Case based interpretation of blood gas in pediatric ICU patients

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Objectives

- Review Components of blood gas
- Review normal blood gas
- Review acid base balance
- Interpret blood gases

Why is it necessary to order an ABG Analysis?

- ★Aids in establishing diagnosis
- ★Guides treatment plan
- ★Aids in ventilator management
- ★Improvement in acid/base management
- ★Determine oxygenation status

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OBTAINING A BLOOD GAS

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Potential Pre-analytical Errors

- Missing or wrong patient/sample identification
- Use of incorrect type or amount of anticoagulant
  - Dilution due to use of liquid heparin
  - Insufficient amount of heparin
  - Binding of electrolytes to heparin
- Inadequate removal of flush solution in arterial lines prior to blood collection
- Inadequate mixing of the sample
- Air bubbles in the sample

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Obtaining Blood Gas

- Venous
  - Not ideal
  - pH slightly lower
  - PCO_2 slightly higher
  - PO_2 not valuable
- Capillary
  - pH, PCO_2 slightly lower
  - PO_2 no value
  - "arterialize"

Obtaining Blood Gas

- Artery
  - Ideal, Most accurate
  - Use all parameters
  - Location
    - Umbilical,
    - radial,
    - posterior tibia,
    - femoral,
    - axillary

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Difference in Blood Gas Type

- Venous and arterial HC03 are roughly the same
- The venous pC02 is slight higher then the arterial pC02 (5-10) because additional C02 is picked up from the tissues
- The venous P02 is substantially lower than the arterial.

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Obtaining a blood gas

- The syringe needs to have heparin in it to prevent clotting of the sample
  - Too much can change the pH
- Air bubbles need to be removed or they can dissolve into the specimen and effect the Pa02
- If in a glass syringe place in ice if in plastic do not put in ice
- must be analyzed within 30 minutes

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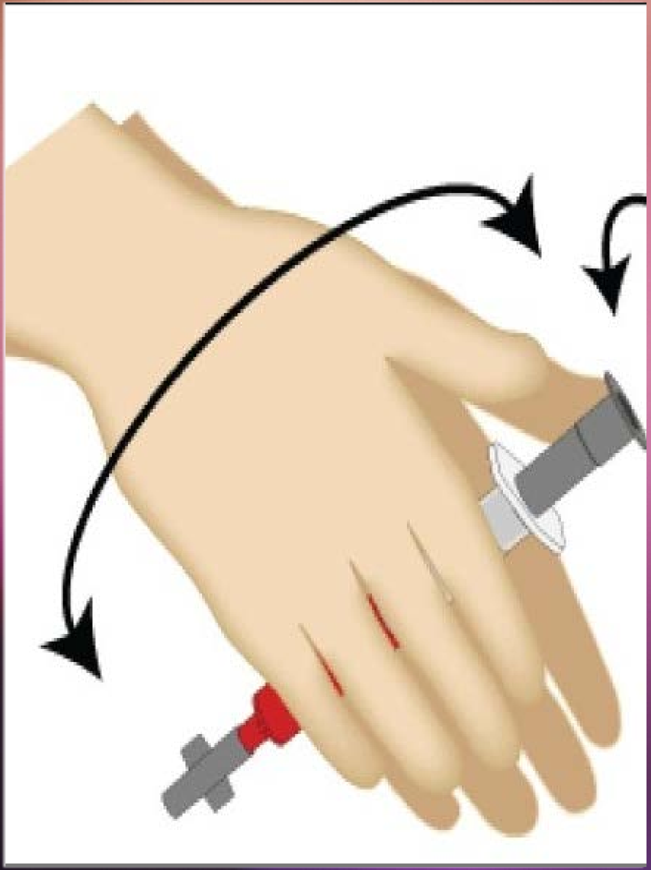
Proper way to mix ABG



- Insufficient mixing can cause clots in the sample
- Invert the syringe 10 times and roll it between the palms
- This method arterial sample mixes with the anticoagulant in two dimensions
- Proper mixing prevents stacking of the red blood cells.

