PHYSIOLOGY TEAM 432

LECTURE : 11

Acid and Base imbalances

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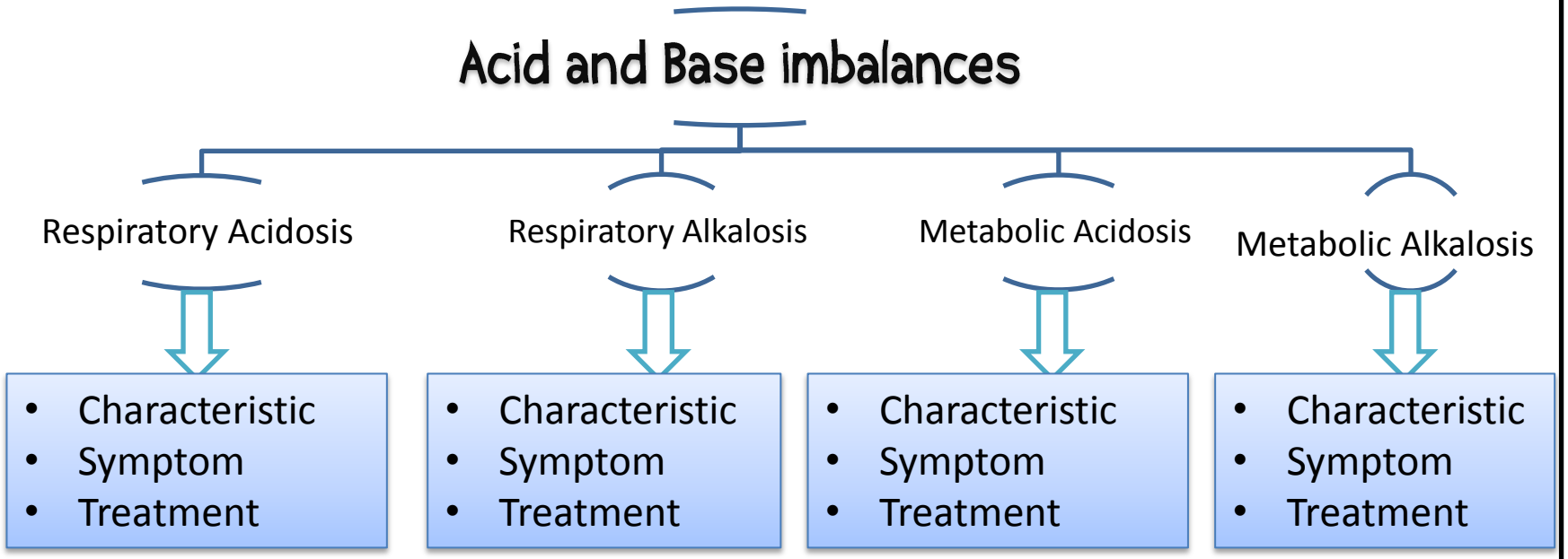
Reviewed By: Khalid Al-Osaimi

OBJECTIVES

1) Identify types of Acid-Base Imbalance
2) Symptoms and signs of Acid-Base imbalances
3) Treatments for Acid-Base imbalances

- Slides
- Important
- What doctor said
- Explanation
- Notes from boy's slides

MIND MAP


Acid and Base imbalances
Respiratory Acidosis
Respiratory Alkalosis
Metabolic Acidosis
Metabolic Alkalosis
• Characteristic
• Symptom
• Treatment
• Characteristic
• Symptom
• Treatment
• Characteristic
• Symptom
• Treatment
• Characteristic
• Symptom
• Treatment

