Let's Talk About Gas:
ABG Interpretation Made Easy

Andrew Walker, PSM, MS, PA-C
Physician Assistant
Instructor of Medicine
Critical Care/Internal Medicine
Mayo Clinic Arizona

Disclosures

- None.

Objectives

At the end of this presentation, the learner should be able to:

1. Analyze an ABG to determine the primary acid-base disorder.
2. Recognize compensation and mixed acid-base disorders.
3. Discuss advanced concepts such as anion gap, corrected gap, and delta gap.
4. Formulate differential diagnoses for acid-base disorders and apply to clinical scenarios and decision making.

Acid-base Physiology

- Henderson-Hasselbach Equation:
  - **$[H^+]$ in nEq/L = 24 x (PCO_2 / $[HCO_3^-]$)**
- Where $[H^+]$ is related to pH by:
  - **$[H^+]$ in nEq/L = $10^{(9\text{-pH})}$**
- To maintain a constant pH, PCO_2/HCO_3^- ratio should be constant
  - When one component of the PCO_2/HCO_3^- ratio is altered, the compensatory response alters the other component in the same direction to keep the PCO_2/HCO_3^- ratio constant

Before You Get an ABG

- Ask yourself…
  - What am I looking for/expecting?
  - Will this help guide or change my management?
    - How?
  - Will comparison be helpful after treatment/intervention?
    - Baseline ABG?

Contraindications to ABG

- Local infection
- Distorted anatomy
- Abnormal Allen test
- AV fistula
- Severe PVD
- Relative contraindications:
  - Anticoagulation, tPA, severe coagulopathy

- Consider a-line if repeat ABGs will be necessary!

Indications for ABG

- Identify respiratory, metabolic, and mixed acid-base disorders
- Monitoring acid-base status in disorders such as DKA
- Quantification of oxyhemoglobin and oxygen carrying capacity of the patient
- Quantification of levels of dyshemoglobins (methemoglobin, carboxyhemoglobin)

Indications for ABG

- Measuring partial pressures of respiratory gases involved in ventilation and perfusion, e.g…
  - COPD exacerbation
  - Asthma exacerbation
  - Pulmonary embolism
  - Pulmonary fibrosis
  - Pneumothorax
  - In these cases, can measure severity and progression of disease/exacerbation
- Assessment of response to mechanical ventilation

Some Clinical Scenarios Where an ABG is Useful in Acute Care

- Respiratory distress
- Hypoxia
- Airway obstruction
- Sepsis or shock
- DKA
- Renal failure
- Drug overdose or intoxication
- AMS or obtundation
- Monitoring response to invasive and non-invasive ventilation
- Code blue

Factors That Can Affect an ABG

- **Delayed Analysis**
  - Consumption of O_2 and production of CO_2 continues even after blood is drawn
  - Iced sample will maintain value for 1-2 hours
  - Un-iced sample will quickly lose value in 15-20 minutes
- **Leukocytosis**
  - ↓ pH and pO_2; ↑ pCO_2
  - 0.1 mL of O_2 consumed/dL of blood every 10 minutes in patients with normal leukocyte count

Factors That Can Affect an ABG

- **Excess Heparin**
  - Dilutional effect on results
    - ↓ HCO_3^- & $PaCO_2$
  - Only 0.05 mL heparin required for 1 mL blood
- **Temperature**
  - Most blood gas analyzers use 37ºC as baseline
    - Some may ask for patient's actual temperature and calculate values at both

Temperature Effects on ABG

- If **severe hyper/hypothermia**, values of pH & PCO_2 reported at 37℃ can be significantly different from *actual* values:

- **For every 1 C decrease below 37℃:**
  - **Subtract 5 mmHg pO2**
  - **Subtract 2 mmHg pCO2**
  - **Add 0.012 pH**

Warmed ABGs from hypothermic patients will show a higher PaO2, higher PaCO2, and a lower pH than what is actually present in the patient's blood *in vivo.*

- No consensus on reporting values after temperature "correction"
  - Temperature usually changes over time, making it harder to compare values if corrected for temperature

ABG vs. VBG

- **How does a VBG compare to an ABG?**
  - <u>Mean differences</u>:
    - **pH** → (+) 0.035 units
    - **pCO_2** → (+) 5.7 mmHg
      - Correlation dissociates in hypercapnia and shock
    - **HCO_3** → (−)1.41 mmol/L
    - **Base excess** → (+) 0.089 mmol/L
    - **Lactate** does *not* correlate >2mM
    - **PO_2** does *not* correlate (venous vs. arterial sampling)

ABG vs. VBG

- **Venous blood gases (VBG)** are widely used in the emergency setting
  - There is no data to confirm that this level of agreement is maintained in shock states or mixed acid-base disturbances
- **Why get a VBG over an ABG?**
  - ABGs are painful, come with increased risk of bleeding, hematoma, pseudoaneurysm, AV fistula, and may be more difficult to obtain resulting in delays of care

ABG vs. VBG

- There are certain scenarios where **ABG is necessary** to accurately determine certain values…
  - $PaCO_2$ in severe shock
  - $PaCO_2$ if hypercapnic (i.e. $PaCO_2$ >45 mmHg)
  - Lactate if >2 mMol

Components of the ABG

- **pH** = acid-base balance
- **PaO_2** = partial pressure of oxygen
- **$PaCO_2$** = the state of alveolar ventilation
- **Alveolar-arterial gradient (A-a gradient)** = gradient between alveolar and arterial oxygen, which increases with ventilation-perfusion mismatch
- **HCO_3^-** = reflects metabolic component of blood
- Calculations for compensation, anion gap, corrected gap, & delta gap must be done separately!

Base Excess

- **Normal = -3 to +3 mEq/L**
- The amount of acid or base it would take to return the pH back to 7.4
- Some consider it the best measure of metabolic disturbance!
- Does not take into account the appropriateness of metabolic response to a disorder

Normal Values

Component	Normal Range	Estimated Normal
pH	7.35 – 7.45	7.4
PaO_2	80 – 100 mmHg	100 – (0.3 x age)
PCO_2	35 – 45 mmHg	40 mmHg
HCO_3	22 – 26 mEq/L	24 mEq/L
A-a gradient	< 10 mmHg	< 10 mmHg

ABG Analysis Steps

1. **pH (normal 7.4)**
2. **PCO_2 (normal 40)**
   - High CO_2 = Respiratory acidosis
   - Low CO_2 = Respiratory alkalosis
3. **HCO_3 (normal 24)**
   - Low HCO_3 = Metabolic acidosis
   - High HCO_3 = Metabolic alkalosis

- Compensation rules
- Calculated/Corrected anion gap
- Delta gap

**paO2 in ABG tells us about the partial pressure of oxygen in blood. It is not used in assessment of acid-base disorders.*

ABG Analysis Steps

- To assess if the primary disorder is **respiratory** or **metabolic**…look at the change in pH and PCO_2
  - If pH and PCO_2 move in *opposite* directions, **respiratory** disorder is present
  - If pH and PCO_2 move in the *same* direction, **metabolic** disorder is present
- Beware of a mixed acid-base disorder
  - We will get there!