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Heparin

- Blood gas syringes and capillary tubes are coated with various types of heparin to prevent coagulation in the syringes and analyzer.
- Types
  - Liquid non-balanced heparin
  - Dry non-balanced heparin
  - Dry electrolyte balanced heparin
  - Dry Ca^{2+}
- The binding effect of Calcium to heparin results in falsely low values.
  - Using electrolyte-balanced heparin reduces the binding

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Anticoagulation

The use of liquid heparin as the anticoagulant causes a dilution of sample;

- Dilutes the plasma but not the contents of the red cells
- Dilution can effect pCO2 and electrolytes
- Dilution does not effect the glucose, pO2, pH
- Positive ions bind to heparin
  - Ca^{2+}
  - K^{+}
  - Na

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COMPONENTS OF A BLOOD GAS

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ABG measures

- Measures 3 components
  - pH
  - pCO_2
  - PO_2
- All other numbers are calculated
  - The HCO_3 value is calculated based on measured pH and pCO_2 using the Henderson-Hasselbalch equation
  - Oxygen saturation is calculated based on the assumption that normal adult Hg is the dominant Hg in the sample.

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Blood Gas Normal Values

- pH = 7.35 – 7.45
- PCO2 = 35 – 45 mm Hg
- PO2 = 55 – 65 mm Hg on room air
- Bicarbonate= 22-26
- O2 saturation 95-100%
- Base Excess= -2 to + 2 meEq/L

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pH

pH is a logarithmic scale of the concentration of hydrogen ions in a solution. Because the numbers are so small

- Moles of H^+
- $pH = -\log(H^+)$
- $pH = 13$ $(H^+) = 10^{-13}$

- This can be confusing the numbers are inverse (reversed)
  - When the H + concentration increases the pH decreases

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pH measurement

- Measures net circulating acid/base level.
- pH can be affected by ventilation and by metabolic factors
- Best to interpret the pH as if HC03 and C02 are independent
  - As Hco03 increases the pH goes up -alkaline
  - As pC02 increases the pH goes down-acidosis

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pH con't

- The pC02 determines the respiratory component of the pH
- Hco3 determines the metabolic component of the pH

Comparing -ROME

- In normal blood gas pH and paC02 (respiratory opposite- Metabolic equal)

- pH ↓ CO_2 ↑ <u>ACIDOSIS</u> HCO3 ↓
- pH ↑ Co_2 ↓ <u>Alkalosis</u> Hco3 ↑

Abnormal

- If the pH and PaCo2 change in the same direction
  - The primary problem is metabolic
- If the HC03 and Paco2 change in opposite directions
  - Then it is a mixed disorder.
  - Check the percent difference
  - The one with the greater % change is the dominant disorder

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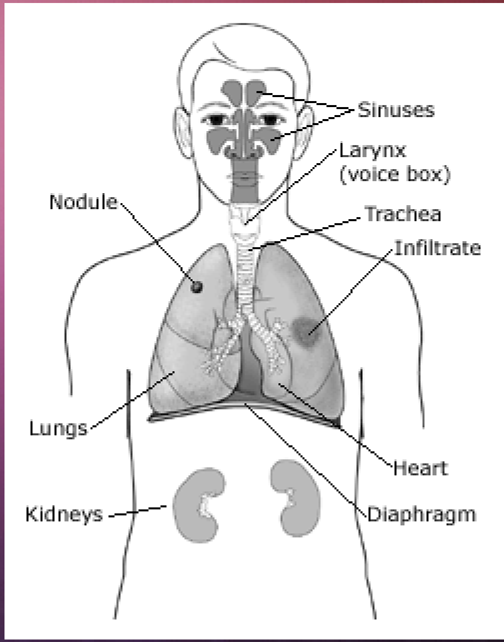
Compensation

- How the body responds:
- Lungs
  - Respiratory system
  - CO_2
  - O_2
- Kidneys
  - Metabolic response
  - Bicarbonate



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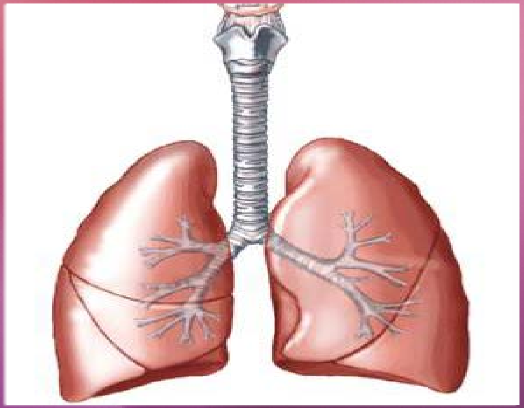
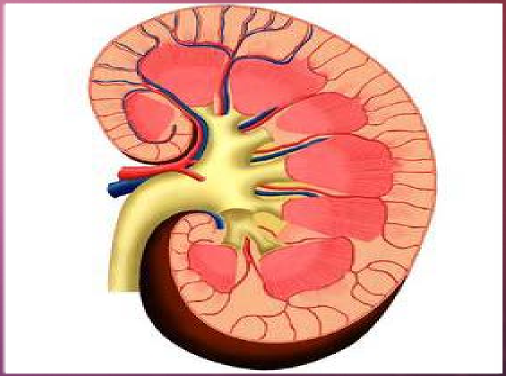
Respiratory/Excretory Response

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3$$



Hyperventilation removes H + ion
Hypoventilation increases H + concentrations



Kidney eliminates or retains H+ or Bicarbonate ions.

