Acid Base Disorders

a practical approach
a four step approach

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Acid Base Problem?

Example A	Example B
7.39 / 39	7.40 / 40
140 | 105 / 23	145 | 100 / 24
No	Yes But why?

Definitions

- Syntax
  - Acid<u>osis</u> vs acid<u>emia</u>
  - Alkal<u>osis</u> vs alkal<u>emia</u>
- normal ranges

– pH	7.40
– $PaCO_2$	40
– HCO_3^-	24

ABG 101

- Standard nomenclature
  - pH / $PaCO_2$ / PaO_2
- Measured
  - pH / $PaCO_2$ / PaO_2
- Calculated
  - HCO^-_3 / Base Excess / O_2 Sat

Relationship H^+ / HCO^-_3 / CO_2

- Henderson-Hasselbalch Eq
- Simplified formula:

$$[H^+] = \frac{24\ [PaCO_2]}{[HCO^-_3]}$$

$[H^+]$ and pH Relationship

$[H^+]$	pH
32	7.50
40	7.**40**
62	7.20
1**00**	7.**00**

Step Zero

- Henderson-Hasselbalch Eq
- Simplified formula:

$$[H^+] = \frac{24\ [PaCO_2]}{[HCO^-_3]}$$

- **Implications:**
  - **If CO_2 ↑ then H^+ ↑ and pH ↓**
  - **If HCO_3 ↑ then H^+ ↓ and pH ↑**

Steps One & Two

- Identify all abnormalities

  pH, $PaCO_2$ and HCO^-_3

1. Look at the pH
   - acidemia vs alkalemia
2. Determine which process is primary
   - acidosis cause acidemia
   - alkalosis cause alkalemia

Examples

Case 1

- Case 1

  7.50 / 29 HCO^{-}_{3} 22

- Alkalemia
  - low $PaCO_2$
  - 1^{o} respiratory alkalosis, acute
- Differential diagnosis

Differential Diagnosis

- Anxiety
- Hypoxia
- CNS disease
- Drugs
  - salicylates
  - catecholamine
  - progesterone
- Pregnancy
- **Sepsis**
- Hepatic encephalopathy
- Mechanical Vent
- Lung disease
  - with hypoxia
  - without hypoxia

Examples

Case 2

- Case 2

  7.25 / 60 HCO^-_3 26

- Acidemia
  - high $PaCO_2$
  - 1^o respiratory acidosis, acute
- Differential diagnosis

Differential Diagnosis

- CNS depression
- Neuromuscular disorders
  - myopathies
  - neuropathies
- Acute airway obstruction
- Severe pneumonia or pulmonary edema
- Impaired lung motion
  - pneumothorax
  - hemothorax
  - flail chest

Examples

Case 3

- Case 3

  7.34 / 60 HCO^-_3 31
- Acidemia
  - high $PaCO_2$
  - 1° respiratory acidosis, chronic

Examples

Case 4

- Case 4

  7.50 / 48 HCO_3^- 36
- Alkalemia
  - high HCO_3^-
  - 1° metabolic alkalosis
- Cl^- responsive vs unresponsive

Differential Diagnosis

Urinary Cl^-

- **Low**
  - **vomiting**
    - NG suction
  - **diuretic use**
    - in past
  - Post-hypercapnia
- **Normal to high**
  - **excess mineralocorticoid activity**
  - excess alkali
  - **diuretic use**
    - current / recent
  - refeeding