ABG Practice

- pH low (<7.4) = Acidosis
- pH high (>7.4) = Alkalosis

pH	PCO_2	HCO_3	Disorder
7.2	70	28	

pH	PCO_2	HCO_3	Disorder
7.2	30	16	

ABG Practice

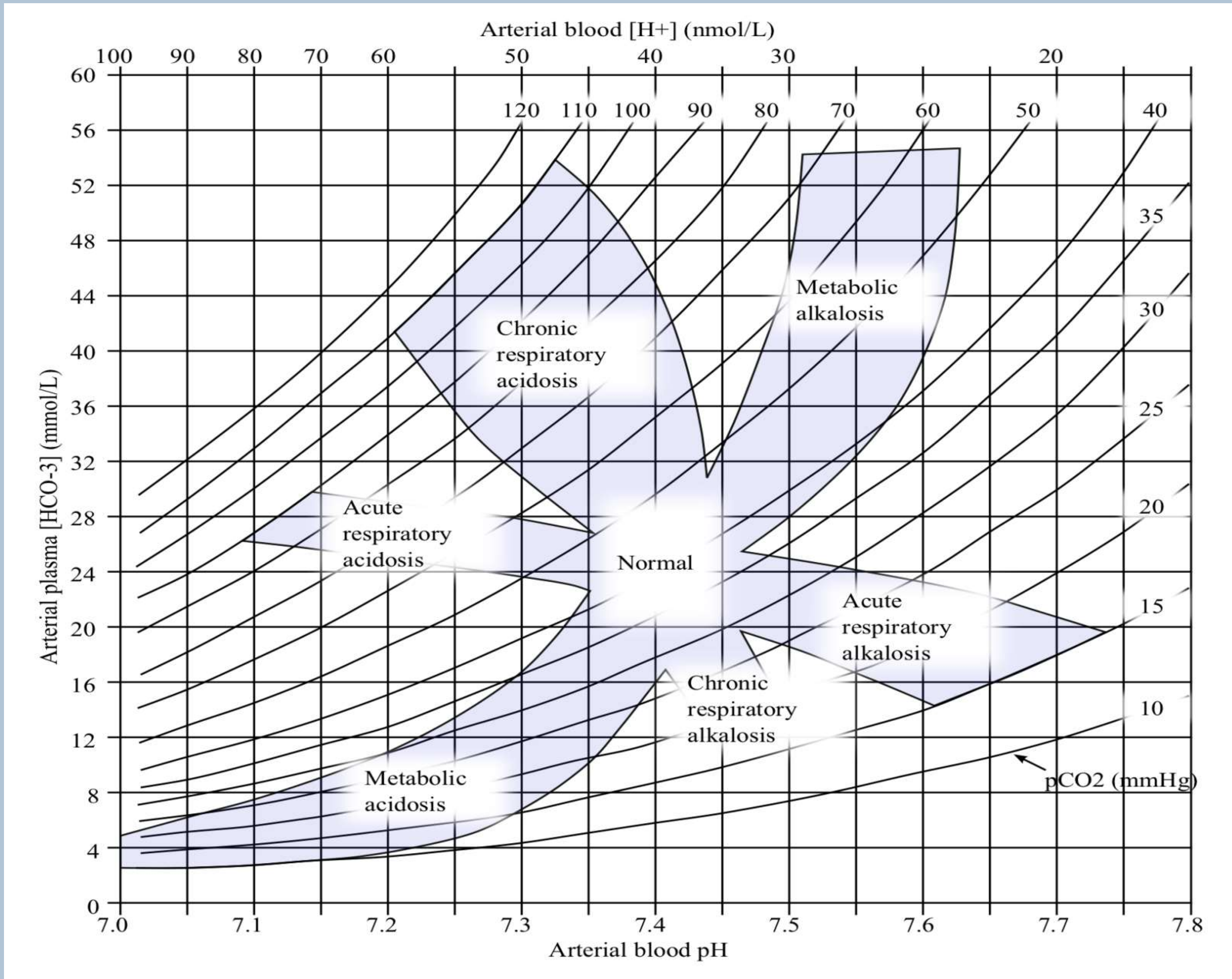
pH	PCO_2	HCO_3	Disorder
7.5	20	16	

pH	PCO_2	HCO_3	Disorder
7.4	60	35	

Steps 2-3: Acid-Base Derangements

Acid-Base Disorder	Primary Change	Compensatory Change
Respiratory acidosis	PCO_2 ↑	HCO_3 ↑
Respiratory alkalosis	PCO_2 ↓	HCO_3 ↓
Metabolic acidosis	HCO_3 ↓	PCO_2 ↓
Metabolic alkalosis	HCO_3 ↑	PCO_2 ↑

Acid-base Nomogram



Acid-base Differentials

Clinical Application: Respiratory Acidosis

- Intracranial issues (TBI, Stroke, SAH, etc.)
- Spinal or peripheral nerve issues (C-spine injury, myasthenia gravis, ALS, peripheral neuropathy, etc.)
- Drug overdose
- Chest wall issues
- Pulmonary issues (ARDS, asthma, pneumonia, COPD, massive PE/Shock)
- Extrathoracic/abdominal distention (obesity, compartment syndrome)