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pH con't

- The pH is tightly controlled to maintain range of 7.35 to 7.45
- This is achieved by buffering systems
  - **Extracellular**
    - Plasma proteins
    - Bicarbonate
- **Intracellular**
  - Proteins
  - Phosphate
  - Hemoglobin

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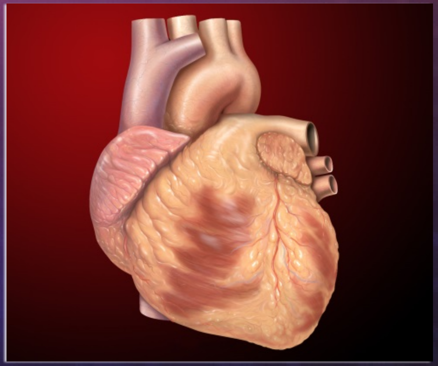
pH effect

- The most general effect of pH changes is on enzymes functions
- Also effect excitability of nerve and muscle cells
- ↓ pH ↓ Excitability

  ↑ pH ↑ Excitability

Acid Base Homeostasis

- Acid base balance requires a very narrow margin to prevent serious disease or death.
- H^+ ion concentration effect many cellular enzymes and functions of vital organ
- Most prominently the brain and the heart.



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Oxygenation

Oxygen evaluation

- Oxygen tension and oxygen saturation
- Oxygen tension is a measure of the partial pressure of 02
  - 760-40- 720 X 0.21%= 160
  - Atmosphere pressure- water pressure X Fi02.
- The Oxygen Tension will determine how much oxygen will be dissolved in blood and will be able to bind to Hgb

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Oxygen carrying capacity

- We cannot survive on dissolved oxygen alone.
- We need something to carry more oxygen –Hemoglobin is the perfect molecule for that.
- $CaO_2 = (SaO_2 \times Hg \times 1.34) + 0.003\ (PaO_2)$

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Oxygen saturation

- Measurement of what percent of Hemoglobin has oxygen attached.
- Oxygen saturation and Pa02 are related
- Can be seen in oxygen dissociation curve

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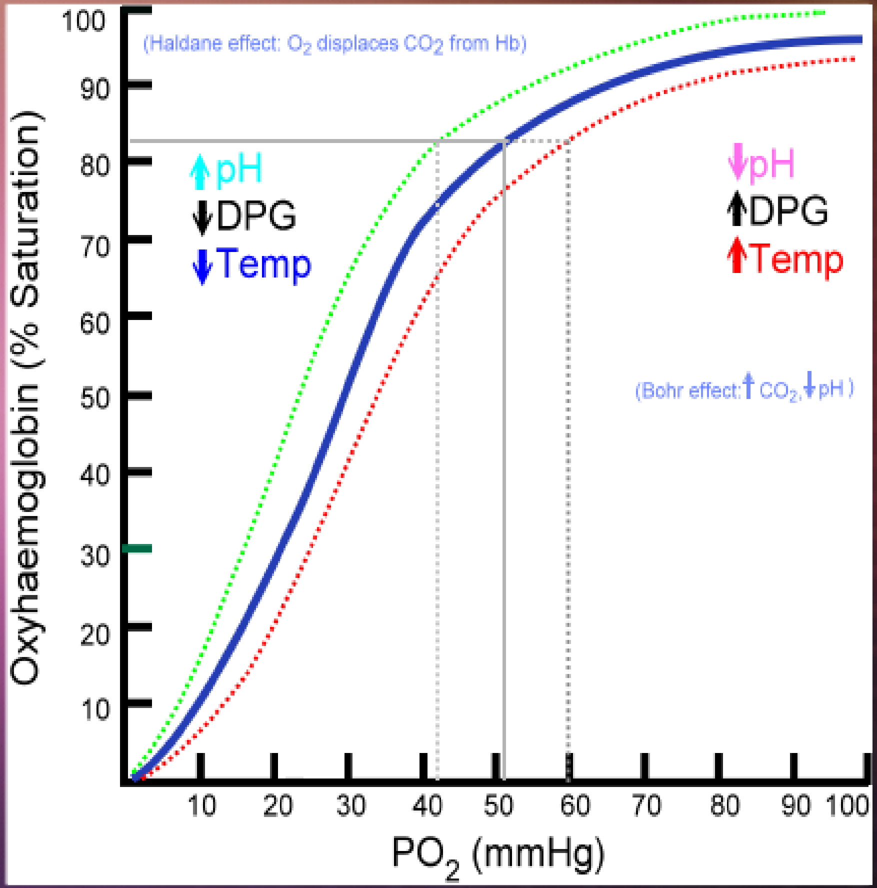
Oxygen saturation

