ABG PRACTICE: STEPS 1-2

- pH low (<7.4) = Acidosis, pH high (>7.4) = Alkalosis
- If pH and PCO2 move in opposite directions, respiratory disorder is primary
- If pH and PCO2 move in the same direction, metabolic disorder is primary

pH	PCO_2	HCO_3	Disorder
7.2	70	28	Respiratory Acidosis

pH	PCO_2	HCO_3	Disorder
7.2	30	16	Metabolic Acidosis

ABG PRACTICE: STEPS 1-3A

pH	PCO_2	HCO_3	Disorder
7.5	40	31	Metabolic alkalosis

pH	PCO_2	HCO_3	Disorder
7.5	30	16	Respiratory alkalosis

ABG PRACTICE: STEP 3

- If both pCO_2 and HCO_3 are ↑ ↑ = respiratory acidosis OR metabolic alkalosis
- If both pCO_2 and HCO_3 are ↓ ↓ = respiratory alkalosis OR metabolic acidosis
- If **pCO_2 and HCO_3 move in opposite direction ↑ ↓ = mixed disorder is present**

pH	PCO_2	HCO_3	Disorder
7.28	55	19	Primary respiratory acidosis, metabolic acidosis

1. Look at pH → acidosis
2. Look at pH and PCO_2 → opposite, respiratory disorder is primary
3. Look at pCO_2 and HCO_3 → opposite, mixed disorder present → HCO_3 low, implies metabolic acidosis also present

ABG PRACTICE: STEP 3

pH	PCO_2	HCO_3	Disorder
7.50	24	28	Respiratory alkalosis primary, metabolic alkalosis

1. Look at pH → alkalosis
2. Look at pH and PCO_2 → opposite, respiratory disorder is primary
3. Look at pCO_2 and HCO_3 → opposite, mixed disorder present → HCO_3 high, implies metabolic alkalosis also present

ABG PRACTICE: STEP 4

pH	PCO_2	HCO_3	Primary Disorder
7.28	60	35	Respiratory acidosis

1. pH: Acidosis
2. pCO_2 and pH move in opposite directions → primary respiratory disorder
3. pCO_2 and HCO_3 both high → respiratory acidosis
4. Expected change with respiratory acidosis → HCO_3 increases ✓

ABG PRACTICE: STEP 4

pH	PCO_2	HCO_3	Primary Disorder
7.5	55	36	Metabolic alkalosis

1. pH: Alkalosis
2. pCO_2 and pH move in same direction → primary metabolic disorder
3. pCO_2 and HCO_3 are high = metabolic alkalosis
4. Expected change with metabolic alkalosis → PCO_2 increases ☑

PRACTICE: MINDING THE GAPS

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

calcAG = 138 – [115+12] = **11**

corrAG = 2 x 2.3 + [0.5 x1] = **5.1 (+/- 2)**

calcAG > corrAG → **HAGMA present**

Delta Gap = [calcAG- corrAG] + HCO_3 = 6 + 12 **= 18**

18 < 24…therefore**, NAGMA present also**

CASE 1

A 26 YO M with asthma presents to the ED with difficulty breathing x 3 days. It is getting progressively worse. He has tried his regular and rescue inhalers; nothing seems to help. He looks pale and is taking rapid, shallow breaths. On exam, he has diffuse wheezing in all lung fields.

Vitals:
- HR – 120
- BP – 113/76
- RR – 28
- SpO_2 – 92%
- Temp – 37.8C

ABG:
- pH – 7.08
- pCO_2 – 80 mmHg
- HCO_3^- – 28 mEq/L

Acute Respiratory Acidosis

CMP:
- Na – 138 mEq/L (135-145)
- K – 4.0 mmol/L (3.6-5.2)
- Cl – 106 mEq/L (96-106)
- Albumin – 3.8 g/dL (3.5-5.5)
- Phos – 3.0 mg/dL (2.8 – 4.5)

CASE 1

ABG results:
- pH – 7.08
- pCO_2 – 80 mmHg
- HCO_3^- – 28 mEq/L

Respiratory rule #1

- pCO_2 ↑ by 40 (10x4)
- Expected pH change = 0.08 X 4 = 0.32
- Actual pH change = 7.4 - 7.08 = 0.32

pH changes INVERSELY by 0.08 for 10 mm CO2 in ACUTE cases

CASE 1 DDX + MANAGEMENT

- Asthma exacerbation → rapid, shallow breaths → retaining CO_2 → Acute Respiratory Acidosis

- Management
  - Reverse the respiratory acidosis, augment breathing to help improve gas exchange until the patient improves and can do so on their own

CASE 2

A 35 YO M presents to the ED with gun shot wound (GSW) to the abdomen. He was found down by a civilian about 20 minutes after the shooting who called 911. Upon arrival, he appears pale, diaphoretic, and is experiencing severe abdominal pain. He is slightly altered and cannot tell you where he is. He has no past medical history.