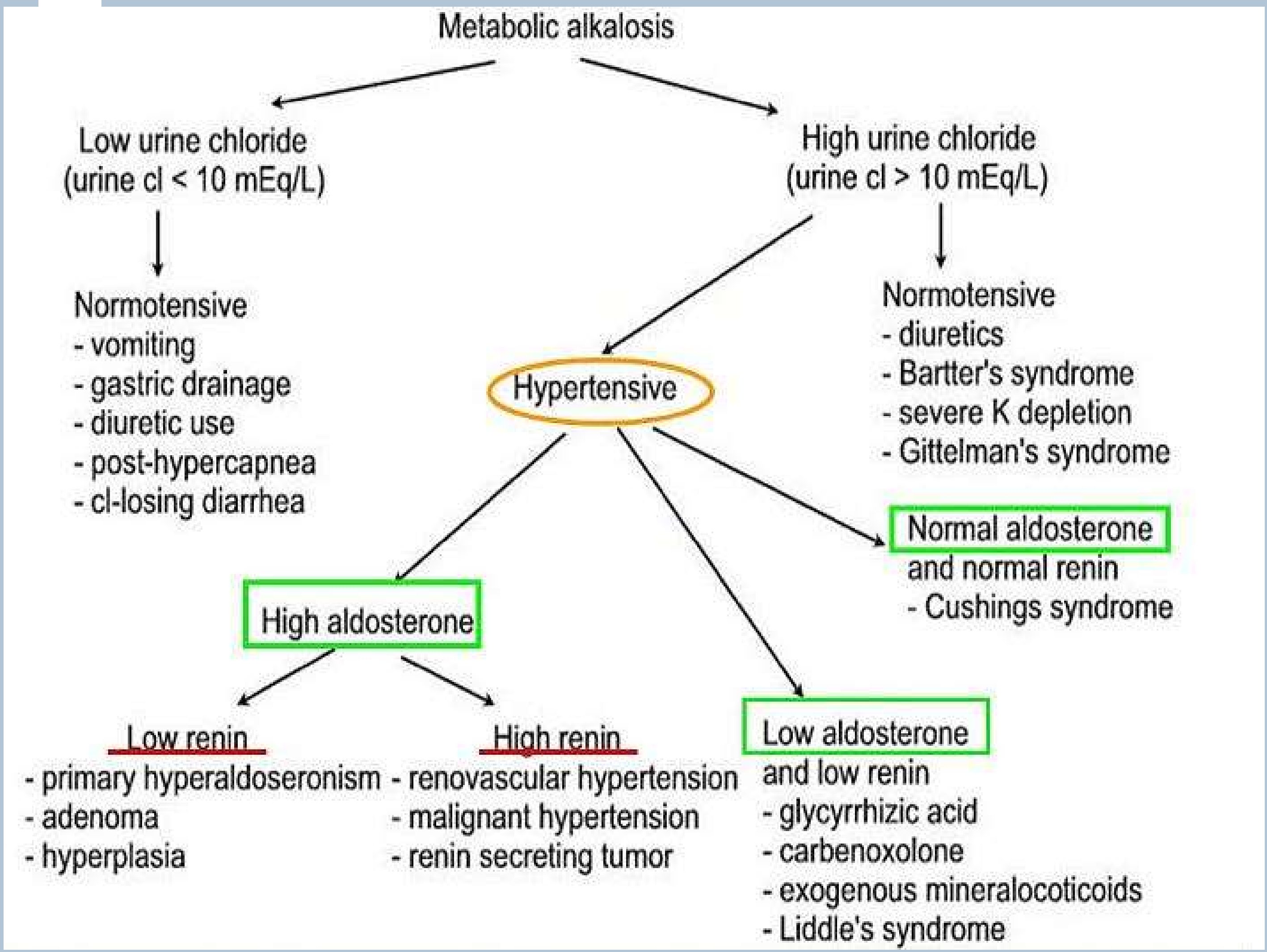
Clinical Application: Respiratory Alkalosis

- Pain
- Trauma
- Sepsis
- Pulmonary embolism
- Shock
- Drugs
- Pregnancy
- Hyperventilation (if they're tachypneic think sick first!)

Clinical Application: Metabolic Acidosis

- **MUDPILES**
  - Methanol
  - Uremia
  - DKA
  - Propylene glycol (ativan, dilantin)
  - Isoniazid/Iron
  - Lactate
  - Ethanol/Ethylene glycol
  - Salicylates / Seizures / Starvation
- **USEDCRAP**
  - Diarrhea
  - Ureteroenterostomy
  - Small bowel fistula
  - Pancreatoenterostomy
  - Excess chloride
  - Carbonic Anhydrase Inhibitors
  - Renal Tubular Acidosis (RTA)
  - Addison’s disease / Acetazolamide

Clinical Application: Metabolic Alkalosis



IV Fluid Composition

Fluid	Na	Cl	K	Mg	Ca	HCO3	Gluc	Ac	Gluc	Osm	pH
Plasma	140	104	4.5	1.25	2.5	24	0.08			290	7.4
0.9% Nacl	154	154								308	5.5
0.45% Nacl	77	77								406	
LR	130	109	4		1.5	28 (as Lac)				273	6.5
P-lyte	140	98	5	1.5				27	23	294	7.4
5% dex							5			278	

Case 1

- A 26 YO M with asthma presents to the ED with difficulty breathing; You suspect acute asthma exacerbation.
- **Vitals:** Temp 37.8; HR 120; BP 113/76; RR 28; SpO_2 93%
- **PE:**
  - He looks pale and is taking rapid, shallow breaths
  - Diffuse wheezing auscultated in all lung fields

Case 1

- ABG reveals the following:
  - pH 7.08
  - PCO_2 80 mmHg
  - $[HCO_3^-]$ 28 mEq/L

ACUTE RESPIRATORY ACIDOSIS

Case 1 Breakdown

- Reason for ABG?
  - Respiratory distress
- How do we manage?
  - What are we trying to correct?
  - Non-invasive vs. invasive strategies?

Case 2

- A 35 YO M presents to the ED with GSW to the abdomen. He is found pale, diaphoretic, and experiencing severe abdominal pain. While he is being resuscitated, an ABG is performed.

- ABG reveals the following:
  - pH 7.18
  - PCO_2 34 mmHg
  - $[HCO_3^-]$ 12 mEq/L

ACUTE METABOLIC ACIDOSIS

Case 2 Breakdown

- Reason for ABG?
  - GSW
  - Possible shock, hemorrhage
- How does the ABG change our course of treatment?
  - Think back to your differentials…

Case 3

- A 23 YO F student returns from a volunteer humanitarian trip to Haiti. She has been vomiting for 2 days. When seen by her physician, she appears dehydrated and her respirations are shallow.
    - ABG reveals the following:
        - pH 7.56
        - PCO_2 40 mmHg
        - $[HCO_3^-]$ 32 mEq/L

ACUTE METABOLIC ALKALOSIS

Case 3 Breakdown

- Reason for ABG?
  - Several days of vomiting
  - Shallow breaths
  - Assess severity
- Management?

Case 4

- An 80 YO F with metastatic breast CA, b/l malignant pleural effusions is admitted with weakness, FTT, and found to be in cardiac tamponade. A pericardial drain is placed.