- It is a measure percent oxygen binding sites.
- Pa02 and saturation are related
- Once Pa02 reaches 100 there is a steep increase in % saturation



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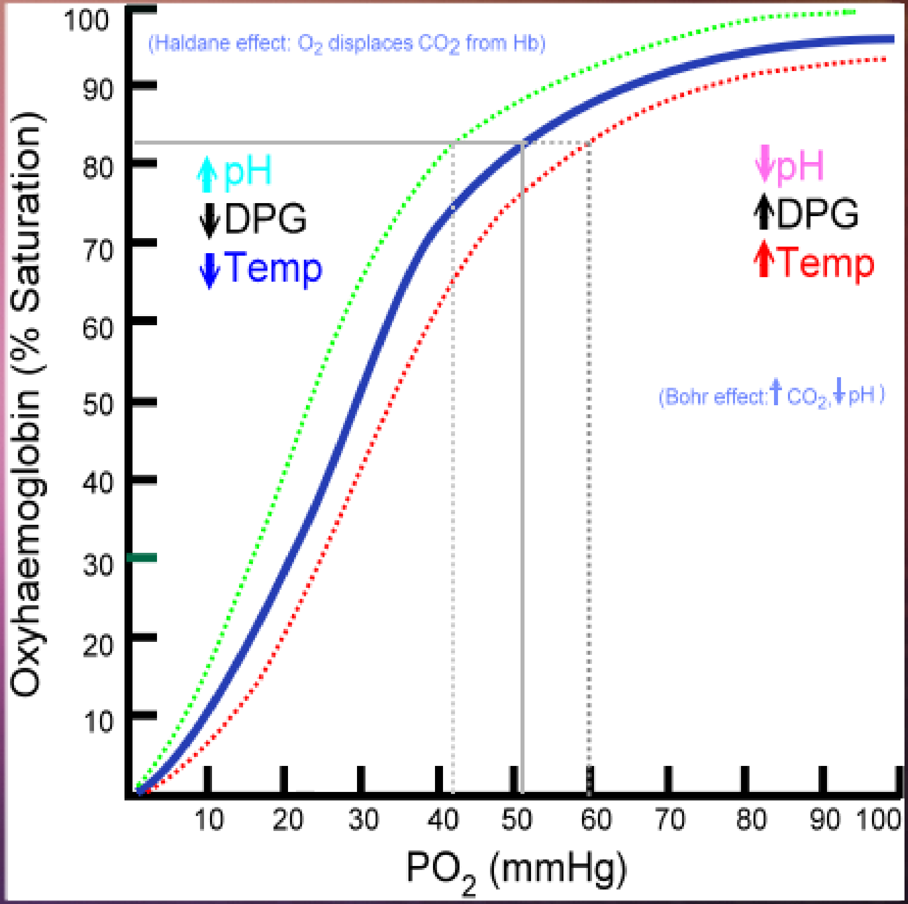
Oxygen dissociation curve

- The curve reaches a plateau the PaO_2 of 200 or400 the saturation remains 100 %
- PaO_2 50- Sat 85%
- PaO_2 60-Sat 90%
- PaO_2 100 Sat 100%



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Base Excess
Base Deficit

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What is Base Excess/Deficit

- Base excess=Defined by the amount of strong acid added to blood to make the pH 7.4 at a PaC02 40.
- Base deficit=the amount of strong base needed.
- It is determined from an equation.
- It is based on amount of Bicarbonate

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High Base Excess

- Excess Bicarbonate –Metabolic alkalosis
- Causes
  - Compensation for primary acidosis
  - Excessive loss of Hydrogen Chloride in gastric acid by vomiting
  - Renal overproduction of bicarbonate

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High Base Deficit

- Low levels of Bicarbonate-metabolic acidosis
  - Compensation for primary respiatory alkalosis
  - Diabetic ketoacidosis
  - Lactic acidosis
  - Chronic renal failure

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Steps in Analysis of blood gas

1. Is the pH normal –acidosis or alkalosis?
2. Is The Co2 normal?
3. Is the HC03 normal?
4. Is there compensation?
5. Which one matches Co2 or HCo3 with pH?
6. Does the C02 or HC03 go in the opposite
7. Are Pa02 and O2 saturation normal

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Does the pH match PCO_2?