Examples

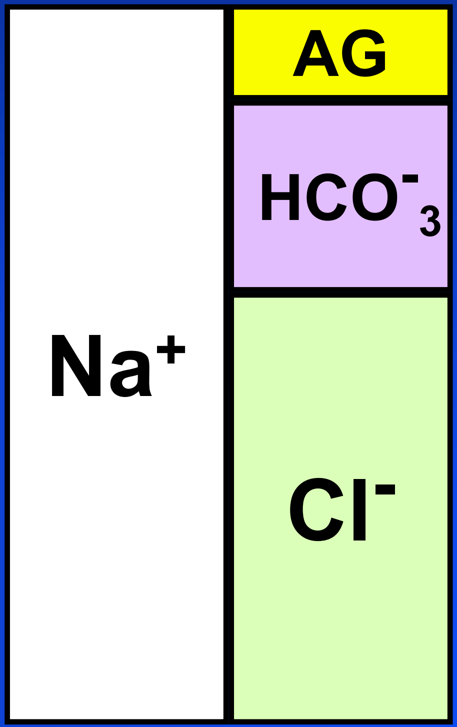
Case 5

- Case 5

  7.20 / 21 HCO_3^- 8
- Acidemia
  - low HCO_3^-
  - 1° metabolic acidosis
- Gap vs non-gap acidosis

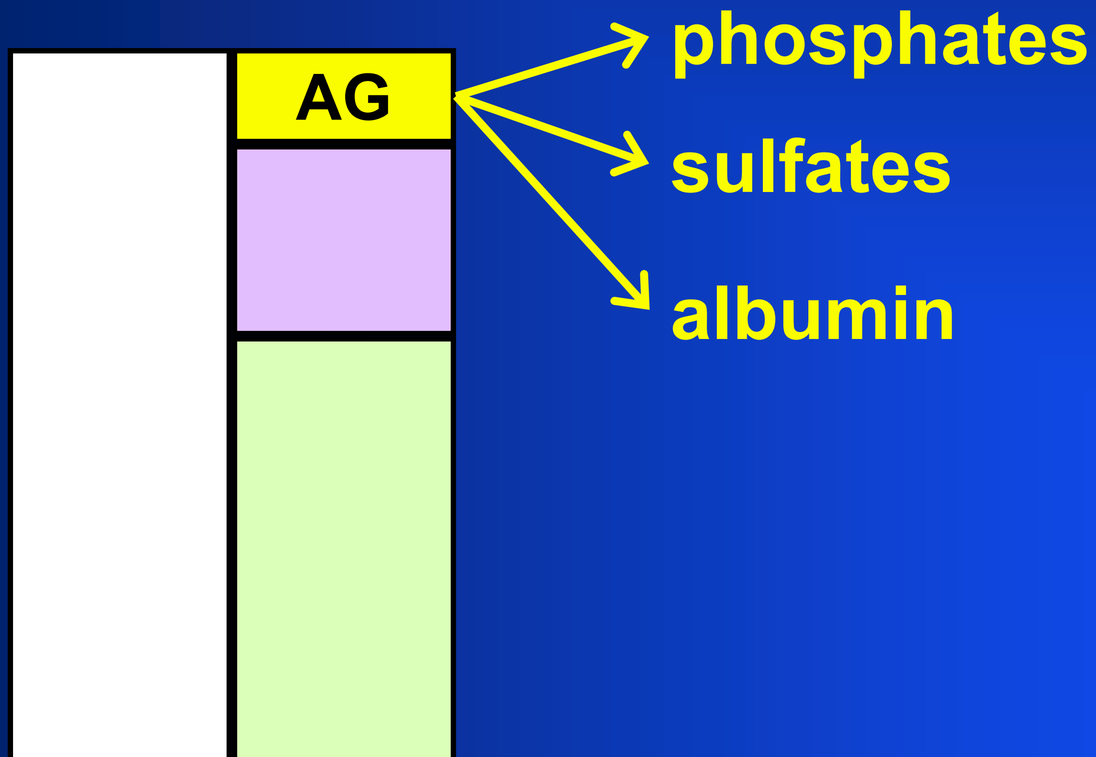
Anion Gap (AG)

- Calculation
  - positive ions
    - Na = 140
  - minus
  - negative ions
    - Cl = 104
    - HCO_3 = 24



