio** =Δ AG/Δ $\mathbf{HCO_3}$ = 6.5/6 = 1.08 (near to 1)
  So it is not complexed by other metabolic acid disorder

- **Calculated plasma osmolarity** = 2 Na + Urea + Glucose = 2 X 140 + 3.3 + 4.7 =288 mosm/L

- **Osmolar gap** = measured osmolarity – calculated osmolarity = 382 – 288 = 94 (it is high) . So may be intoxication .
- **Comment :** Compensated (simple) high anion gap metabolic acidosis .

CASE SCENARIO 2

- A young lady presented with severe abdominal pain and vomiting . Her laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.69	Creatinine	2.5 mg/dl
HCO_3	54 mmol/L	Serum lactate	2.2 mmol/L
PCO_2	45 mmHg	Urine pH	6.0
PO_2	90 mmHg	Urine Na	21 mmol/L
Na	148 mmol/L	Urine K	58 mmol/L
K	2.0 mmol/l	Urine Cl	5.0 mmol/L
Cl	80 mmol/L		

CASE SCENARIO 2 CONTD.

- **pH** is High . So it is **alkalosis.**
- **HCO_3** is high . **High HCO_3** can increase pH as pH and HCO_3 are directly related. So it is **metabolic alkalosis**
- **PCO_2** is high . High PCO_2 cannot increase pH because pH and PCO_2 are inversely related. So possibly it is not respiratory alkalosis.
- **Compensation** : Expected PCO_2 = [40 +(HCO_3 - 24) X 0.7] ± 2 mmHg = [40 + (54 - 24) X 0.7] ± 2 mmHg = 61 ± 2 = 59-63

Patient PCO_2 is < expected PCO_2 .

So, it is not compensated . And complexed by **respiratory alkalosis .**

CASE SCENARIO 2 CONTD.

- **Plasma AG** = (Na +K) – (Cl + HCO_3) = (148 + 2.0) – (80 + 54) = 16 mmol/L (<20 mmol/L)
- So AG is normal .
- **Urinary Cl** is 5 mmol/L (< 10 mmol/L) so it is saline responsive metabolic alkalosis
- **Comment :** Saline responsive **Metabolic alkalosis with respiratory alkalosis .**

CASE SCENARIO 3

- A 72- year- old diabetic woman with history of CCF and renal failure admitted for vomiting and shortness of breath. She took insulin and frusemide. Laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.4	Creatinine	4.0 mg/dl
HCO_3	23 mmol/L	Glucose	8.0 mmol/L
PCO_2	40 mmHg	Serum lactate	1.8 mmol/L
PO_2	90 mmHg	Urine ketone body	negative
Na	142 mmol/L		
K	4.0 mmol/l		
Cl	94 mmol/L		

CASE SCENARIO 3 CONTD.

- **pH** is normal . **HCO_3** is normal . **PCO_2** is normal . So no clue
- **Compensation** : No clue
- **Plasma AG** = (Na +K) – (Cl + HCO_3) =

(142 + 4.0) – (94 + 23) = 29 mmol/L (> 20 mmol/L)

So there is **high anion gap metabolic acidosis** .

- Delta ratio =**Δ** AG/**Δ** **HCO_3** = 9/1 . It is > 1 (infinity) So it is **complexed by hidden metabolic alkalosis.**

CASE SCENARIO 3 CONTD.

- **Comment :** High anion gap metabolic acidosis with metabolic alkalosis .
- **Metabolic acidosis** is due to renal failure

  (creatinine 4 mg/dl)
- **Metabolic alkalosis** is due to vomiting and frusemide

CASE SCENARIO 4

- A 68- year- old man with COPD attended hospital with breathlessness at rest . Chest examination revealed respiratory rate 28/min, breath sound-vesicular with prolonged expiration and rhonchi. Her laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.3	Creatinine	1.0 mg/dl
HCO_3	30 mmol/L	Glucose	6.5 mmol/L
PCO_2	54 mmHg	Serum lactate	1.2 mmol/L
PO_2	40 mmHg	Urine ketone body	nil
Na	144 mmol/L	$\boldsymbol{SaO_2}$	78%
K	4.0 mmol/l		
Cl	102 mmol/L		

CASE SCENARIO 4 CONTD.

- **pH is** Low . So it is **acidosis.**
- **HCO_3** is High. **High HCO_3** can't **decrease pH** as pH and HCO_3 are directly related. So it is **not metabolic acidosis**
- **PCO_2** is High. **High PCO_2** can **decrease pH** because pH and PCO_2 are inversely related. So it is **respiratory acidosis.**
- **Compensation :** Expected HCO_3 = 24 + (PCO_2 - 40) X 0.4 mmol/L = 24 + (54 - 40) X 0.4 = **29.6 mmol/L**

Patient HCO_3 = expected HCO_3 .

So it is compensated .

CASE SCENARIO 4 CONTD.

- **Plasma AG** = (Na +K) – (Cl + HCO_3) = (144 + 4.0) – (102 + 30) = 16 mmol/L (< 20 mmol/L)

So, it is normal anion gap .