- Does the pH match the PC02?
  - Guide:
  - For every 10 the C02 is above 40 the pH should change 0.08 in acute change
  - 60 — 40 =20 / 10=2
  - 2 X 0.08 = 0.16
  - 7.4 — 0.16= 7.24
  - Therefore this is pure acute respiratory acidosis without compensation

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Chronic respiratory acidosis

- Kidneys hold on to HC03
- Does C02 match chronic change ?
- 60-40 =20/10 =2 X 0.03 = 0.06
- 7.4 - 0.06 = 7.34
- Hc03 30 Be +4
- Therefore this is respiratory acidosis with metabolic compensation

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Case one

- A 12 Kg 2 year old has been admitted with pneumonia and is intubated and ventilated.
- The patients ventilator settings are
  - PiP 24, PEEP 5, Rate 20, 50% Fi02 TV
- pH 7.28, PC02 is 55 PaO2 70 HCO3 25

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Choose from the following:

1. This is acute respiratory acidosis
2. This is respiratory acidosis with metabolic compensation
3. The patient has hypoxia and respiratory acidosis

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CASE TWO

- A 4 Kg 6 month old male from the home ventilator program is admitted to the hospital with desaturations.
- Vent settings: PIP 22 PEEP 5, rate 30,FiO2 40%,TV 30
- His blood gas is a follows:
- 7.32, pCO2 66, PaO2 80

Choose from the following

- 1. Increase the PIP
- 2. Increase the rate to 35
- 3. Decease the rate to 25
- 4. Make no changes to the ventilator

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Conventional Ventilator changes to improve C02

- 1. Increase the ventilator respiratory rate.
- 2. Increase the tidal volume
- 3. Change the I:E ratio
- 4. Decrease the ventilator rate
  - When there is breath stacking and hyperinflation
  - Example asthma patients

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Blood Gas with Ventilators

- High CO_2
  - Obstructed ET Tube
  - Pneumothorax
  - Patent Ductus Arteriosus
  - Right Main stem intubation

- Treat
  - Increase
    - PIP
    - Rate
    - Increase expiratory time
  - Correct underlying problem

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Respiratory acidosis

- pC02 is indicative of the minute ventilation
- Tidal Volume X respiratory rate
- As the minute ventilation increases the pC02 decreases
- A high pC02 signifies a decreased minute ventilation

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Etiology Respiratory Acidosis

- CNS depression
- Obstructive sleep apnea
- Obesity hypoventilation
- Lung and airway disease
  - ARDS
  - Chronic lung disease of newborn

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Respiratory acidosis

- A high $pC0_2$ in conjunction with a low $P0_2$ suggest mixed respiratory failure
  - $PaO_2 < 60$ $PaCO_2 > 50$
- The patient may appear lethargic, with poor respiratory effort.
- The patient requires positive pressure ventilation by bag mask and may need intubation with mechanical ventilation

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Case Three

- A patient with type I diabetes presents to the ED with abdominal pain and vomiting.

- pH 7.27 $PaCo_2$ 23 PaO_2 95 HC0 10
- Na 132, K 6.0, Cl 93, HCo_3 11 glucose 730

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Choose from the following

- 1. This is primary respiratory alkalosis
- 2. This is primary metabolic acidosis
- 3. This is anion gap metabolic acidosis
- 4. The $PaCO_2$ matches the pH
- 5. 2, 3, 4.
- 6. 2,3

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Assessment of Acid Base Balance

- May require more than a Blood Gas
- Anion Gap will need to be included
- Serum electrolytes will need to be determined.