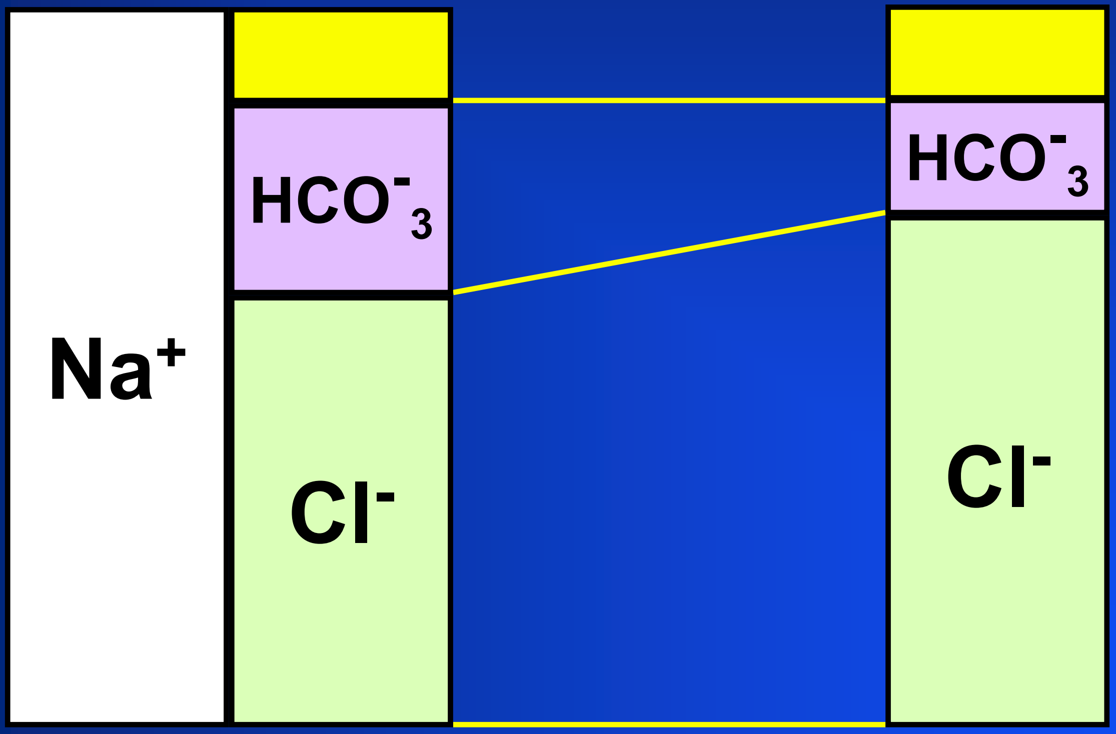
Anion Gap (AG)