- She then decompensates from respiratory standpoint, requiring 65L high flow nasal cannula at 100% FiO_2.
- **CXR:** worsening R sided loculated pleural effusion
- **TTE: (-)**
- **CTA: (-)**

Case 4

Laboratory and Microbiology Testing	28-Jul-2017 00:43 MST (2nd ABG)	27-Jul-2017 22:19 MST	27-Jul-2017 21:40 MST	27-Jul-2017 21:39 MST (1st ABG)
Blood Gases				
Pt Intubated?	No			NA
pH Arterial	7.223 (L)			7.253 * (L)
PaCO2	57.1 (H)			57.1 (H)
PaO2	79.4 (L)			86.3
Sat AO2	94.5			95.7
Cl Arterial	105			
Na Arterial	131.2 (L)			
K Arterial	4.57			
FIO2 Arterial	80.00			100.00
Art O2 PP Diff	415.1			549.6
Base Excess Arterial	-5.3 (L)			-3.5 (L)
Allen Test	Not Performed			Performed
Device Settings	hi flo 60l 80%			65L 100%
Sample Site Arterial	Arterial Line			Left Radial
Bicarbonate	23.0			24.6
THB	13.5			14.7
COHB	0.0			1.0
Methemoglobin	0.5			0.6
Temperature	37.0			37.0
Blood Gas Sample Site			Left Radial	
PaO2/FiO2 Ratio	0.99			0.86

ACUTE RESPIRATORY ACIDOSIS

Case 4 Breakdown

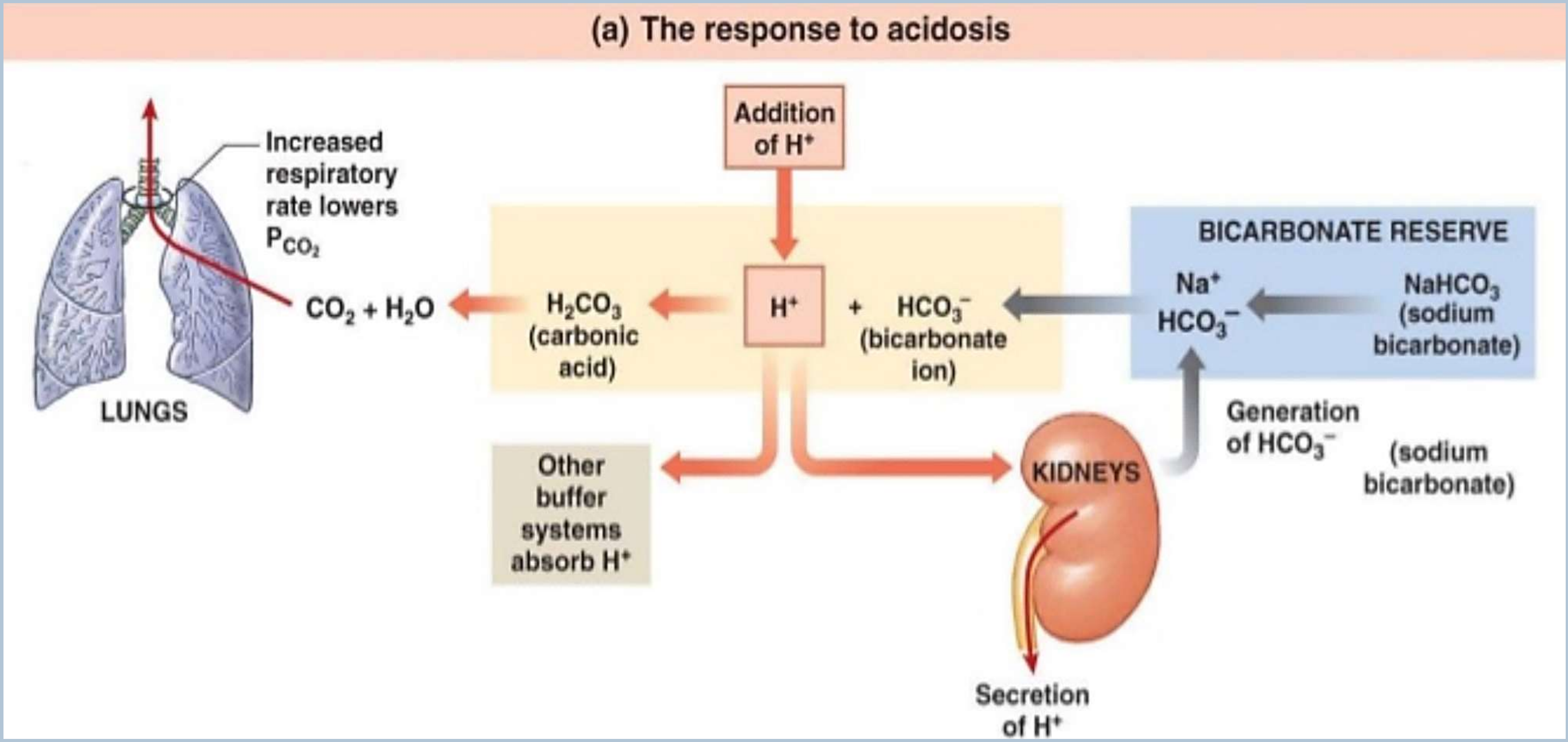
- Reason for ABG?
  - Respiratory decompensation
- How did these ABGs help our treatment course?

Case 5

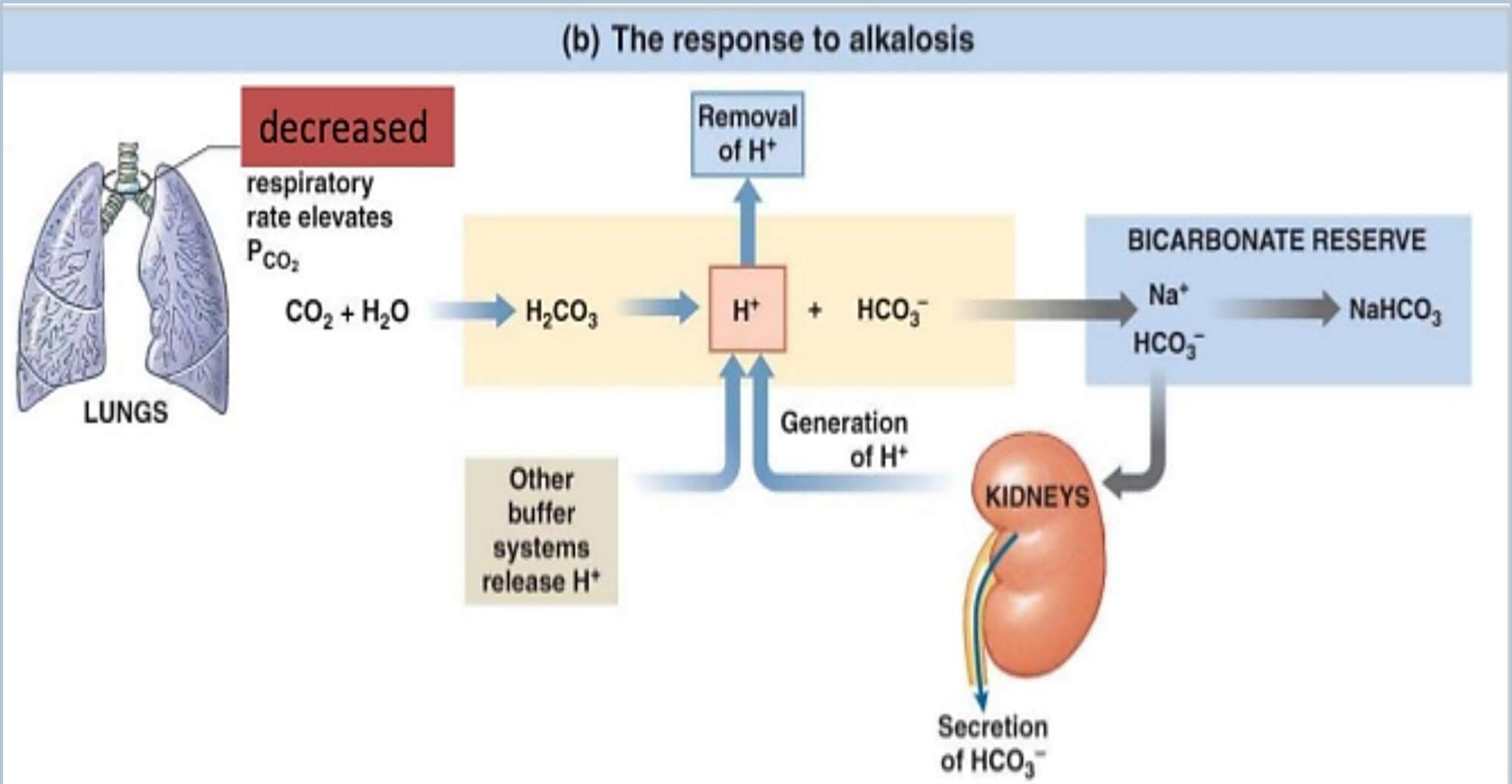
- A 20 YO M presents to the ED with 3 days of abdominal pain, nausea, vomiting, and dehydration. He appears unwell.
- Vitals:
  - HR 126, BP 100/64, RR 32, sPO2 96%
- ABG reveals the following:
  - pH 7.08
  - PCO_2 <17 mmHg
  - $[HCO_3^-]$ < 5 mEq/L

