Acid/Base and ABG Interpretation Made Simple
A-a Gradient

- $FIO_2 = PA\ O_2 + \left(\frac{5}{4}\right) PaCO_2$
- $FIO_2 = 713 \times O2\%$
- A-a gradient = $PA\ O_2 - PaO_2$
  - Normal is 0-10 mm Hg
  - $2.5 + 0.21 \times \text{age in years}$
- With higher inspired O2 concentrations, the A-a gradient will also increase
PaO2-FiO2 ratio

- Normal PaO2/FiO2 is 300-500
- <250 indicates a clinically significant gas exchange derangement
- Ratio often used clinically in ICU setting
Hypoxemia

- Hypoventilation
- V/Q mismatch
- Right-Left shunting
- Diffusion impairment
- Reduced inspired oxygen tension
Hypoventilation

- CNS depression (OD or structural/ischemic CNS lesions involving respiratory center)
- Neural conduction D/O’s (amyotrophic lateral sclerosis, Guillain-Barre, high cervical spine injury)
- Muscular weakness (polymysitis, MD)
- Diseases of chest wall (flail chest, kyphoscoliosis)
V/Q mismatch

- Lung regions with low ventilation compared to perfusion will have low alveolar oxygen content and high CO2 content.
- Lung regions with high ventilation compared to perfusion will have a low CO2 content and high oxygen content.
- V/Q varies with position in lung (lower in basilar than apical) – WEST ZONES.
Diseases that affect V/Q

- Obstructive lung diseases
- Pulmonary vascular diseases
- Parenchymal lung diseases
Right to Left Shunt

- Extreme example of V/Q mismatch
- Shunt physiology may result from parenchymal diseases leading to atelectasis or alveolar flooding (lobar pneumonia or ARDS)
- Can also occur from pathologic vascular communications (AVM or intracardiac shunts)
Diffusion Impairment

- When available path for movement of oxygen from alveolus to capillary is altered
- Diffuse fibrotic diseases are the classic entities
Reduced inspired oxygen delivery

- Delivery to tissue beds determined by arterial oxygen content and cardiac output
- Oxygen content of blood is affected by level and affinity state of hemoglobin
  - Example is CO poisoning: reduction of arterial O2 content despite normal PaO2 and Hgb caused by reduction in available O2 binding sites on the Hgb molecule
- Reduced CO will lead to impairment in tissue O2 delivery and hypoxemia and lactic acidosis
Oxygen Delivery, cont.

- Tissue hypoxia may occur despite adequate oxygen delivery
  - CN poisoning causes interference with oxygen utilization by the cellular cytochrome system, leading to cellular hypoxia
- Disease states such as sepsis may result in tissue ischemia possibly because of diversion of blood flow away from vital organs
ACID/BASE

- 15,000 mmol of CO2 (generates H2CO2) and 50-100 meq of nonvolatile acid (mostly sulfuric from sulfur-containing amino acids) are made.
- Balance is maintained by normal pulmonary and renal excretion of these acids.
Renal excretion

- Involves the combination of hydrogen ions with urinary titratable acid, particularly phosphate (HPO42- + H+ to H2PO4-) or with ammonia to form ammonium.

- Ammonium is the primary adaptive response since ammonia production from the metabolism of glutamine can be increased in the presence of an acid load.
Definitions

- **Acidosis**: process that lowers the ECF pH by a fall in HCO3 or elevation in PCO2
- **Alkalosis**: process that raises ECF pH by an elevation in ECF HCO3 or fall in PCO2
- **Met Acidosis**: low pH and low bicarb
- **Met Alkalosis**: high pH and high bicarb
- **Resp Acidosis**: low pH and high PCO2
- **Resp Alkalosis**: high pH and low PCO2
Metabolic Acidosis

- Respiratory compensation results in 1.2 mm Hg fall in PCO2 for every 1 meq/L fall in bicarb
- \[ pCO2 = 1.5 (HCO3) + 8 \]
- DON’T LEARN IT!!!
- OR Last two digits of pH should equal PCO2
  - if equal = no respiratory disturbances
  - if PCO2 high = overlapping respiratory acidosis
  - if PCO2 low = overlapping respiratory alkalosis
Metabolic Acidosis, cont.

- Calculate anion gap on chem7
- Na - (Cl + CO2) = around 8
- If > 8 = Anion Gap metabolic acidosis
Metabolic Acidosis...continued

- Add delta gap back to CO2 = corrected bicarb
- if corrected bicarb = 24-26 then no other disturbance
- if corrected bicarb < 24-26 then non-anion gap acidosis is superimposed (or chronic resp alkalosis)
- if corrected bicarb >24-26 then met alkalosis is superimposed (or chronic resp acidosis)
- if <8 = Non Anion Gap metabolic acidosis
Metabolic Alkalosis

- Respiratory compensation raises PCO2 by 0.7 mmHg for every 1 meq/L rise in HCO3
- Causes include vomiting, intake of alkali, diuretics, or very commonly, NG suction without the use of proton-pump inhibitors or H2 blockers
Respiratory Acidosis

- Compensation occurs in 2 steps
  - 1. Cell buffering that acts within minutes to hours
  - 2. Renal compensation that is not complete for 3-5 days

- IN ACUTE: Bicarb rises 1 meq/L for every 10 mmHg elevation in PCO2
  - or for every 1 up of PCO2, pH should fall .0075

- IN CHRONIC: Bicarb rises 3.5 for every 10
  - or for every 1 up of PCO2, pH should fall .0025
  - due to tighter control of pH by increased renal excretion of acid as ammonium
Respiratory Alkalosis

- **ACUTE**: Plasma bicarb falls by 2 for every 10 fall in PCO2
- **CHRONIC**: Bicarb falls by 4 for every 10 fall in PCO2
TO SUM UP...