- Gap composed of “unmeasured” anions



Non-Gap Acidosis

- Infuse 10 mEq of H^+ Cl^-



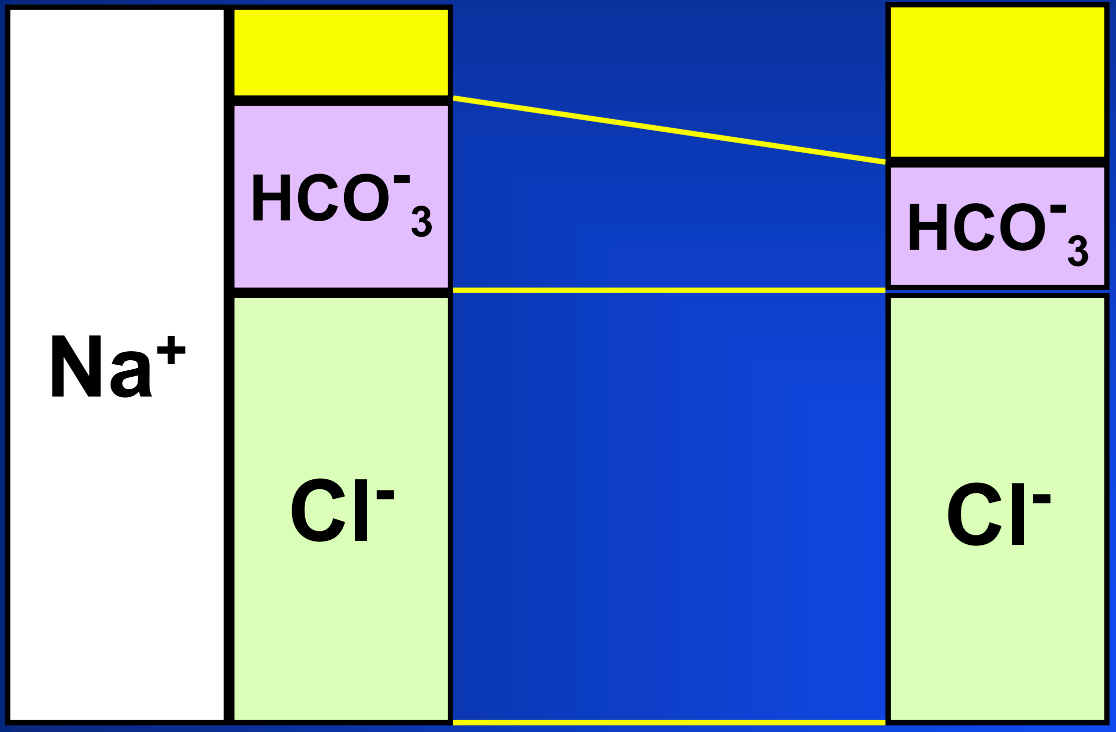
- or Na^+ HCO_3^- loss

Differential Diagnosis

- **Non-Gap**
  - **H** - hyperalimentation (TPN)
  - **E** - expansion acidosis (IV NS)
  - **A** - acetazolamide
  - **R** - renal tubular acidosis (RTA)
  - **T** - loose stools (T-Diarrhea)
  - **C** - cholestyramine (or any bile acid sequestrant)
  - **C** - carbonic anhydrase inhibitors
  - **U** - ureterosigmoidostomy

Gap Acidosis

- Infuse 10 mEq of $H^+ X^-$



- What is the unmeasured anion?

Differential Diagnosis

- **Non-Gap**
  - **H**
  - **E**
  - **A**
  - **R**
  - **T**
  - **C**
  - **C**
  - **U**
- **Gap**
  - **M** methanol
  - **U** uremia
  - **D** DKA
  - **P** paraldehyde
  - **I** INH / infection
  - **L** lactic acidosis
  - **E** ethylene glycol
  - **S** salicylates

Differential Diagnosis

- **Non-Gap**
  - **H**
  - **E**
  - **A**
  - **R**
  - **T**
  - **C**
  - **C**
  - **U**
- **Gap**
  - **M** methanol
  - **U** uremia
  - **D** DKA
  - **P** **propylene glycol**
  - **I** **ingestion**
  - **L** lactic acidosis
  - **E** ethylene glycol
  - **S** salicylates

Step Three

1. Look at the pH
   - acidemia vs alkalemia
2. Determine which process is primary
   - acidosis cause acidemia
   - alkalosis cause alkalemia
3. Calculate the anion gap

The Anion Gap (AG)

- **Always calculate AG**
- **If AG $\geq$ 20**
  - metabolic acidosis is present, regardless of the pH or $[HCO_3^-]$
- **Always calculate AG !**
- **Always calculate AG !!**

For Example

140	103
	15

- AG = 22 (which is $\geq$ 20)
- a primary metabolic acidosis present
- even if pH 7.9!

Acid Base Problem?

Example A

7.39 / 39

140	**105**
	23

Example B

7.40 / 40

145	**100**
	24

Step Four

1. Look at the pH
   - acidemia vs alkalemia
2. Determine which process is primary
   - acidosis cause acidemia
   - alkalosis cause alkalemia
3. Calculate the anion gap
4. Calculate the excess anion gap ($\Delta\Delta$)
   - used only if there is an anion gap
   - determines “corrected” bicarbonate

Excess Anion Gap

- **$\Delta\Delta$ = total anion gap (calculated) minus normal (predicted) anion gap**
- **Add $\Delta\Delta$ to measured HCO_3^-**
  - **if new $[HCO_3^-] \geq 30$**
    - underlying 1° metabolic alkalosis
  - **if new $[HCO_3^-] \leq 23$**
    - underlying 1° metabolic acidosis
    - non-gap