Vitals:

- HR – 116
- BP – 86/68
- RR – 10
- SpO_2 – 96%
- Temp – 37.6C

ABG:

- pH – 7.18
- pCO_2 – 34 mmHg
- HCO_3^- – 12 mEq/L

Acute Metabolic Acidosis

CMP:

- Na – 132 mEq/L (135-145)
- K – 3.6 mmol/L (3.6-5.2)
- Cl – 92 mEq/L (96-106)
- Albumin – 3.2 g/dL (3.5-5.5)
- Phos – 2.1 mg/dL (2.8 – 4.5)

CASE 2

ABG:
- pH – 7.18
- pCO_2 – 34 mmHg
- HCO_3^- – 12 mEq/L

Winter's formula (metabolic acidosis)

- Expected PCO_2 in metabolic acidosis:

  $= 1.5 \times HCO_3 + 8 =$ **26 (+/- 2)**

Expected pCO_2 is lower than our actual… what does this mean?

CASE 2 EXPLANATION

- The expected degree of respiratory compensation is not present.
- There is also a respiratory acidosis
- Respiratory depression/AMS → slower, shallow breaths → CO_2 retention → respiratory acidosis
  - Expect patient to ventilate more in response to metabolic acidosis.

CASE 2

ABG results:
- pH – 7.18
- pCO_2 – 34 mmHg
- HCO_3^- – 12 mEq/L

Other results (pertinent):
- Na – 132 mEq/L (135-145)
- K – 3.6 mmol/L (3.6-5.2)
- Cl – 92 mEq/L (96-106)
- Albumin – 3.2 g/dL (3.5-5.5)
- Phos – 2.1 mg/dL (2.8 – 4.5)

- calcAG = 132 – [92+12] = 28
- corrAG = [2x3.2]+[0.5x2.1] = 7.45
- calcAG>corrAG = HAGMA present (we already know this)
- Delta gap = [28-7.45]+12 = 32.55
- Delta gap > 24 → metabolic alkalosis also present

HAGMA + Respiratory Acidosis + Metabolic Alkalosis

CASE 2 DDX

calcAG = 132 – [92+12] = 28

Respiratory Acidosis

- ↓respiratory stimulus
- Atelectasis
- Additional injuries?