- **Comment :** Compensated respiratory acidosis with Chronic type II respiratory failure

CASE SCENARIO 5

A 45 –year-old woman presented with sudden onset of breathlessness and chest pain. She had a H/O major surgery few days back. Respiratory rate 32breaths /mim, pulse rate 114/min and blood pressure 100/70 mmof Hg. Laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.5	Creatinine	1.0 mg/dl
HCO_3	19mmol/L	Glucose	5 .0 mmol/L
PCO_2	30 mmHg	lactate	1.0mmol/L
PO_2	68 mmHg	Ionic calcium	1.2 mmol/L
Na	135 mmol/L	SaO2	80%
K	4.0 mmol/l		
Cl	101 mmol/L		

CASE SCENARIO 5 CONTD.

- **pH** is High . So it is alkalosis.
- **HCO_3** is low. **Low HCO_3** can't increase pH because pH and HCO_3 are directly related. So it may **not be metabolic alkalosis**
- **PCO_2** is low. **Low PCO_2** can increase pH because pH and PCO_2 are inversely related. So it is **respiratory alkalosis**.
- **Compensation** : Expected HCO_3 = 24 - (40 - PCO_2) X .5

  mmol/L = 24 – (40 – 30) X .5 =**19 mmol/L**

Patient HCO_3 = expected HCO_3

So it is compensated

CASE SCENARIO 5 CONTD.

- **Plasma AG** = (Na +K) – (Cl + HCO_3) = (135 + 4.0) – (101 + 19) = 19 mmol/L (> 20 mmol/L)

So there is **normal anion gap**

- **Comment :** Compensated respiratory alkalosis with Type I respiratory failure.

CASE SCENARIO 6

- A 52- year- old diabetic patient presented with vomiting and abdominal pain for last 4 days . Laboratory report shows :

Analyte	Result	Analyte	Result
pH	7.47	Creatinine	3.5 mg/dl
HCO_3	18 mmol/L	Glucose	40 mmol/L
PCO_2	23 mmHg	Urine pH	5.0
PO_2	95 mmHg	Urine ketone body	positive
Na	120 mmol/L		
K	4.0 mmol/l		
Cl	60 mmol/L		

CASE SCENARIO 6 CONTD.

- **pH** is High . So it is alkalosis.
- **HCO_3** is low. **Low HCO_3** can't increase pH as pH and HCO_3 are directly related. So it may **not be metabolic alkalosis**
- **PCO_2** is low . **Low PCO_2** can increase pH because pH and PCO_2 are inversely related. So it is **respiratory alkalosis**.
- **Compensation** : Expected HCO_3 = 24 - (40 - PCO_2) X .5

  mmol/L = 24 – (40 – 23) X .5 =**15.5 mmol/L**

Patient HCO_3 > expected HCO_3

So not compensated . And complexed by metabolic alkalosis

CASE SCENARIO 6 CONTD.

- **Plasma AG** = (Na +K) – (Cl + HCO_3) = (120 + 4.0) – (60 + 18) = 46 mmol/L (> 20 mmol/L)

So there is **high anion gap metabolic acidosis**

- **Delta ratio** =**Δ** AG/**Δ** **HCO_3** = 26/7 . It is > 2. So it is **complexed by metabolic alkalosis.**
- **Comment :** High anion gap metabolic acidosis with respiratory alkalosis with metabolic alkalosis.

MANAGEMENT OF ACIDOSIS

Metabolic acidosis :

1. Identify & correct the underlying cause. *Controlling diarrhea, Treating DM, Correction of shock , Removal of toxin, Hemodialysis in case of renal failure .*
2. Use of IV bicarbonate is controversial & only reserved for severe acidaemia where the patient deteriorating rapidly .

HCO3 deficit = 0.6 X wt(kg) X (15 – measured HCO3)

MANAGEMENT OF ACIDOSIS

RESPIRATORY ACIDOSIS

Management of underlying cause or diseases according to severity & rate of onset.

Assisted Ventilation :

Non invasive *: Bi-PAP or CPAP*

Invasive Mechanical Ventilation.

ALKALOSIS : MANAGEMENT

Metabolic Alkalosis :

1. Correction of the underlying stimulus for HCO_3 generation: *Primary aldosteronism, renal artery stenosis, Cushing syndrome*.
2. Diuretics Discontinuation.
3. Isotonic saline infusion if ECV contraction.
4. Acetazolamide.
5. Dilute hydrochloric acid.
6. Hemodialysis : against a dialysate low in [HCO_3^-] and high in [Cl^-] when renal function impaired.

ALKALOSIS : MANAGEMENT

Respiratory Alkalosis :

Alleviation of the underlying disorder :

Reduction of anxiety, pain

Rebreathing in a closed bag:

Allow CO2 levels to rise.

CONCLUSION

Solving the puzzle of acid–base disorders requires two tasks.

- First, acid-base variables in the blood must be reliably measured to determine the effect of multiple ions and buffers.
- Second, the data must be interpreted in relation to disease to define the patient's acid–base status.

THANK YOU