Examples

Case 6

- Case 6

7.50 / 20

140	103
	15

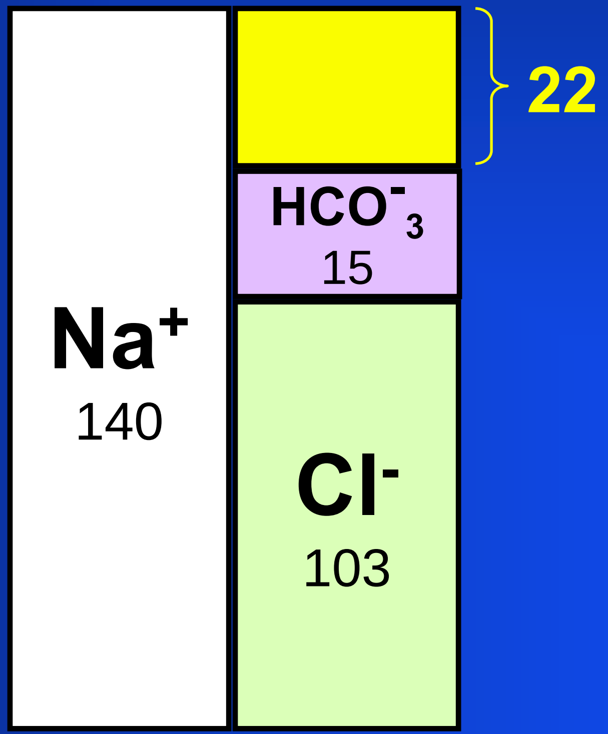
Case 6

- Alkalemia with low $PaCO_2$
  - 1^{o} respiratory alkalosis

- Next step:
  - calculate AG

Calculate Anion Gap

140 - 103 - 15 =

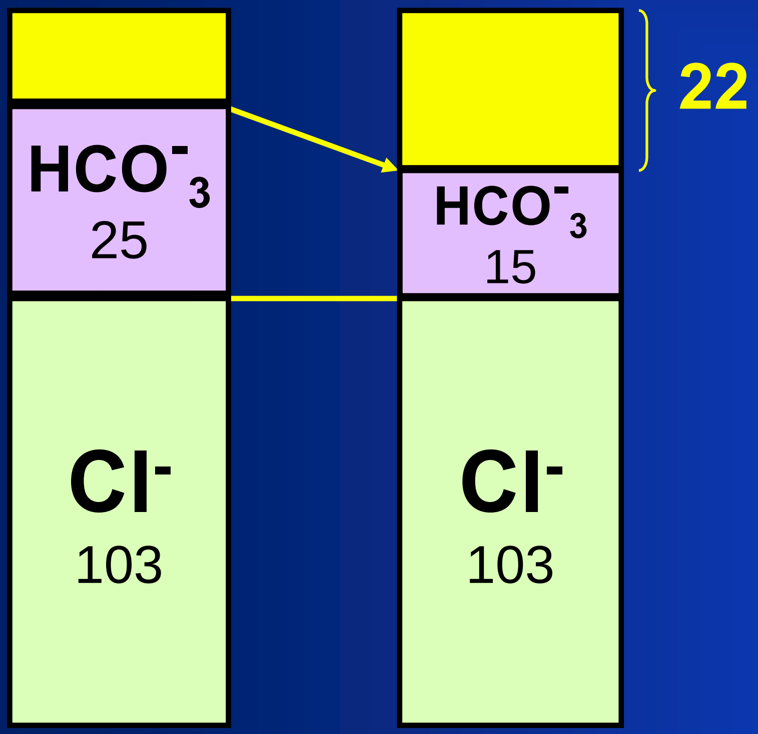


Case 6

- Alkalemia with low $PaCO_2$
  - 1° respiratory alkalosis
- Anion Gap 22
  - underlying 1° metabolic acidosis
- Remember
  - one <u>never</u> compensates by creating AG