ACUTE METABOLIC ACIDOSIS

Buffering Systems/Compensation



Buffering Systems/Compensation



Compensation

- **Respiratory Rule #1:** pH changes INVERSELY by 0.08 for 10 mm CO_2 in **ACUTE** cases
  - DO NOT USE IN CHRONIC CASES…pH usually corrects/compensates to normal (7.4).
    - If CO_2= 50, pH will be 7.32 (0.08 below)
    - If CO_2=30, pH will be 7.48 (0.08 above)

- **Respiratory Rule #2**: For CO_2 change, how much does the HCO_3 change?
  - **Boston and Winter's Formulas**

Boston and Winter

Change in CO2	Change in HCO3	Condition	Example
10	1	Acute Resp Acidosis	If CO2=50, HCO3=25
10	2	Acute Resp Alkalosis	If CO2=30, HCO3=22
10	4	Chronic Resp Acidosis	If CO2=50, HCO3=28
10	5	Chronic Resp Alkalosis	If CO2=30, HCO3=19

- **Metabolic Rule:**
  - Metabolic acidosis, use Winter's famous formula: **Expected pCO_2= 1.5 x HCO_3 + 8 +/- 2**

<u>ABG:</u>	
pH	7.18
PCO_2	34 mmHg
HCO_3	12 mEq/L

Back to Case 2…

- The expected degree of respiratory compensation is not present…
    - Expected PCO_2 in metabolic acidosis:
    - **= 1.5 x HCO3 + 8 (+/- 2)**
    - = 1.5 x 12 + 8 = **26** (+/- 2)

- BUT…we got a PCO_2 of **34** mmHg so the *expected degree of respiratory compensation is not present (2/2 respiratory depression from GSW and AMS)*. What does this mean?

Both respiratory and metabolic acidosis are present!!

Case 6

- A 78 YO M with metastatic squamous cell carcinoma of the maxilla is admitted with multifocal PNA.
- He initially required 3-4L O2, but was eventually weaned off.
- He then decompensated, requiring high flow nasal cannula oxygen.

Case 6

Blood Gases	
Pt Intubated?	No
pH Arterial	7.507 (H)
PaCO2	25.0 (L)
PaO2	63.8 (L)
Sat AO2	92.8 (L)
FIO2 Arterial	60.00
Art O2 PP Diff	324.5
Base Excess Arterial	-2.8 (L)
Allen Test	Performed
Device Settings	Simple Mask
Sample Site Arterial	Right Radial
Bicarbonate	19.4 (L)
THB	9.0 (L)
COHB	0.3
Methemoglobin	0.3
Temperature	37.0
Blood Gas Sample Site	
PaO2/FiO2 Ratio	1.06

RESPIRATORY ALKALOSIS + METABOLIC ACIDOSIS

Case 6 Breakdown

- Reason for ABG?
  - Respiratory decompensation
- Is compensation present?
- How does this help management of the patient?

Case 7

- A 64 M with ESRD 2/2 DM s/p kidney transplant on immunosuppression and chronic systolic HF presents with 3 days of with shortness of breath, fatigue, and crackles on chest auscultation.
- Vitals:
  - HR 100; BP 92/76; RR 20; SpO2 84%

Case 7

Laboratory and Microbiology Testing	16-Aug-2017 20:03 MST	16-Aug-2017 20:01 MST
Blood Gases		
Pt Intubated?		No
pH Arterial		7.296 (L)
PaCO2		23.3 (L)
PaO2		52.9 (L)
Sat AO2		85.5 (L)
FIO2 Arterial		40.00
Art O2 PP Diff		197.5
Base Excess Arterial		-13.7 (L)
Allen Test		Performed
Device Settings		5 L NC
Sample Site Arterial		Right Radial
Bicarbonate		11.1 (L)
THB		10.7 (L)
COHB		0.9
Methemoglobin		0.3
Temperature		37.0
Blood Gas Sample Site	Right Radial	
PaO2/FiO2 Ratio		1.32

RESPIRATORY ALKALOSIS

+

METABOLIC ACIDOSIS

Case 7 Breakdown

- Reason for ABG?
  - Shortness of breath, hypoxia, underlying comorbidities
  - Hypotension/tachycardia
- Is compensation present?
- How do we manage this patient?

Case 8

- A 63 YO male with chronic respiratory failure 2/2 restrictive and obstructive lung disease, heart failure (Bi-V nonischemic, EF 33%), and ESRD 2/2 diabetic nephropathy presents to the ED.
- He missed his last 2 sessions of hemodialysis and appears unwell and is short of breath.

Case 8

Blood Gases	
Pt Intubated?	No
pH Arterial	7.131 * (!)
PaCO2	49.6 (H)
PaO2	339.2 (H)
Sat AO2	99.4
Lactate POC	1.42
FIO2 Arterial	100.00
Art O2 PP Diff	304.2
Base Excess Arterial	-12.6 (L)
Allen Test	Not Performed
Device Settings	bipap 16/8
Sample Site Arterial	Right Brachial
Bicarbonate	16.2 (L)
THB	11.0 (L)
COHB	0.1
Methemoglobin	0.1
Temperature	37.0
PaO2/FiO2 Ratio	3.39

RESPIRATORY ACIDOSIS
+
METABOLIC ACIDOSIS

Case 8

- Reason for ABG?
    - Clinical suspicion
    - Missed HD, appears unwell
    - Acute on chronic hypoxic hypercarbic respiratory failure
- Is compensation present?
- How does this change management?