Acidosis

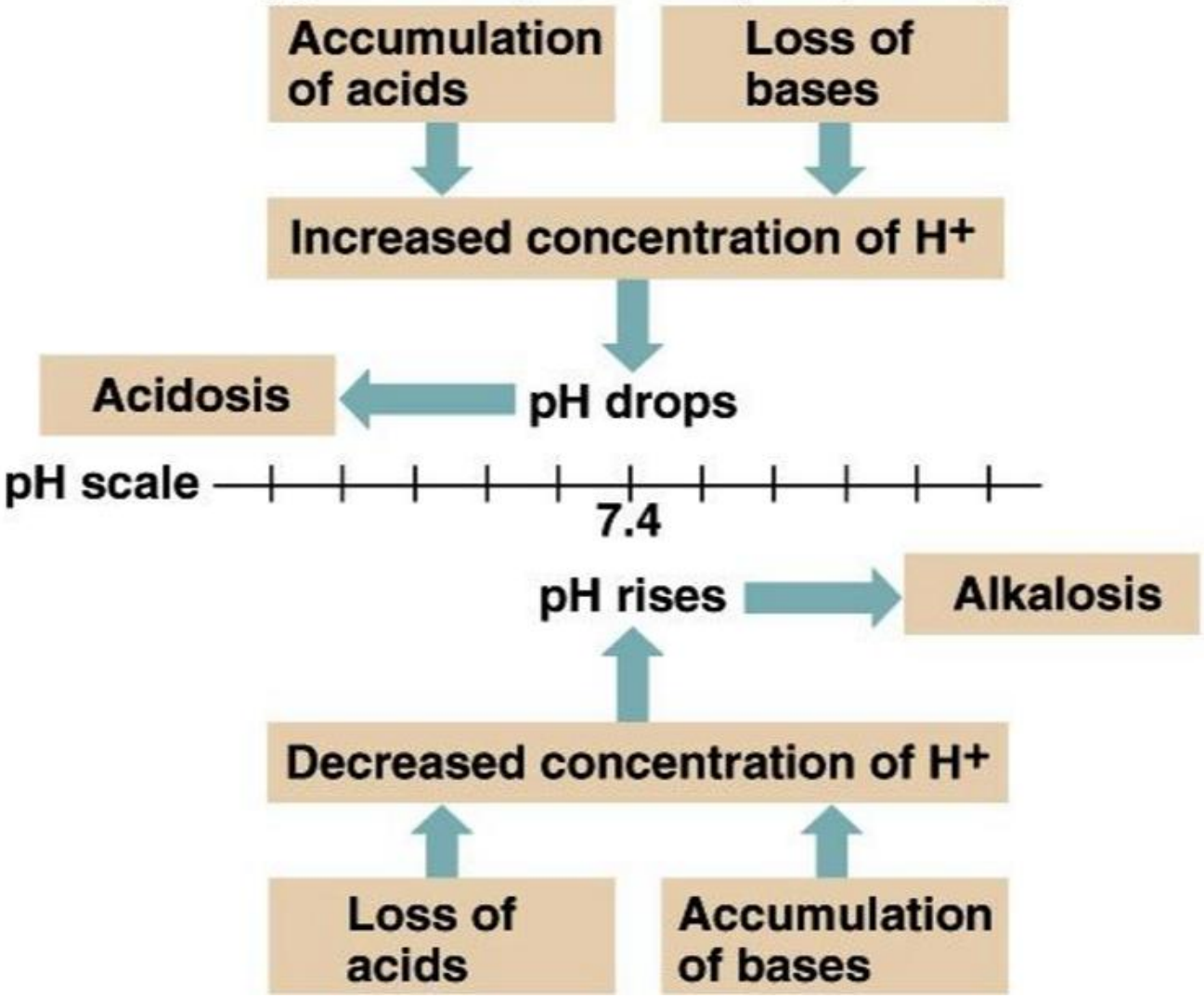
• Principal effect of acidosis is depression of the CNS through ↓ in synaptic transmission. • Generalized weakness

(Symptoms) • Severe acidosis causes – Disorientation – coma – death

Alkalosis

• Alkalosis causes over excitability of the central and peripheral nervous systems.

(Symptoms) • Numbness • Lightheadedness • It can cause : – Nervousness – muscle spasms or tetany – Convulsions – Loss of consciousness – Death



Respiratory Acidosis

Respiratory acidosis:

- Low pH
- High PCO2 (Hypercapnia) because of depressed ventilation;CO2 accumulated

The normal partial pressure of CO2 is 35- 45

- HCO3 = Normal (in acute ; when there is no compensation)

Signs and Symptoms of Respiratory Acidosis:

- Breathlessness
- Restlessness
- Lethargy and disorientation
- Tremors, convulsions, coma
- Respiratory rate rapid, then gradually depressed
- Skin warm and flushed due to vasodilation caused by excess CO2

Causes of Respiratory Acidosis:

- Chronic conditions:

1) Depression of respiratory center in brain that controls breathing rate as a result of certain drugs or head trauma 2)Paralysis of respiratory or chest muscles
3) Emphysema

- Acute conditions:

1) Adult Respiratory Distress Syndrome
2)Pulmonary edema
3)Pneumothorax
(The end result : breathing is depressed CO2 is accumulated leading to respiratory acidosis)

Respiratory Acidosis

Compensation for Respiratory Acidosis:

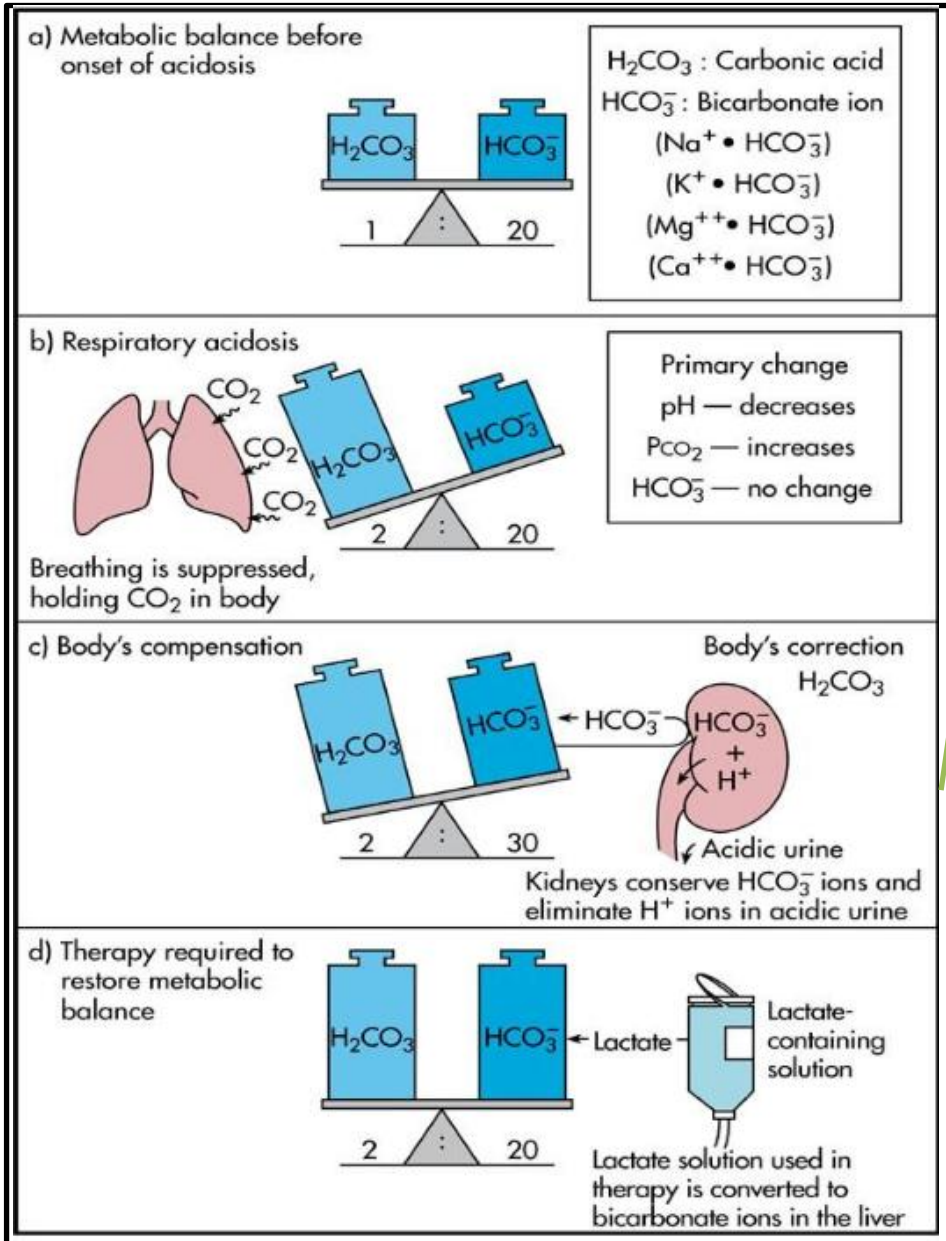
- Kidneys eliminate hydrogen ion and retain bicarbonate ion
- Blood picture after compensation:
  - pH = N
  - PCO_2 = High (the underlying problem still exists)
  - HCO_3 = High compensation
- Low Urine HCO_3

Treatment of Respiratory Acidosis:

- Restore ventilation
- IV lactate solution (compensate for the pH)
- Treat underlying dysfunction or disease

Kidneys will increase the bicarbonate reabsorption and increase secretion of hydrogen ion

comparing to the previous blood picture of acute acidosis the pH returned to its normal range and the bicarbonate has increased



From Thibodeau GA, Patton KT: *Anatomy & physiology*, ed 5, St Louis, 2003, Mosby.

The balance : carbonic acid to bicarbonate ratio : 1:20
*If he had a problem with breathing more CO2 is retained which will result in an increase in the carbonic acid ; the ratio becomes 2:20as a result the kidney will try to add bicarbonate to return the balance to normal and we can give him lactate solution which will be metabolized in the liver to bicarbonate hence returning pH back to normal

Respiratory Alkalosis

Respiratory alkalosis:

- high pH
- low PCO2 – hyper ventilation
- Hysterical
- pneumonia
- HCO3 normal
- PCO2 less than 35 mm Hg (hypocapnea)
- Primary cause is hyperventilation

Respiratory Alkalosis Causes:

- Oxygen deficiency at high altitudes people living at high altitudes hyperventilate to compensate for the o2
- Pulmonary disease and Congestive heart failure – caused by hypoxia
- Acute anxiety
- Fever, anemia
- Early salicylate intoxication
- Cirrhosis
- Gram-negative sepsis