Case 6

A normal AG = 12, but here it is 22

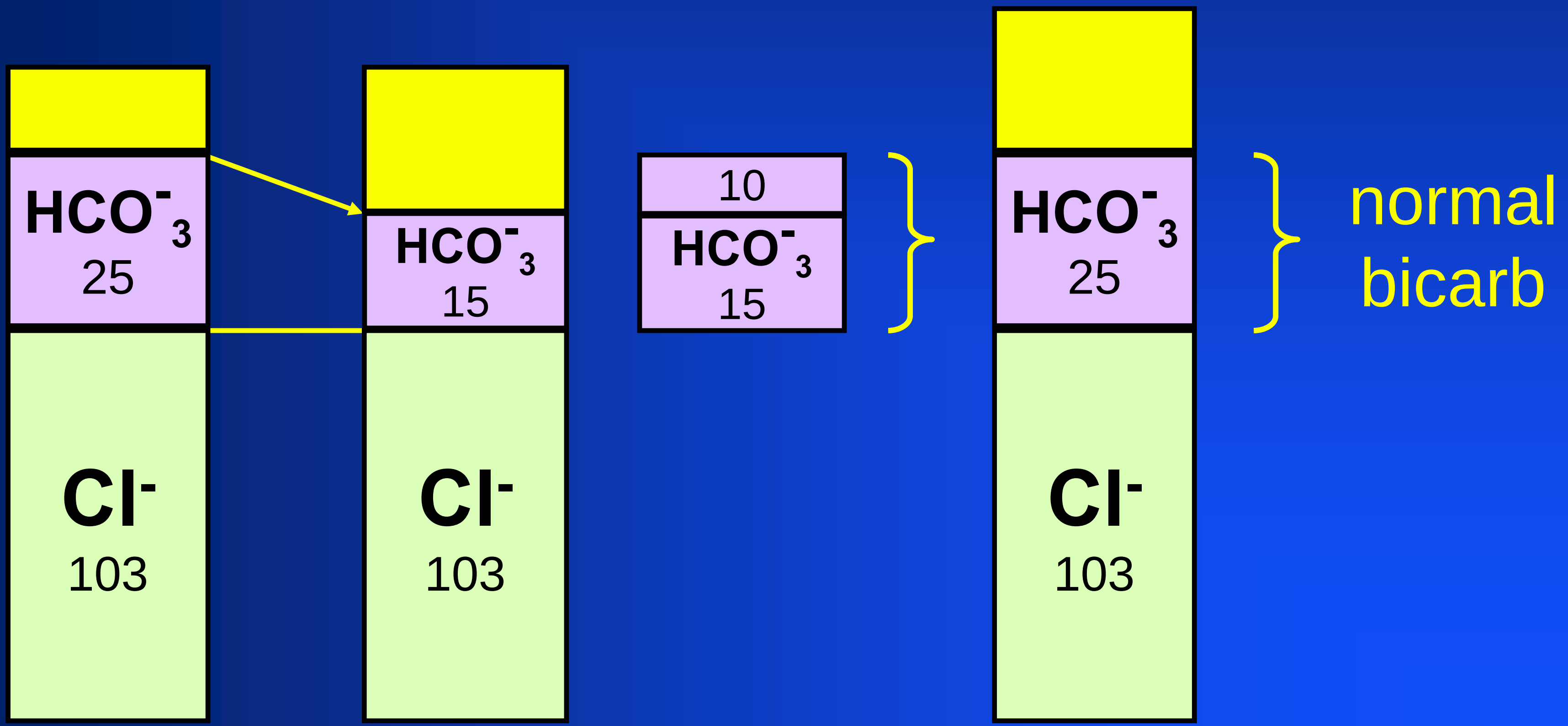


Subtracting measured AG 22
with the predicted AG <u>12</u>
10 ΔΔ

Therefore, suspect that 10 units of H^+X^- have been added to the system

ΔΔ is 10

Therefore, the measured bicarb should be down by 10
If add back 10 to actual bicarb. . .