Case 9

- A 79 YO male with complicated PMHx presents to the ED in hypovolemic and vasodilatory shock 2/2 aspiration PNA, n/v/d, and PE.

Case 9

Blood Gases	
Pt Intubated?	No [2]
pH Arterial	7.308
PaCO2	17.2 [(!
PaO2	107.2
Sat AO2	97.5
Cl Arterial	106
Na Arterial	141.1
K Arterial	4.75
FIO2 Arterial	28.00
Art O2 PP Diff	61.9
Base Excess Arterial	-15.1
Allen Test	Not Performed [
Device Settings	2 NC [2]
Sample Site Arterial	Arterial Line [2]
Bicarbonate	8.8
THB	10.5 [(L)
COHB	0.2
Methemoglobin	0.4
Temperature	37.0
Blood Gas Sample Site	Arterial Line
PaO2/FiO2 Ratio	3.83

RESPIRATORY ALKALOSIS

+

METABOLIC ACIDOSIS

Case 9 Breakdown

- Reason for ABG?
  - Shock
  - PE
  - N/V/D
- Does the ABG change management?

Case 10

- A 79 YO male with CAD s/p CABG, CHF, atrial fibrillation, and mild aortic stenosis presents to the ED with GI bleeding and an AKI.

Case 10

Blood Gases	
Pt Intubated?	No
pH Arterial	7.470 (H)
PaCO2	52.4 (H)
PaO2	129.4 (H)
Sat AO2	98.4
Cl Arterial	94 (L)
Na Arterial	136.1
K Arterial	3.72
FIO2 Arterial	40.00
Art O2 PP Diff	87.5
Base Excess Arterial	12.1 (H)
Allen Test	Not Performed
Device Settings	Bipap 10/6 40%
Sample Site Arterial	Arterial Line
Bicarbonate	37.3 (H)
THB	9.3 (L)
COHB	1.1
Methemoglobin	0.2
Temperature	37.0
PaO2/FiO2 Ratio	3.23

RESPIRATORY ACIDOSIS

+

METABOLIC ALKALOSIS

Case 10 Breakdown

- Reason for ABG?
  - Comorbidities, AKI
- Is compensation present?

Case 11

- A 55 YO M with Type 1 DM presents to the ED with 2 days of nausea, vomiting, and shortness of breath.

Case 11

Blood Gases	
Pt Intubated?	No
pH Arterial	7.327 (L)
PaCO2	19.9 * (!)
PaO2	129.3 (H)
Sat AO2	98.2
Cl Arterial	98
Na Arterial	142.3
K Arterial	3.23 (L)
FIO2 Arterial	21.00
Art O2 PP Diff	
Base Excess Arterial	-13.9 (L)
Allen Test	Performed
Device Settings	ra
Sample Site Arterial	Left Brachial
Bicarbonate	10.2 (L)
THB	10.2 (L)
COHB	0.2
Methemoglobin	0.2
Temperature	37.0
Blood Gas Sample Site	
PaO2/FiO2 Ratio	6.16

RESPIRATORY ALKALOSIS

+

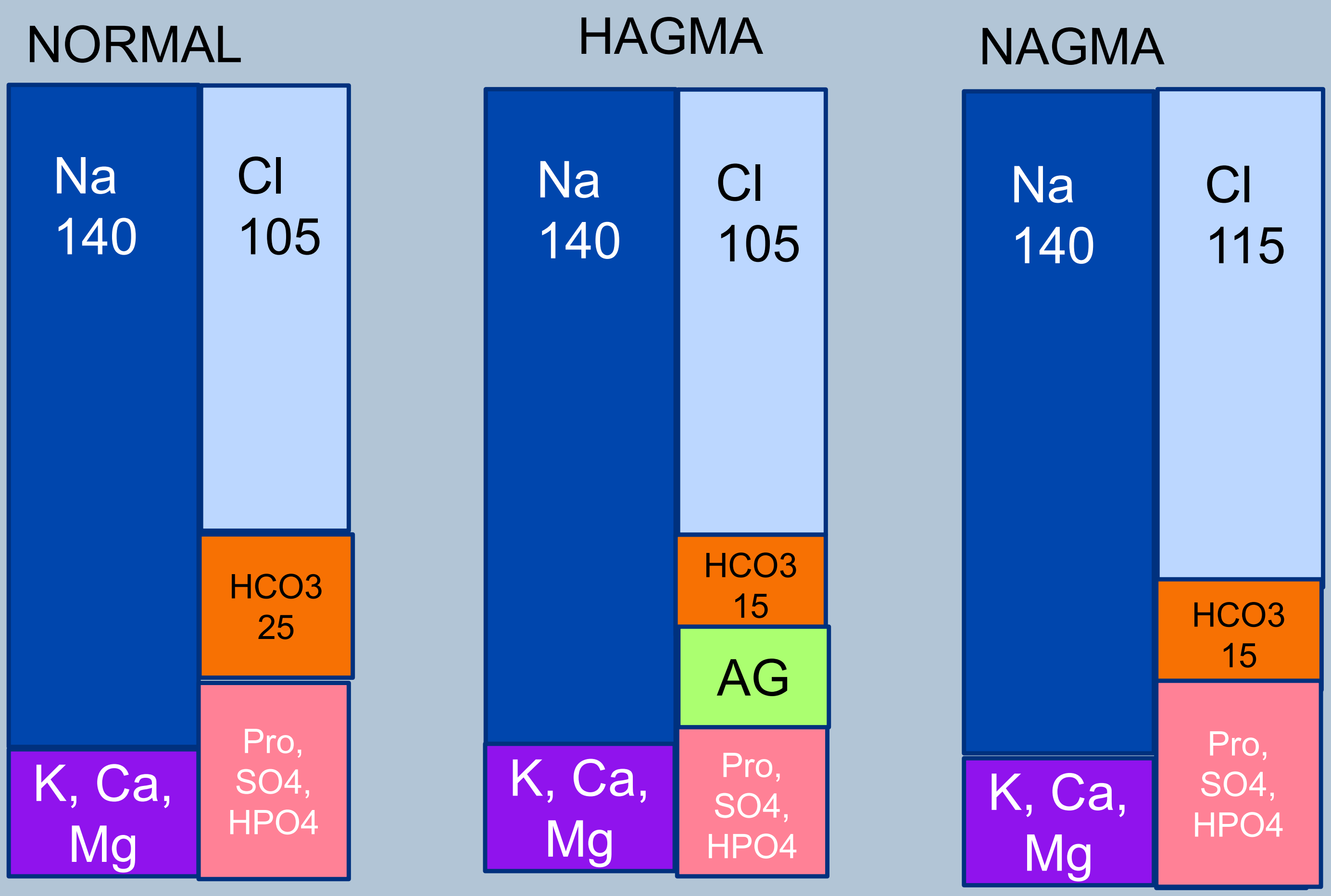
METABOLIC ACIDOSIS (DKA)

Mind the Gap

Anion Gap, Delta Gap

What Is Anion Gap?