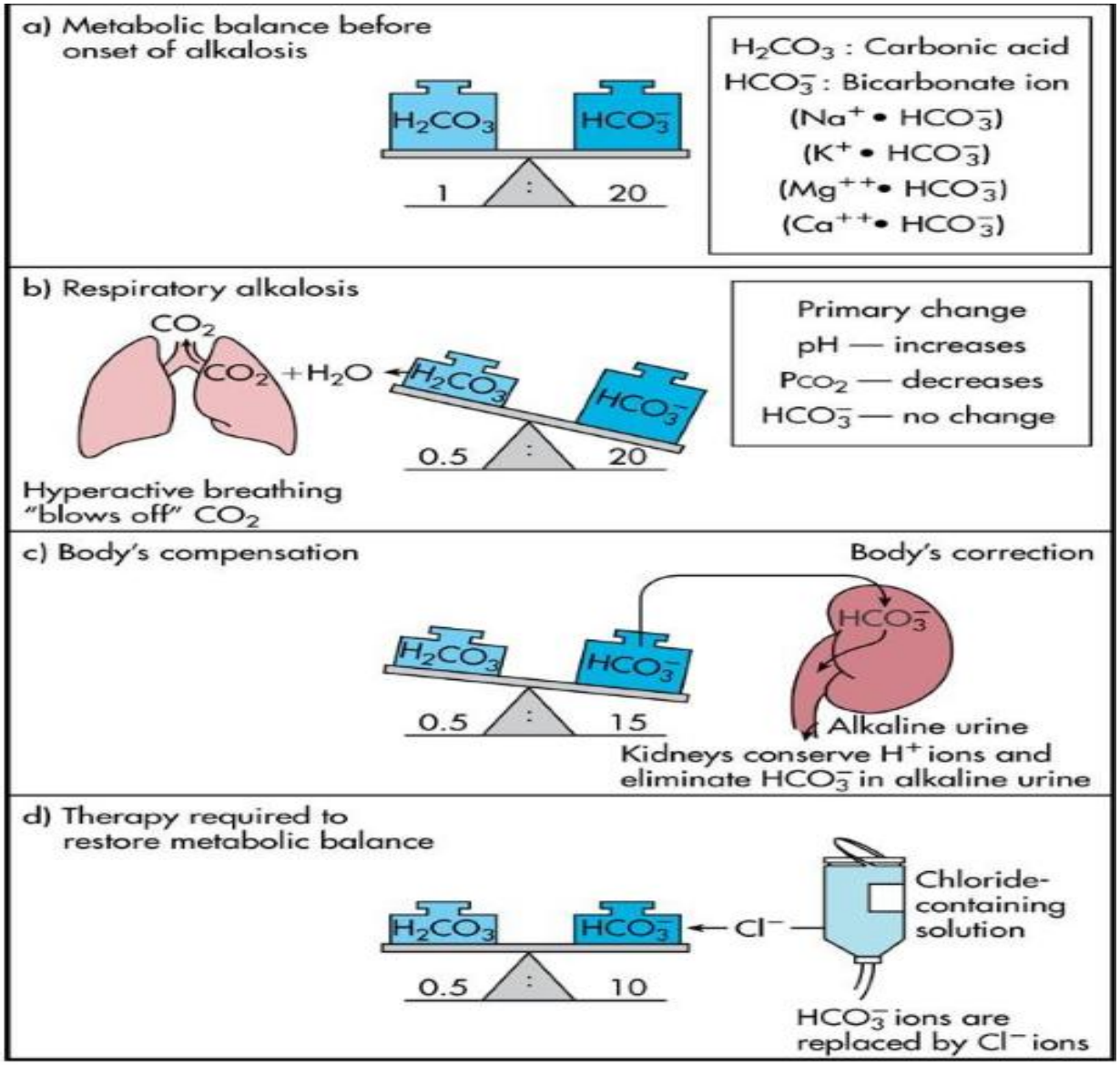
Respiratory Alkalosis

Compensation of Respiratory Alkalosis :

- Kidneys conserve hydrogen ion
- Excrete more bicarbonate ion
- Blood picture after compensation:
  - pH = N
  - PCO2 = Low
  - HCO3 = Low compensation
- High urine HCO3

Treatment of Respiratory Alkalosis :

- Treat underlying cause
- Breathe into a paper bag
- IV Chloride containing solution – Cl^- ions replace lost bicarbonate ions


a) Metabolic balance before onset of alkalosis
H_2CO_3
HCO_3^-
1 : 20
H_2CO_3 : Carbonic acid
HCO_3^- : Bicarbonate ion
$(Na^+ \bullet HCO_3^-)$
$(K^+ \bullet HCO_3^-)$
$(Mg^{++} \bullet HCO_3^-)$
$(Ca^{++} \bullet HCO_3^-)$
b) Respiratory alkalosis
CO_2
CO_2 + H_2O
H_2CO_3
HCO_3^-
0.5 : 20
Primary change
pH — increases
P_{CO_2} — decreases
HCO_3^- — no change
Hyperactive breathing "blows off" CO_2
c) Body's compensation
Body's correction
H_2CO_3
HCO_3^-
0.5 : 15
HCO_3^-
Alkaline urine
Kidneys conserve H^+ ions and eliminate HCO_3^- in alkaline urine
d) Therapy required to restore metabolic balance
H_2CO_3
HCO_3^-
Cl^-
Chloride-containing solution
0.5 : 10
HCO_3^- ions are replaced by Cl^- ions