- **Respiratory Acidosis**
  - HCO₃ goes UP by:
    - 1 in acute (for 10 PCO₂ up)
    - 3.5 in chronic (for 10 PCO₂ up) = just remember 3, not 3.5 for memory purposes

- **Respiratory Alkalosis**
  - HCO₃ goes DOWN:
    - 2 in acute (for 10 PCO₂ down)
    - 4 in chronic (for 10 PCO₂ down)
SO...

- For the respiratory compensation calculations, EVERYTHING is in units of 10 mm Hg PCO2
- You just have to remember 4 numbers and remember that it starts with Acute Resp Acidosis...
- 1, 3, 2, and 4!!!
Anion Gap

- Anion Gap = Na - (Cl + HCO3) = UA – UC
  - Because Na + UC has to equal Cl + HCO3 + UA
  - Remember algebra?

- UA = Unmeasured anions = albumin, phosphate, sulfate, lactate

- UC = Unmeasured cations = Ca, K, Mg
Low Anion Gap

- Caused by decrease in UA
  - albuminuria secondary to nephrotic syndrome
- Caused by increase in UC
  - Multiple myeloma (positively charged Ab’s)
Delta Gap

- Delta Gap = AG - 8
- Corrected Bicarb = Bicarb + delta gap
- 24-26 roughly = no other d/o
- <24-26 = hyperchloremic acidosis or chronic resp alkalosis
- >24-26 = metabolic alkalosis or chronic resp acidosis
Chloride/Sodium Correction

- 7/10 rule: Multiply Na excess by 0.7 and add to chloride
- if hypochloremic = metabolic alkalosis or chronic resp acidosis
- if hyperchloremic = metabolic acidosis or chronic resp alkalosis
Approach To ALL Acid/Base Problems

- Don’t get overwhelmed by all the numbers at once!
- Use a methodical system to dissect the numbers, and you will never be stumped (almost never).
- Don’t jump ahead when doing calculations.
METHODICAL SYSTEM

- Get all your numbers in front of you first...
- Chem 8 + ABG, or sometimes just ABG
- Look at pH first: Acidotic or alkalotic?
- Metabolic or Respiratory?
- Go straight to Bicarb!
- Correlate bicarb with PCO2 and it should be obvious
- Calculate anion gap no matter what the disturbance is!
After you come up with “primary disturbance”, your next question should ALWAYS BE =

“Is there compensation?”

For metabolic acidosis… do last two digits of pH equal PCO2 or not

For resp acidosis… is it acute or chronic, and is the HCO3 up appropriately?

For resp alkalosis… is it acute or chronic, and is the HCO3 down appropriately?
Compensation

The Two Given Rules of Compensation:

1. **METABOLIC = BICARB (HCO3)**
   
   ...So if you dealing with figuring out your disturbance and it is metabolic (up or down HCO3), then the compensation will be RESPIRATORY (is the PCO2 appropriately up or down)
2. RESPIRATORY = PCO2

...So if you are dealing with respiratory alkalosis or acidosis, you want to know if the METABOLIC (HCO3) compensation is appropriate or not
- If the compensation is INAPPROPRIATE, then you automatically have a SECOND superimposed acid/base disorder
- If have a metabolic acidosis, and the compensation is inappropriate, it is possible to have a TRIPLE acid/base disturbance if you have a superimposed resp disorder AND a non-anion gap disorder (remember calculation of delta-gap?)
EXAMPLE 1

- Pt with diarrhea and ABG done
- 7.23/23/??/10
- Anion-gap normal
- Low pH, low bicarb = Metabolic Acidosis
- Last two digits of pH = PCO2 = SIMPLE
- If PCO2 had been 40…= concurrent resp acidosis
- If PCO2 had been 16…= concurrent resp alkalosis
EXAMPLE 2

- 7.27/70/??/31
- pH low, PCO2 high = Respiratory Acidosis
- Acute or Chronic? --correlate with clinical hx
- If Acute = HCO3 should go up by 1 per 10 rise in PCO2 = 3, so HCO should be up to 27
- 27 < 31 = superimposed metabolic alkalosis (HCO3 is higher than it should be)
- If Chronic = HCO3 should go up by 3 per 10 = 9, so HCO3 should be up to 33
- 33 > 31 = superimposed mild metabolic acidosis
EXAMPLE 3