- Anion Gap = unmeasured anions – unmeasured cations = Na – [Cl + HCO_3]



Anion Gap

- **Calculated AG (calAG) = Na – [Cl+HCO_3]**
  - Normal range = 8-12
  - If anion gap is present, **metabolic acidosis is present**
- Anion Gap may look normal especially in sick/chronically ill patients…but sometimes we have to look further
  - **Corrected Anion Gap (corrAG) =**
  - **[2 x Albumin] + [0.5 Phosphate] (+/- 2)**
  - OR **[3 x Albumin]**
- If **calAG > corrAG**, there is **high gap metabolic acidosis**
  - Normally, calAG = corrAG

Delta Gap

- **Delta Gap = [calAG – corrAG] + HCO_3**
  - **Net sum = 24**
    - HAGMA only
  - **Net sum < 24**
    - NAGMA (non-anion gap acidosis) is present
  - **Net sum > 24**
    - METABOLIC ALKALOSIS is present

High Anion Gap Metabolic Acidosis (HAGMA)

- HAGMA = gaining **bad ions**
- **MUDPILES:**
  - Methanol
  - Uremia
  - DKA
  - Propylene glycol (ativan, dilantin)
  - Isoniazid/Iron
  - Lactate
  - Ethanol/Ethylene glycol
  - Salicylates/Seizures/Starvation

Normal Anion Gap Metabolic Acidosis (NAGMA)

- Gaining acid from:
  - **loss of bicarb**
  - **gaining of hydrogen ions**
- **HARDUP**
- **USEDCRAP**
- Hyperchloremia, diarrhea, renal failure (RTA) are most commonly seen

Expanded Causes (HARDUP)

- Hyperchloraemia
- Acetazolamide, Addison's disease
- Renal tubular acidosis
- Diarrhoea, ileostomies, fistulae
- Ureteroenterostomies
- Pancreatoenterostomies

or USEDCRAP

- Ureteroenterostomies
- Small bowel fistula
- Excess Chloride
- Diarrhoea
- Carbonic anhydrase inhibitors
- Renal tubular acidosis
- Addisson's disease
- Pancreatoenterostomies

Normal Anion Gap Metabolic Acidosis (NAGMA)

ABG:
pH 7.18
PCO_2 34 mmHg
HCO_3 12 mEq/L

BMP:
Na= 138, K=3.8,
Cl=115 Albumin=2.3,
Phos=1

calAG = 138 – [115+12] =

corrAG = 2 x 2.3 + [0.5 x1] =

calAG > corrAG →

Delta Gap = [calAG- corrAG] + HCO3 =

18 < 24…therefore,

Case 6 Revisited

- A 78 YO M with metastatic squamous cell carcinoma of the maxilla is admitted with multifocal PNA.
- Initially, he required 3-4L O2, was weaned off, then decompensated, requiring HF NC.

Blood Gases	
Pt Intubated?	No
pH Arterial	7.507 (H)
PaCO2	25.0 (L)
PaO2	63.8 (L)
Sat AO2	92.8 (L)
FIO2 Arterial	60.00
Art O2 PP Diff	324.5
Base Excess Arterial	-2.8 (L)
Allen Test	Performed
Device Settings	Simple Mask
Sample Site Arterial	Right Radial
Bicarbonate	19.4 (L)
THB	9.0 (L)
COHB	0.3
Methemoglobin	0.3
Temperature	37.0
Blood Gas Sample Site	
PaO2/FiO2 Ratio	1.06

1) Metabolic acidosis
2) Respiratory alkalosis

<u>Winter's formula:</u> (1.5 x 21) + 8 = 39.5 (expected pCO_2) as compared to 25.0 (actual pCO_2)

Case 6 Revisited

Case 6 revisited

General Chemistry	
Na	134 (L)
K	3.7
Cl	101
TCO2	21 (L)
Anion Gap	12
Ca	8.4 (L)
TP	
Albumin	
Glucose	118 (H)
Bili Total	
Creat	0.8
Estimated GFR	> 60 *
BUN	19.1
Lactate, Plasma	1.70

Case 7 Revisited

- A 64 M with ESRD 2/2 DM s/p kidney tx, on HD and immunosuppression, and acute on chronic systolic HF, presents to the ED with shortness of breath, fatigue, and crackles on chest auscultation.

Laboratory and Microbiology Testing	16-Aug-2017 20:03 MST	16-Aug-2017 20:01 MST
Blood Gases		
Pt Intubated?		No
pH Arterial		7.296 (L)
PaCO2		23.3 (L)
PaO2		52.9 (L)
Sat AO2		85.5 (L)
FIO2 Arterial		40.00
Art O2 PP Diff		197.5
Base Excess Arterial		-13.7 (L)
Allen Test		Performed
Device Settings		5 L NC
Sample Site Arterial		Right Radial
Bicarbonate		11.1 (L)
THB		10.7 (L)
COHB		0.9
Methemoglobin		0.3
Temperature		37.0
Blood Gas Sample Site	Right Radial	
PaO2/FiO2 Ratio		1.32

General Chemistry	
Na	136
K	5.2
Cl	106
TCO2	13 (L)
Anion Gap	18 (H)
Glucose	240 (H)
Creat	4.3 (H)
Estimated GFR	14.0 * (L)
BUN	89.1 (H)
Lactate, Plasma	1.30

Glucose Studies	
Beta-Hydroxybutyrate	1.7 (H)

1) High anion gap metabolic acidosis 2/2 uremia and DKA
2) Respiratory alkalosis

Winter's formula: (1.5 x 13) + 8 = 27 (expected pCO_2) as compared to 23 (actual pCO_2)

Case 7 Revisited

Case 8 Revisited

- A 63 YO male with acute on chronic hypoxic, hypercarbic respiratory failure 2/2 restrictive and obstructive lung physiology, heart failure (Bi-V nonischemic HF, EF 33%), and ESRD 2/2 diabetic nephropathy presents to the ED.
- He missed his last 2 sessions of hemodialysis and appears unwell, short of breath.