Metabolic Acidosis

Metabolic Acidosis:

- Low pH
- Low HCO3
  - Production or accumulation of Lactic acid (anaerobic metabolism)
  - Production of ketoacid (uncontrolled diabetes)
  - Excessive loss of alkali (diarrhea, content of intestine is alkaline therefore excessive diarrhea might cause acidosis)
  - Renal failure (because its how H is secreted)
- PCO2 = normal

Metabolic Acidosis:

- Bicarbonate deficit < 22mEq/L

Normal Range 24-28 mEq/L

- Causes:
  - Loss of bicarbonate through diarrhea or renal dysfunction
  - Accumulation of acids (lactic acid or ketones)
  - Failure of kidneys to excrete H+

Symptoms of Metabolic Acidosis:

- Headache, lethargy
- Nausea, vomiting, diarrhea
- Coma • Death

Metabolic Acidosis

Compensation for Metabolic Acidosis :

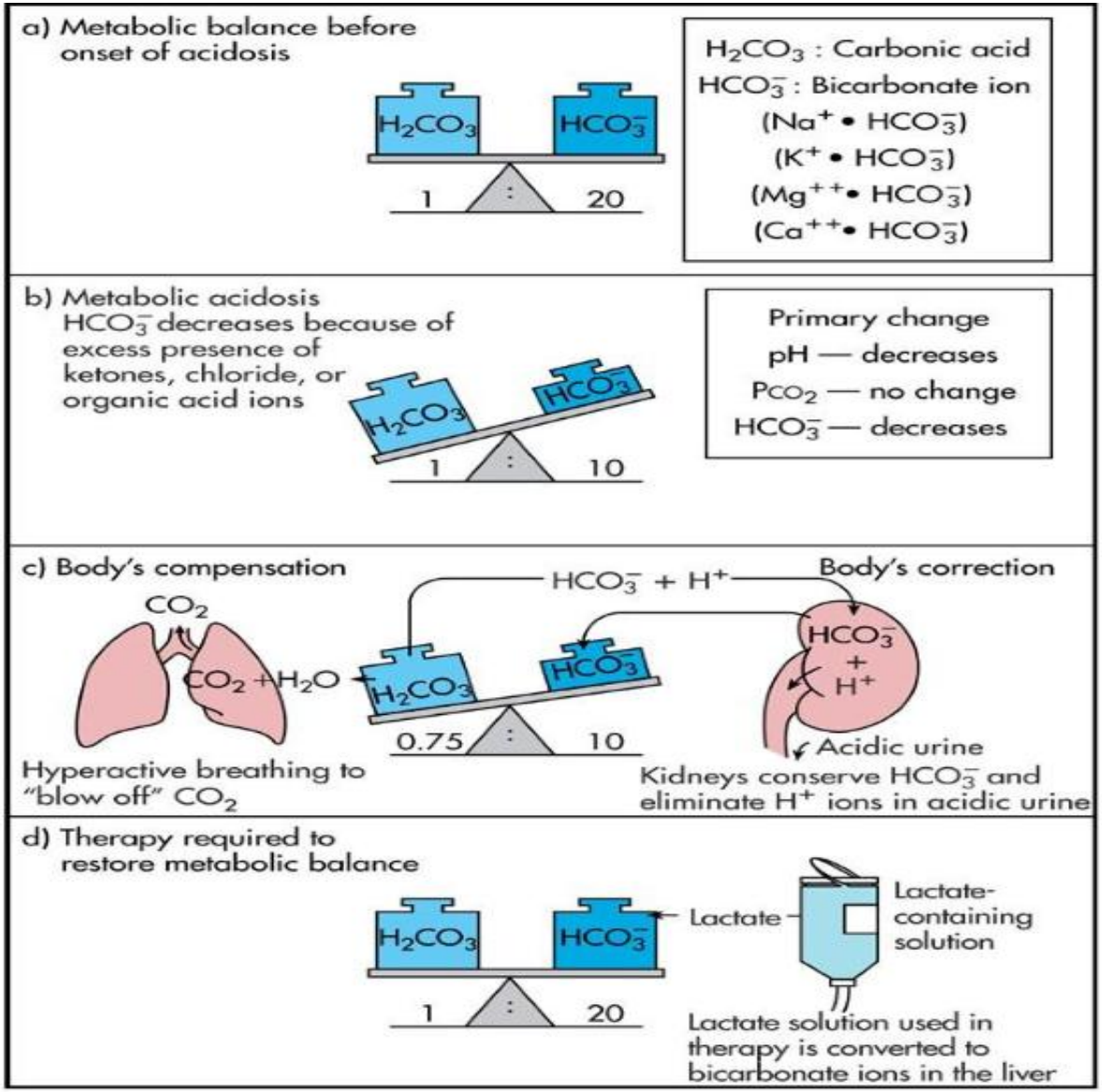
- Stimulation of ventilation (hyperventilation) decrease PCO2 & increase pH back to normal value
- Renal excretion of hydrogen ions if possible
- K+ exchanges with excess H+ in ECF