- 85 year old male with bloody diarrhea
- 7.32/33/80/20
- Na 138, K 4, Cl 104, CO2 20, CI 104, Cr 8.4, Gl 129
- GO STRAIGHT TO BICARB!!! = 20 (too low)
- Low pH, low bicarb = Metabolic Acidosis
- Compensation?
- Last two digits of pH 32 pretty close to pCO2 33
- Anion gap?
- 14 = Anion gap met acidosis = uremia
- Delta gap? 14-8 = 6
- Corrected bicarb = 6 + 20 = 26 (fairly close) = no other dist
EXAMPLE 4

- 71 year old diabetic male who is weak
- Na 135, K 6.9, Cl 108, CO2 19, BUN 63, Cr 2.2, Gl 152
- >> HCO3 low at 19!!
- Don’t know about compensation yet because no ABG
- Metabolic Acidosis : what is gap?
- Gap 8: non anion gap acidosis: etiology?
- Diarrhea vs RTA = do urinary anion gap gap = positive
- Which RTA gives you hyperkalemia in a diabetic with renal insufficiency?
- Type IV = hyporeninemic hypoaldosteronism
EXAMPLE 5

- 88 yo female with lethargy and weakness
- Na 141, K 3, Cl 95, CO2 36, BUN 51, Cr 3.4, Gl 112
- Ca 15.4
- High CO2 = metabolic alkalosis or chronic resp acidosis?
- Further hx reveals taking too much tums and Oscal D
- =Metabolic Alkalosis and hypercalcemia
- =Metabolic Alkalosis + High Ca + renal dysfxn = ???
- Milk-Alkali syndrome
EXAMPLE 6

- 31 year old AAM took too many pills for suicide attempt
- Na 139, K 5.2, Cl 110, CO2 16, BUN 47, Cr 6.8, Glu nl
- What is disturbance?
- Met acidosis or chronic resp alkosis
- ABG 7.30/30/80/15 = appropriate resp compensation
  - No other disturbance present
- What is Gap? = 13 = Anion Gap Met Acidosis
- Delta Gap 13-8 = 5
- Corrected Bicarb = 21
- Still too low = second met acidosis superimposed
- Non Anion Gap Acidosis = likely RTA secondary to ARF
EXAMPLE 7

- 21 year old WF with SLE
- Na 136, K 4.7, Cl 117, CO2 14, BUN 102, Cr 4.1, G nl
  - Last Cr was 0.6 two months PTA
- What is the disturbance?
- Met acidosis or chronic resp alkalosis: What is Gap?
- Gap = 5 = Non Anion Gap Met Acidosis : likely from RTA secondary to ARF
- Albumin 1.3 = so unmeasured anions LOW which can make anion gap low (or increase in UC)
- So likely anion gap met acidosis secondary to ARF + non anion gap met acidosis secondary to RTA
EXAMPLE 8

- AIDS patient c/o dyspnea OFF HAART
- Na 121, Cl 88, CO2 13, BUN 116, Cr 7.8
- ABG 7.31/22/63
- START with BICARB = 13 = too low
- Low pH, Low bicarb = Metabolic acidosis
- Compensation? PCO2 should be 31, it is 22, so superimposed Resp Alkalosis
- Anion Gap? = 20, so AG metabolic acidosis
- Delta Gap = 20-8 = 12, cHCO3 = 25 (OK)
- Etiology?
EXAMPLE 9

- 74 year old WF with AMS and h/o quadriplegia
- Na 121, K 5.3, Cl 84, CO2 18, BUN 15, Cr 0.5, Gl nl
- What is disturbance? Met acidosis or chronic resp alk
- Compensation? 7.42/29/75/19
- pCO2 should be 42 = 29 too low = addnl Resp Alkalosis
- What is gap? = 19 = Anion Gap met Acidosis
- Delta Gap = 19-8 = 11
- Correctected Bicarb = 18 + 11 = 29 = too high = superimposed met alkalosis
- TRIPLE D/O!!!
- What causes met acidosis + resp alk ?
- SALICYLATES vs infection
- Infection in her case with likely urosepsis syndrome
82 year old hypotensive transfer with massive GI bleed
- Na 148, K 4.7, Cl 123, CO2 16, BUN 158, Cr 3, Glc nl
- ABG 7.22/39/34/16
- >>HCO3 16 with low pH = met acidosis
- Compensation? PCO2 should be 22, it is 39, so superimposed RESP ACIDOSIS = ?etiology?
- Gap? 9 so Anion Gap Acidosis = ?etiology?
- Delta gap? 9-8=1, so cHCO3 = 17 = too low, so...
- Superimposed non-anion gap acidosis = ?etiology?
- TRIPLE D/O!!
CONCLUSIONS...

- Don’t get overwhelmed, identify the primary (or even just an obvious) disorder and build from that.
- When answering the question about compensation, you may often uncover a second disorder.
- When calculating the delta gap, you may even uncover a third disorder!
CONCLUSIONS…

- Now did you ever think in medical school that you would be able to interpret a triple acid/base disorder?
- If you use this method to tease out the disturbances, you will NOT get stumped.
- You can then use these interpretations to better understand the patient and possibly entertain diagnoses that you might not have considered using your differential lists for the various acid/base disorders!
The End...