Acid/Base and ABG Interpretation Made Simple

A-a Gradient

- FIO2 = PA O2 + (5/4) PaCO2
- FIO2 = 713 x O2%
- A-a gradient = PA O2 - PaO2
  - Normal is 0-10 mm Hg
  - 2.5 + 0.21 x 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 (polymositis, 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 CO_2 content
- Lung regions with high ventilation compared to perfusion will have a low CO_2 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 ($HPO_4^{2-} + H^+$ to $H_2PO_4^-$) 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 CO_2 = 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 PCO_2 by 0.7 mmHg for every 1 meq/L rise in HCO_3
- 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
  - HCO_3 goes UP by:
    - 1 in acute (for 10 PCO_2 up)
    - 3.5 in chronic (for 10 PCO_2 up) = just remember 3, not 3.5 for memory purposes
- Respiratory Alkalosis
  - HCO_3 goes DOWN:
    - 2 in acute (for 10 PCO_2 down)
    - 4 in chronic (for 10 PCO_2 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 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!

SYSTEM…continued

- 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 (HCO_3)

…So if you dealing with figuring out your disturbance and it is metabolic (up or down HCO_3), then the compensation will be RESPIRATORY (is the PCO_2 appropriately up or down)

Compensation…continued

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

SYSTEM…continued

- If the compensation is INAPPROPRIATE, then you automatically have a SECOND superimposed acid/base disorder
- If have a metabolic acidosis, and the compensation is inapropriate, 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, Cl 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 = positive
- Which RTA gives you hyperkalemia in a diabetic with renal insuffiency?
- Type IV = hyporeninemic hypoaldosteronism

EXAMPLE 5

- 88 yo female with lethargy and weakness
- Na 141, K 3, Cl 95, CO_2 36, BUN 51, Cr 3.4, Gl 112
- Ca 15.4
- High CO_2 = 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, CO_2 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

EXAMPLE 10

- 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…