(H+ into cells, K+ out of cells)

- Blood picture after compensation:
  - pH = ~Normal (approximately because respiratory system doesn't compensate a 100%
  - HCO3 = Low
  - PCO2 = Low due to the compensation

Treatment of Metabolic Acidosis:

- IV lactate solution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$(Na^+ \bullet HCO_3^-)$
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$(Mg^{++} \bullet HCO_3^-)$
$(Ca^{++} \bullet HCO_3^-)$
b) Metabolic acidosis
HCO_3^- decreases because of excess presence of ketones, chloride, or organic acid ions
1 : 10
Primary change
pH — decreases
P_{CO_2} — no change
HCO_3^- — decreases
c) Body's compensation
CO_2
$CO_2 + H_2O$
$HCO_3^- + H^+$
Body's correction
0.75 : 10
HCO_3^- + H^+
Acidic urine
Hyperactive breathing to "blow off" CO_2
Kidneys conserve HCO_3^- and eliminate H^+ ions in acidic urine
d) Therapy required to restore metabolic balance
1 : 20
Lactate
Lactate-containing solution
Lactate solution used in therapy is converted to bicarbonate ions in the liver

Metabolic Alkalosis

Metabolic Alkalosis
- high pH
- High HCO3
– Loss of gastric acid (vomiting)
– Excessive intake of alkali (antiacid)
- PCO2 = Normal

Metabolic Alkalosis
- Bicarbonate > 26 mEq/L •

Causes: – Excess vomiting = loss of stomach acid
– Excessive use of alkaline drugs
– Certain diuretics
– Endocrine disorders
– Heavy ingestion of antacids
– Severe dehydration

Compensation for Metabolic Alkalosis:

- Correction – depress ventilation increase blood PCO2 & decrease pH back to normal value (limited by hypoxia)
- Alkalosis most commonly occurs with renal dysfunction, so can't count on kidneys
- Blood picture after compensation:

– pH = ~N
– HCO3 = High
– PCO2 = High compensation

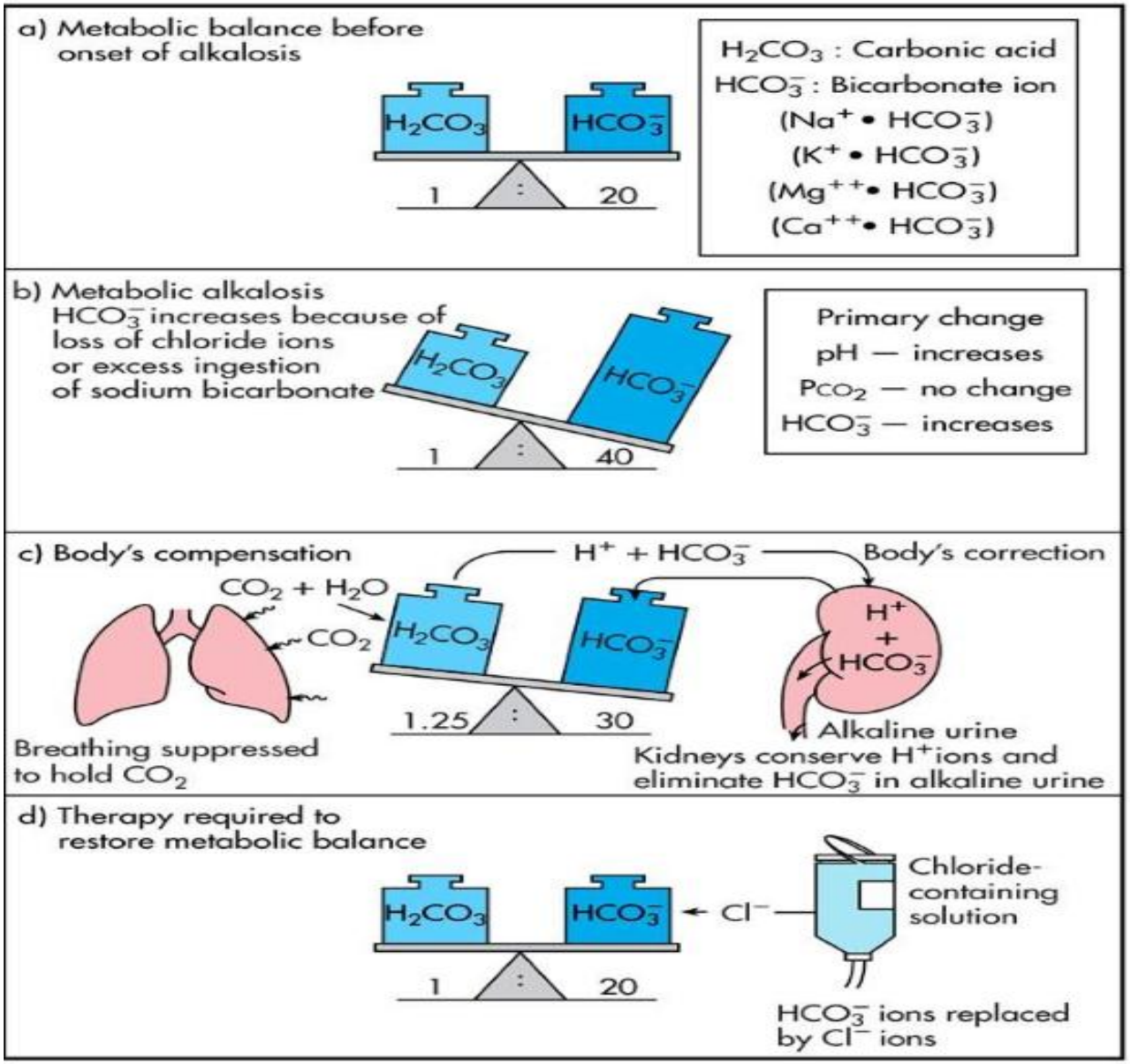
Metabolic Alkalosis

Symptoms of Metabolic Alkalosis :

- Respiration slow and shallow
- Hyperactive reflexes tetany
- Often related to depletion of electrolytes
- Atrial tachycardia
- Dysrhythmias

Treatment of Metabolic Alkalosis:

- Electrolytes to replace those lost
- IV chloride containing solution
- Treat underlying disorder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$(K^+ \bullet HCO_3^-)$
$(Mg^{++} \bullet HCO_3^-)$
$(Ca^{++} \bullet HCO_3^-)$
b) Metabolic alkalosis
HCO_3^- increases because of loss of chloride ions or excess ingestion of sodium bicarbonate
1 : 40
Primary change
pH — increases
P_{CO_2} — no change
HCO_3^- — increases
c) Body's compensation
$CO_2 + H_2O$
CO_2
Breathing suppressed to hold CO_2
1.25 : 30
$H^+ + HCO_3^-$
Body's correction
Alkaline urine
Kidneys conserve H^+ ions and eliminate HCO_3^- in alkaline urine
d) Therapy required to restore metabolic balance
Cl^-
Chloride-containing solution
1 : 20
HCO_3^- ions replaced by Cl^- ions

Example

• A patient is in intensive care because he suffered a severe myocardial infarction 3 days ago. The lab reports the following values from an arterial blood sample: – pH 7.3 – HCO_3^- = 20 mEq / L (22 - 26) – pCO_2 = 32 mm Hg (35 - 45)

Diagnosis

• Metabolic acidosis

• With compensation

We decided it is metabolic acidosis because in respiratory acidosis the CO_2 level is supposed to be high .. While in the example it is decreased as a result of hyperventilation(respiratory compensation) in attempt to get rid of the excess CO_2

SUMMARY

- **Acidosis**

Note: Double sided arrow " ⇔ " means normal

These two tables are very important (This table and the next one)

	Abnormalities			
pH	⇓	⇔	⇓	⇔
PCO_2	⇑	⇑	⇔	⇓
HCO_3	⇔	⇑	⇓	⇓
Type	Resp	Resp	Metab	Metab
Correction	No	Yes Metab	No	Yes Resp

SUMMARY

- **Alkalosis**

Note: Double sided arrow " ⇔ " means normal

	Abnormalities			
pH	⇑	⇔	⇑	⇔
PCO_2	⇓	⇓	⇔	⇑
HCO_3	⇔	⇓	⇑	⇑
Type	Resp	Resp	Metab	Metab
Correction	No	Yes Metab	No	Yes Resp

SUMMARY

- Acidosis Principal effect of acidosis is depression of the CNS through ↓ in synaptic transmission. Generalized weakness . Symptoms: Severe acidosis causes, Disorientation ,coma , death.
- Alkalosis causes over excitability of the central and peripheral nervous systems. Symptoms: Numbness, Lightheadedness, It can cause: Nervousness, muscle spasms or tetany, Convulsions, Loss of consciousness – Death
- Simple acid-base disorder can be metabolic or respiratory in origin. Metabolic disorder involve a primary disturbance of the (HCO_3^- , caused by gain or loss of fixed H^+ · When there is a gain of fixed H^+ metabolic acidosis occurs, when there is a loss of fixed H^+ metabolic alkalosis occurs. Respiratory disorders involve a primary disturbance of P_{CO2} , caused by hypoventilation (respiratory acidosis), or hyperventilation (respiratory alkalosis).
- Compensation for acid0bace disorders are either respiratory or renal. When the primary disorder is metabolic, compensation is respiratory, When the primary disorders is respiratory, compensation is renal (metabolic).