Case 6

- Alkalemia
  - 1° respiratory alkalosis
  - 1° metabolic acidosis
- ΔΔ:
  - 22 - 12 = 10
- Add ΔΔ to measured bicarb
  - 15 + 10 = 25 ⟶ **normal**
  - **therefore no hidden acid / alkalosis**
- **Clinical story: ASA overdose**

Examples

Case 7

- Case 7

7.40 / 40

145	100
	24

Case 7

- **Normal pH!**
- **Anion Gap = 21**
  - **1° metabolic acidosis**
- **ΔΔ:**
  - 21 - 12 = 9
  - add to bicarb (9 + 24) = 33
  - **1° metabolic alkalosis**
- **Clinical story: CKD c/b acute emesis**

Examples

Case 8

- **Case 8**

7.10 / 50

145	100
	15

Case 8

- Acidemia - high $PaCO_2$ & low $[HCO^-_3]$
  - 1° respiratory acidosis
  - 1° metabolic acidosis
- Anion Gap = 30
- ΔΔ:
  - 30 - 12 = 18 + 15 = 33
  - 1° metabolic alkalosis
- Clinical story: DKA, obtunded with emesis

Examples

Case 9

- **Case 9**

7.15 / 15

140	110
	5

Case 9

- Acidemia - low $[HCO^{-}_{3}]$
  - 1^{o} metabolic acidosis
- Anion Gap = 25
- ΔΔ:
  - 25 - 12 = 13 + 5 = 18
  - 1^{o} non-anion gap metabolic acidosis (a second metabolic process)
- Clinical story: DKA recovery phase

Dr Weir's Case 1

- 38-year-old woman
  - recurrent pyelonephritis
  - progressive CKD
  - admitted increased weakness & emesis
- PE
  - VS BP 174110, RR 22, T 98.0
  - moderate hypertensive retinopathy
  - displace PMI with mid-systolic murmur
  - no crackles, hepatomegaly or edema

Dr Weir's Case 1

7.26 / 27

139	95	159
5.6	12	24.0

- What is the acid-base disturbance(s)?
- What is the most likely etiology(s)?

Dr Weir's Case 5

- 22-year-old man
  - previously healthy
  - choked while eating
- PE
  - VS BP 170/111, HR 125, RR 16 labored
  - marked cyanosis
  - stridor

Dr Weir's Case 5

7.08 / 94

143	104	
4.8	17	

- What is the acid-base disturbance(s)?

Dr Weir's Case 5

- Does this make sense?

$$[H^+] = \frac{24\ [PaCO_2]}{[HCO^-_3]}$$

$$[H^+] = \frac{24 * 94}{17}$$

$$[H^+] = 133 \longrightarrow \text{pH } 6.88$$

Dr Weir's Case 5

7.08 / 94

143	104	
4.8	27	

- **What is the acid-base disturbance(s)?**
- **What is the most likely etiology(s)?**

Dr Weir's Case 2

- 68-year-old woman
  - acute Salmonella enteritis
  - profuse diarrhea x 1 week

7.24 / 12

133	118	
2.5	5	6.3

Dr Weir's Case 2

Day 1

7.24 / 12

133	118	
2.5	5	6.3

AG 10

Day 2

7.51 / 17

137	114	
4.2	13	

AG 10

- **Although the bicarbonate deficit was only partially corrected on day 2, the plasma became quite alkaline. Why?**

Dr Weir's Case 3

- 35-year-old woman
  - Glasgow Coma Scale 5
  - progressive weakness 2 months PTA
- PE
  - decreased DTRs without lateralizing signs

Dr Weir's Case 3

6.88 / 40

135	118	
1.5	7	

- What is the acid-base disturbance(s)?
- What is the most likely etiology(s)?

Formulas

- Winters' formula
  - $PaCO_2 = (HCO^-_3 * 1.54) + 8.36$
- Simplified
  - $PaCO_2 = (HCO^-_3 * 1.5) + 8.5$

Albert, Ann Intern Med. 1967 Feb;66(2):312-22