Blood Gases	
Pt Intubated?	No
pH Arterial	7.131 * (!)
PaCO2	49.6 (H)
PaO2	339.2 (H)
Sat AO2	99.4
Lactate POC	1.42
FIO2 Arterial	100.00
Art O2 PP Diff	304.2
Base Excess Arterial	-12.6 (L)
Allen Test	Not Performed
Device Settings	bipap 16/8
Sample Site Arterial	Right Brachial
Bicarbonate	16.2 (L)
THB	11.0 (L)
COHB	0.1
Methemoglobin	0.1
Temperature	37.0
PaO2/FiO2 Ratio	3.39

General Chemistry	
Na	137
K	7.8 (!)
Cl	94 (L)
TCO2	20 (L)
Anion Gap	23 (H)
Glucose	115 (H)
Creat	6.3 (H)
Estimated GFR	9.0 * (L)
BUN	128.4 (H)

1) High anion gap metabolic acidosis
2) Respiratory acidosis

Winter's formula: (1.5 x 20) + 8 = 38 (expected pCO_2) as compared to 50 (actual pCO_2)

Case 8 Revisited

Case 9 Revisited

- A 79 YO M with complicated PMHx presents to the ED in hypovolemic and vasodilatory shock 2/2 aspiration PNA, n/v/d, and PE.

Blood Gases

Pt Intubated?	No [2]
pH Arterial	7.308 - 7.325 [2]
PaCO2	17.2 - 18.7 [2][(!
PaO2	107.2 - 111.8 [2]
Sat AO2	97.5 - 97.8 [2]
Cl Arterial	106
Na Arterial	141.1
K Arterial	4.75
FIO2 Arterial	28.00 [2]
Art O2 PP Diff	61.9 [2]
Base Excess Arterial	-15.1 - -14.9 [2][(
Allen Test	Not Performed [
Device Settings	2 NC [2]
Sample Site Arterial	Arterial Line [2]
Bicarbonate	8.8 - 9.2 [2][(L)]
THB	10.5 - 12.0 [2][(L)

General Chemistry

Na	146 (H)
K	5.1
Cl	98
TCO2	8 (L)
Anion Gap	40 (H)
Ca	9.1
Ionized Ca	4.50 (L)
Phos	6.0 (H)
TP	6.0 (L)
Albumin	3.9
Glucose	167 (H)
Bili Total	0.3
Bili Direct	0.2
Creat	2.0 (H)
Estimated GFR	32.4 * (L)
BUN	39.1 (H)
Lactate, Plasma	2.90 - 8.10 [2][(H
Osmo	319 (H)

Glucose Studies	
Beta-Hydroxybutyrate	8.2 (H)
Enzymes	
Alk Phos	147 (H)
ALT	102 (H)
AST	127 (H)
LD	284 (H)
Lipase	13
Troponin T	<0.010{ 0.014 (H)
Random Urine Chemistry	
U Cl Random	23
U Creat Random	139
U Na Random	74
U Osmo	408

1) High anion gap metabolic acidosis
2) Respiratory Alkalosis
3) Metabolic Alkalosis

Winter's formula: (1.5 x 9) + 8 = 21.5 (expected pCO_2) as compared to 18 (actual pCO_2)

Corrected AG = (2 x 3.4) + (0.5 x 6) = 11
calcAG (40) > corrAG (11) —> **HAGMA**

Delta Gap = (40-11) + 8 = 37
37 > 24 —> **metabolic alkalosis**

Case 9 Revisited

Case 10 Revisited

- A 79 YO M with CAD s/p CABG, CHF, atrial fibrillation, and mild aortic stenosis presents to the ED with GI bleeding and an AKI.

Blood Gases	
Pt Intubated?	No
pH Arterial	7.470 (H)
PaCO2	52.4 (H)
PaO2	129.4 (H)
Sat AO2	98.4
Cl Arterial	94 (L)
Na Arterial	136.1
K Arterial	3.72
FIO2 Arterial	40.00
Art O2 PP Diff	87.5
Base Excess Arterial	12.1 (H)
Allen Test	Not Performed
Device Settings	Bipap 10/6 40%
Sample Site Arterial	Arterial Line
Bicarbonate	37.3 (H)
THB	9.3 (L)
COHB	1.1
Methemoglobin	0.2
Temperature	37.0
PaO2/FiO2 Ratio	3.23

Corrected AG = 3 x albumin = 8.7
cAG and corrAG are approximately equal
Delta gap = 0 + 39
39 > 24 —> metabolic alkalosis

General Chemistry	
Na	143
K	3.6
Cl	96 (L)
TCO2	39 (H)
Anion Gap	8
Ca	9.4
Ionized Ca	
TP	4.9 (L)
Albumin	2.9 (L)
Glucose	238 (H)
Bili Total	0.9
Creat	2.7 (H)
Estimated GFR	Unable to calcul
BUN	150.4 (H)

1) Metabolic alkalosis
2) Respiratory acidosis

12 mmHg increase in pCO_2 yields expected pH decrease by 0.08 x 1.2 = 0.096
7.4 – 0.096 = 7.30

Case 10 Revisited

Case 11 Revisited

- A 55 YO M with history of type 1 DM presents with nausea, vomiting, and shortness of breath.

Blood Gases	
Pt Intubated?	No
pH Arterial	7.327 (L)
PaCO2	19.9 * (!)
PaO2	129.3 (H)
Sat AO2	98.2
Cl Arterial	98
Na Arterial	142.3
K Arterial	3.23 (L)
FIO2 Arterial	21.00
Art O2 PP Diff	
Base Excess Arterial	-13.9 (L)
Allen Test	Performed
Device Settings	ra
Sample Site Arterial	Left Brachial
Bicarbonate	10.2 (L)
THB	10.2 (L)
COHB	0.2
Methemoglobin	0.2
Temperature	37.0
Blood Gas Sample Site	
PaO2/FiO2 Ratio	6.16
Calculated O2 Conc	97.80 (H)

General Chemistry	
Na	144
K	3.5 (L)
Cl	92 (L)
TCO2	10 (L)
Anion Gap	42 (H)
TP	
Albumin	
Glucose	768 (!)
Bili Total	
Creat	1.3
Estimated GFR	57.3 * (L)
BUN	38.1 (H)
Lactate, Plasma	2.60 (H)

Glucose Studies	
Beta-Hydroxybutyrate	14.8 (H)
Lactate, Plasma	6.90 (H)

1) High anion gap metabolic acidosis
2) Respiratory alkalosis

<u>Winter's formula</u>: (1.5 x 10) + 8 = 23 (expected pCO_2) as compared to 20 (actual pCO_2).

Case 11 Revisited

In Summary...

- Look at the pH first
  - Do pH and PCO_2 change in the same direction?
- Use all components/calculations of the ABG
  - Don't skip the calculations…it may change your management!
- Apply clinically to your patient, don't just treat the numbers
  - Use your differentials…MUDPILES, USEDCRAP, etc.
- Consider what will happen if you start treatment
  - Will treating help or hurt?

Questions?
walker.andrew@mayo.edu