SUMMARY

From: Ashwag Al-Harbi

- If the PH is depressed, it is an acidosis
- If the CO2 is elevated, there is a respiratory acidosis
- If the bicarbonate is reduced, there is a metabolic acidosis
- If the CO2 is elevated and bicarbonate is depressed, it is combined respiratory and metabolic acidosis
- If the PH is elevated, it is an alkalosis
- If the CO2 is depressed, there is a respiratory alkalosis
- If the bicarbonate is elevated, there is a metabolic alkalosis
- If the CO2 is depressed and bicarbonate is elevated, it is combined respiratory and metabolic alkalosis
- Respiratory response to metabolic acidosis is hyperventilation
- Respiratory response to metabolic alkalosis is hypoventilation
- The renal response to an acidosis is the excretion of acid and the generation of new bicarbonate
- The renal response to an alkalosis is the excretion of bicarbonate

SUMMARY

From: Ashwag Al-Harbi

- A widening of the anion gap occurs when anion other than chloride accumulate during a metabolic acidosis. This does not occur with diarrhea or Type I and II renal tubular acidosis
- A metabolic acidosis can originate with the kidney ,or is the result of increased acid production or the loss of bicarbonate in diarrhea
- RTA type I – decreased capacity of distal nephron to excrete H ions urine PH >5.5- 6.0
- RTA type II – decreased capacity of proximal tubule to reabsorb bicarbonate urine PH < 5.5- 6.0
- Renal failure- – decreased capacity of the kidney to excrete H ions because of a loss of functioning nephrons
- A metabolic alkalosis is caused by a primary rise in plasma bicarbonate and is maintained by decreased capacity of the kidney to eliminate the excess bicarbonate

SUMMARY

Table 7-2 Summary of Acid-Base Disorders

Disorder	$CO_2 + H_2O$	⇄	$H^+ + HCO_3^-$	Respiratory Compensation	Renal Compensation or Correction
Metabolic Acidosis	↓		↑ **↓**	Hyperventilation	↑ HCO_3^- reabsorption (correction)
Metabolic Alkalosis	↑		↓ **↑**	Hypoventilation	↑ HCO_3^- excretion (correction)
Respiratory Acidosis	**↑**		↑ ↑	None	↑ HCO_3^- reabsorption (compensation)
Respiratory Alkalosis	**↓**		↓ ↓	None	↓ HCO_3^- reabsorption (compensation)

Bold arrows indicate initial disturbance.

Table 7-3 Renal Rules for Predicting Compensatory Responses in Simple Acid-Base Disorders

Acid-Base Disturbance	Primary Disturbance	Compensation	Predicted Compensatory Response
Metabolic Acidosis	↓ $[HCO_3^-]$	↓ P_{CO_2}	1 mEq/L decrease in HCO_3^- → 1.3 mm Hg decrease in P_{CO_2}
Metabolic Alkalosis	↑ $[HCO_3^-]$	↑ P_{CO_2}	1 mEq/L increase in HCO_3^- → 0.7 mm Hg increase in P_{CO_2}
Respiratory Acidosis			
Acute	↑ P_{CO_2}	↑ $[HCO_3^-]$	1 mm Hg increase in P_{CO_2} → 0.1 mEq/L increase in HCO_3^-
Chronic	↑ P_{CO_2}	↑ $[HCO_3^-]$	1 mm Hg increase in P_{CO_2} → 0.4 mEq/L increase in HCO_3^-
Respiratory Alkalosis			
Acute	↓ P_{CO_2}	↓ $[HCO_3^-]$	1 mm Hg decrease in P_{CO_2} → 0.2 mEq/L decrease in HCO_3^-
Chronic	↓ P_{CO_2}	↓ $[HCO_3^-]$	1 mm Hg decrease in P_{CO_2} → 0.4 mEq/L decrease in HCO_3^-

Questions

Q1) Which condition has highest excretion of NH_4^+ ?

A) Chronic renal failure
B) diabetic ketoacidosis
c) vomiting
d) physical hyperventilation

Q2) In the conversion from acute to chronic respiratory alkalosis, what happen to blood PH ?

A)Increase
B)Decrease to normal
c)Severe decreasing
D)Constant

Q3) A patient is seen in the emergency department with following blood value PH=7.8,HCO3- =29,P_{CO2} =38 what is the acid-base disorder?

A) Respiratory Acidosis
B) Respiratory Alkalosis
C) Metabolic Acidosis
D) Metabolic Alkalosis

Q4) We can measure the osmolarity by ?

A) mOsm/ml
B) mlOsm/ml
C) mOsm/L
D) B-C

1	2	3	4
B	B	D	C

THE END

If there are any problems or suggestions
Feel free to contact:

Physiology Team Leaders
Mohammed Jameel & Khulood Al-Raddadi

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THANK YOU

Actions speak louder than Words