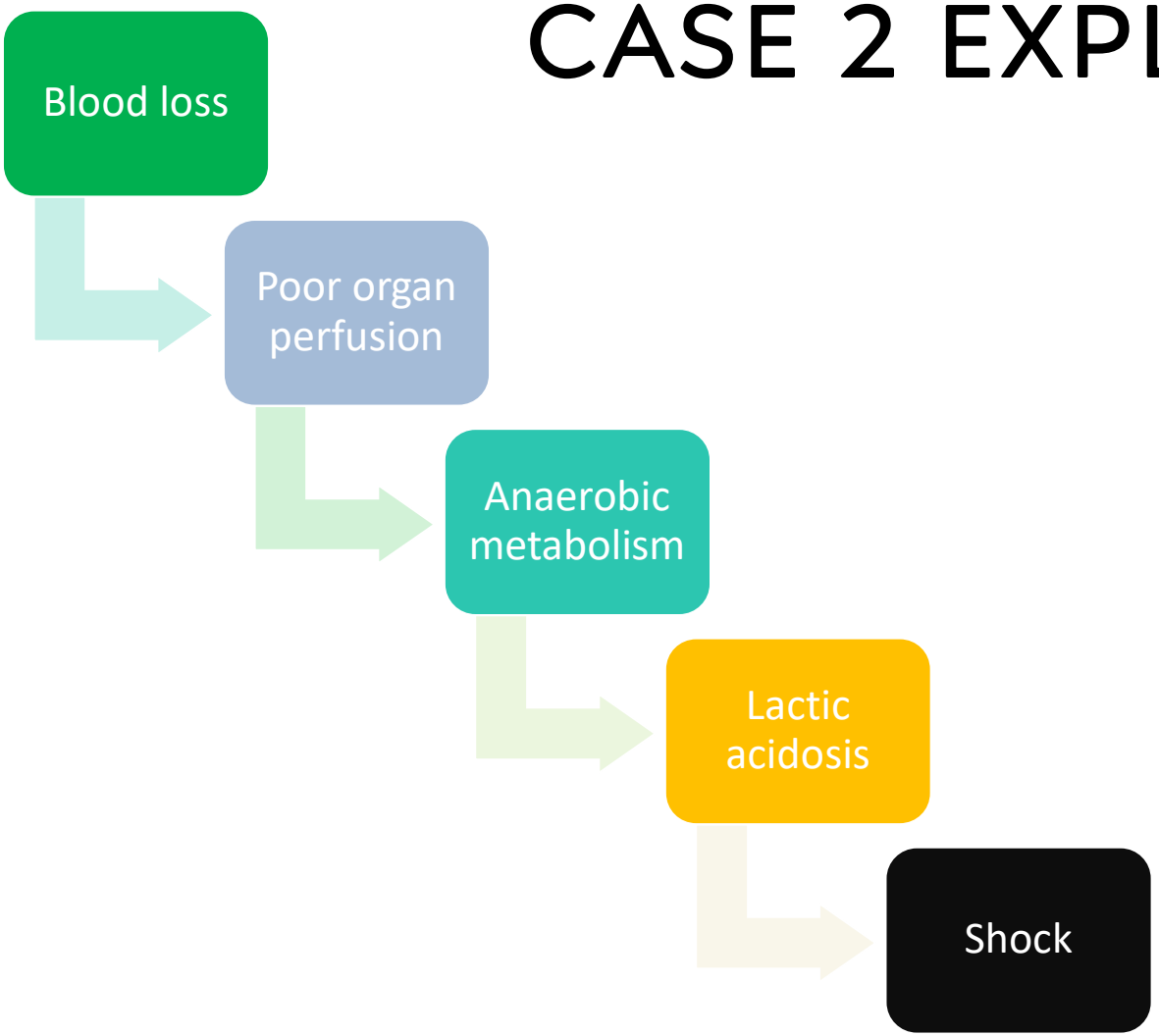
HAGMA

- MUDPILES:
  - Methanol
  - Uremia
  - DKA
  - Propylene glycol (Ativan, Dilantin)
  - Isoniazid/Iron
  - Lactate
  - Ethanol/Ethylene glycol
  - Salicylates/Seizures/Starvation

CASE 2 MANAGEMENT

- You obtain a lactate level to confirm your suspicion: 6.2 mmol/L (<2.3).
- His renal function is normal for now.
- His H/H is 8 g/dL / 26% (13.2-16.6 / 38.3-48.6%).

CASE 2 EXPLANATION



CASE 3

A 64 YO M with ESRD s/p kidney transplant, type 2 DM, and chronic HFrEF presents to the ED with 3 days of fatigue, abdominal pain, and shortness of breath. He is unsure, but he may have had a fever. On exam, he appears unwell and has crackles in the L lung base. He missed dialysis today. CXR shows a L basilar infiltrate.

Vitals:
- HR 100
- BP 92/78
- RR 20
- SpO_2 84%
- Temp 38.0

ABG:
- pH 7.29
- pCO_2 23.3
- HCO_3^- 11.1
- pO_2 52.9

Acute Metabolic acidosis

labs:
- Na – 136
- K – 5.2
- Cl – 106
- AG – 18
- Glucose - 260
- Albumin – 2.8
- Phos – 3.0
- BUN – 89.1
- Cr – 4.3
- Lactate – 1.3
- Beta-hydroxybutyrate – 2.7

CASE 3

ABG results:
- pH 7.29
- pCO_2 23.3
- HCO_3^- 11.1
- pO_2 52.9

Winters formula

Expected pCO_2= 1.5 x 11 + 8 = 24.5 (+/- 2)