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Acidosis Clinical Features

- pH <7.2
  - Can produce cardiovascular, respiratory , CNS symptoms
  - Myocardial contractility is impaired and can progress to circulatory shock
  - Respirations become deep and slow
  - CNS depress can lead to coma
  - Hyperkalemia is potential complication

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Metabolic Acidosis

- Definition -fall of Hc03 below 24 usually associated with low pH
- Causes -three main types
  - Loss of HC03
    - Renal losses of Hc03
    - Diarrhea
  - Gain of acid
    - Ingestion of acid
    - Ketoacidosis
    - Lactic Acidosis
  - Failure to excrete acid
    - Renal failure

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Metabolic acidosis

- Treat underlying cause
- Fluids
- Inotropic agents
- Antibiotics
- NaHc03 -controversial

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Metabolic alkalosis

- Metabolic Alkalosis
  - Excess alkali- chronic antacids
  - Potassium depletion
  - Loss of Chloride and retaining HC03
- Is there respiratory compensation?
  - Rare but patients can hypo ventilate and become apneic

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Anion Gap

- Serum anion gap is useful to determine whether a base deficit is caused by addition of acid or loss of bicarbonate.
- Anion Gap: positive ions minus the negative ions
- $(Na) - (Cl^{-} + HC0_3^{-}) = 6\text{-}12$ meq/L

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High anion gap metabolic acidosis

- M methanol
- U uremia
- D DKA, diuretics
- P paraldehyde ,propofol
- I INH
- L lactate
- E ethanol
- S salicylates

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Non anion gap metabolic acidosis

- H hyperalimentation
- A acetazolamine
- R renal tubular acidosis
- D diarrhea
- U uretosigmoid fistual- colon waste $HC0_3$
- P pancreatic secretes bicarbonate

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Case 3 review

- Anion gap
  - AG: 132- (93 +11) = 28
  - This is metabolic acidosis with compensated elevated anion gap acidosis
  - Since the $PC0_2$ and $HC0_3$ are abnormal in the same direction this is most likely a metabolic problem

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Case 4

- A 10 year old CHD patient was admitted for fever. Home medications are thiazide diuretic and digoxin
- pH 7.38 $PC0_2$ 32 $HC0_3$ 19 PaO_2 82
- Na 132 K 2.7 Cl 79, Hco_3 19

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Choose from the following

- 1. This is a primary metabolic acidosis
- 2. This is a acute respiratory alkalosis
- 3. This is anion gap metabolic acidosis
- 4. This is chronic respiratory alkalosis
- 5. 1,3,4
- 6. 1,3,4

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Case Five

- A 8 year old female with chronic renal failure. Presented to the ED with tachypnea and fever.
- pH 7.28, $PaCO_2$ 32, PaO_2 85, HCO_3 16
- Na 131 Cl 105, HCO_3 15

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Choose from the following

- 1. This is a mixed metabolic acidosis and respiratory alkalosis
- 2. This a mixed metabolic acidosis and respiratory acidosis
- 3. This is anion gap metabolic acidosis
- 4. This is non-anion gap metabolic acidosis
- 5. 1 and 4 above

Choose from the following

- 1. This is respiratory acidosis
- 2. This is respiratory alkalosis
- 3. This is metabolic acidosis
- 4. The change in HCO_3 matches CO_2
- 5. 3, 5 , 2 above

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Respiratory Alkalosis

- Acute respiratory alkalosis with PC02 <30; pH>7.50 represents acute alveolar hyperventilation
  - Usually increased work of breathing
  - Seen in
    - Response to hypoxemia
    - Response to metabolic acidosis

      CO2= (HCO3 X 1.5) + 8 (+ or – 2)
    - CNS malfunction

Blood Gas with Ventilators

- Low Oxygen
  - Blood gas type
    - Venous/Capillary
  - Low FiO2
  - Low/No PEEP
  - ARDS

- Treat
  - Increase
    - FiO2
    - PEEP
    - Increase Inspiratory time

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Examples

- First check the pH if it less than or greater than 7.40
- Example:
- pH 7.24 pC02 60, p02 70, Hco3 24 Be -3
- pH is acidosis
- $PC0_2$ is elevated maybe signs of respiratory failure
- Respiratory acidosis with a normal Hco3

Respiratory acidosis

- If the patient is not intubated the following ABG is seen
- pH 7.04 PC02 60 P02 70 HC03 16 BE -13
- Due to tissue hypoxia patient changes to anaerobic metabolism and generates lactic acid.
- NaHc03 decreases.
- Now is metabolic and respiratory acidosis

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Stages of ABG's with respiratory failure

Stage	pH	PAC02	PaO2
0	7.40	40	100
1	7.53	20	100
2	7.53	20	70
3	7.44	37	70
4	7.20	60	50

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Other Causes

- Other causes of metabolic acidosis with respiratory alkalosis
  - Ketoacidosis- here the pC02 is usually lower
  - Dehydration
  - Sepsis
  - Shock

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QUESTIONS

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