Actual pCO_2 = 23.3 ✔

CASE 3

ABG results:
- pH 7.29
- pCO_2 23.3
- HCO_3^- 11.1
- pO_2 52.9

Other results (pertinent):
- Na – 136
- K – 5.2
- Cl – 106
- Glucose – 260
- Albumin – 2.8
- Phos – 3.0
- BUN – 89.1
- Cr – 4.3
- Lactate – 1.3
- Beta-hydroxybutyrate – 2.7

- calcAG = 136 – [106+11] = 19
- corrAG = [2x2.8] + [0.5x3.0] = 7.1
- calcAG>corrAG = HAGMA present (we already know this)
- Delta gap = [19-7] + 11 = 23
- Delta gap < 24 = NAGMA also present

HAGMA + NAGMA

CASE 3 DDX

MUDPILES = HAGMA

- **M**ethanol
- **U**remia
- **D**KA
- **P**ropylene glycol (Ativan, Dilantin)
- **I**soniazid/Iron
- **L**actate
- **E**thanol/Ethylene glycol
- **S**alicylates / Seizures / Starvation

calcAG = 136 – [106+11] = 19

labs:

- Na – 136
- K – 5.2
- Cl – 106
- AG – 18
- Glucose - 260
- Albumin – 2.8
- Phos – 3.0
- BUN – 89.1
- Cr – 4.3
- Lactate – 1.3
- Beta-hydroxybutyrate – 2.7

CASE 3 DDX

MUDPILES = HAGMA

- **M**ethanol
- **U**remia
- **D**KA
- **P**ropylene glycol (Ativan, Dilantin)
- **I**soniazid/Iron
- **L**actate
- **E**thanol/Ethylene glycol
- **S**alicylates / Seizures / Starvation

ABCDE = NAGMA

- **A**ddison's
- **B**icarbonate loss (GI or renal – think v/d, fistula, ostomy)
- **C**hloride excess
- **D**iuretics (acetazolamide)
- **E**xtra – Renal tubular acidosis (RTA**)**

CASE 4

A 68 YO F presents to the ED with 3 days of progressively worsening cough and shortness of breath. She has been experiencing intermittent fevers. Her appetite is diminished, and she is fatigued. On exam, she has scattered crackles. CXR reveals multifocal pneumonia.

Vitals:
HR 96
BP 112/82
RR 26
SpO_2 84%
Temp 37.9 C

ABG:
- pH 7.55
- pCO_2 22 mmHg
- HCO_3^- 16 mEq/L

Acute Respiratory Alkalosis

Labs:
Na – 134
K – 4.2
Cl – 100
BUN – 32
Cr – 1.2
Albumin – 3.8
Phos – 3.0
Lactate – 3.2

CASE 4

ABG Results:
- pH 7.55
- pCO_2 22 mmHg
- HCO_3^- 16 mEq/L

Compensation rules…Boston Approach for Resp Disorders

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

CASE 4

ABG Results:
- pH 7.55
- pCO_2 22 mmHg
- HCO_3^- 16 mEq/L

Compensation rules…Boston Approach for Resp Disorders

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

pCO_2 went from 40 → 22 (roughly 20)

We expect HCO_3 to decrease by 4 (using 24 baseline): HCO_3 should be 20 but it is 16 → is there a mixed disorder present?

CASE 4

ABG Results:
- pH 7.55
- pCO_2 22 mmHg
- HCO_3^- 16 mEq/L

Other results (pertinent):
Na – 134
K – 4.2
Cl – 100
BUN – 32
Cr – 1.2
Albumin – 3.8
Phos – 3.0
Lactate – 3.2

- calcAG = 134– [100+16] = 18
- corrAG = [2x3.8] + [0.5x3.0] = 9.1
- calcAG>corrAG = HAGMA present
- Delta gap = [18-9.1] +16 = 32.9
- Delta gap = 24.9 …close enough! Only HAGMA present

Acute Respiratory Alkalosis + HAGMA

CASE 4 DDX

- Hypoxia 2/2 pneumonia leads to hyperventilation reducing systemic CO_2 → acute respiratory alkalosis

calcAG = 134– [100+16] = 18

- **MUDPILES = HAGMA**
  - **M**ethanol
  - **U**remia
  - **D**KA
  - **P**ropylene glycol (Ativan, Dilantin)
  - **I**soniazid/Iron
  - **L**actate
  - **E**thanol/Ethylene glycol
  - **S**alicylates / Seizures / Starvation

ABG:

- pH 7.55
- pCO_2 22 mmHg
- HCO_3^- 16 mEq/L