TEACHING ACID-BASE INTERPRETATION: WHAT IS THE BEST APPROACH?

Doug Pursley, M.Ed., RRT-ACCS, FAARC

AARC Summer forum
Where Challenges Become Opportunities

Objectives

- 1. Discuss various simplistic, stepwise methods for interpreting the acid-base status of a patient
- 2. Describe the primary components of a comprehensive approach to assessing acid-base balance

References

- 1. All You Really Need To Know To Interpret Arterial Blood Gases, Lawrence Martin
- 2. Clinical Blood Gases, William Malley
- 3. ABG Pocket Guide, Dana Oakes
- 4. Anaesthesia Education Website
- http://www.anaesthesiamcq.com/default.php

Stepwise methods (classification)

- Uses systematic arrangement of values according to established criteria in order to arrive at a diagnosis

Stepwise methods

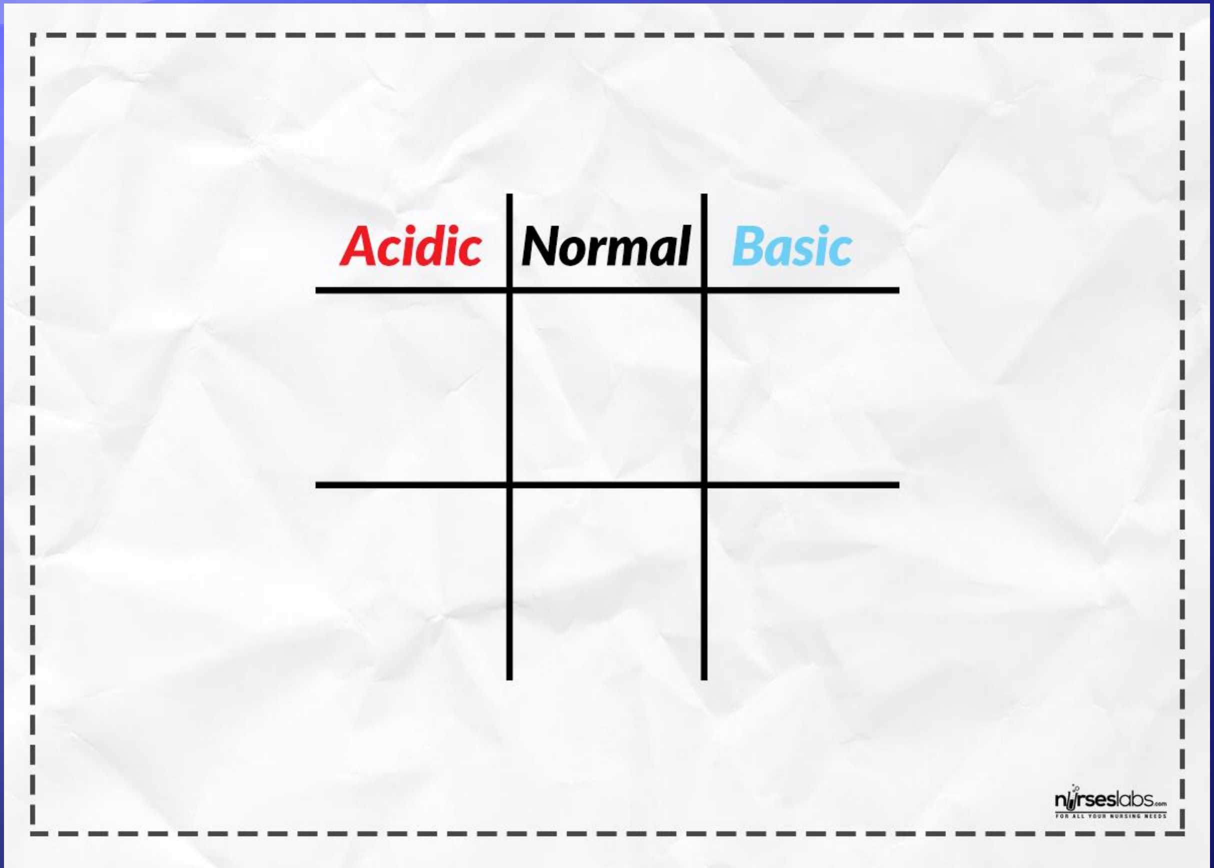
- Arrow Method (high-low)
- Variations of the arrow method
  - Tic-Tac-Toe method
  - Romanski method
  - “H” method

Arrow System

	pH	Pa_{CO_2}	HCO_3^-
Respiratory alkalosis			
Uncompensated	↑	↓	N
Partially compensated	↑	↓	↓
Fully compensated	N	↓	↓
Respiratory acidosis			
Uncompensated	↓	↑	N
Partially compensated	↓	↑	↑
Fully compensated	N	↑	↑
Metabolic acidosis			
Uncompensated	↓	N	↓
Partially compensated	↓	↓	↓
Fully compensated	N	↓	↓
Metabolic alkalosis			
Uncompensated	↑	N	↑
Partially compensated	↑	↑	↑
Fully compensated	N	↑	↑

N, Within normal range; ↑, above normal range; ↓, below normal range.

Tic-Tac-Toe method



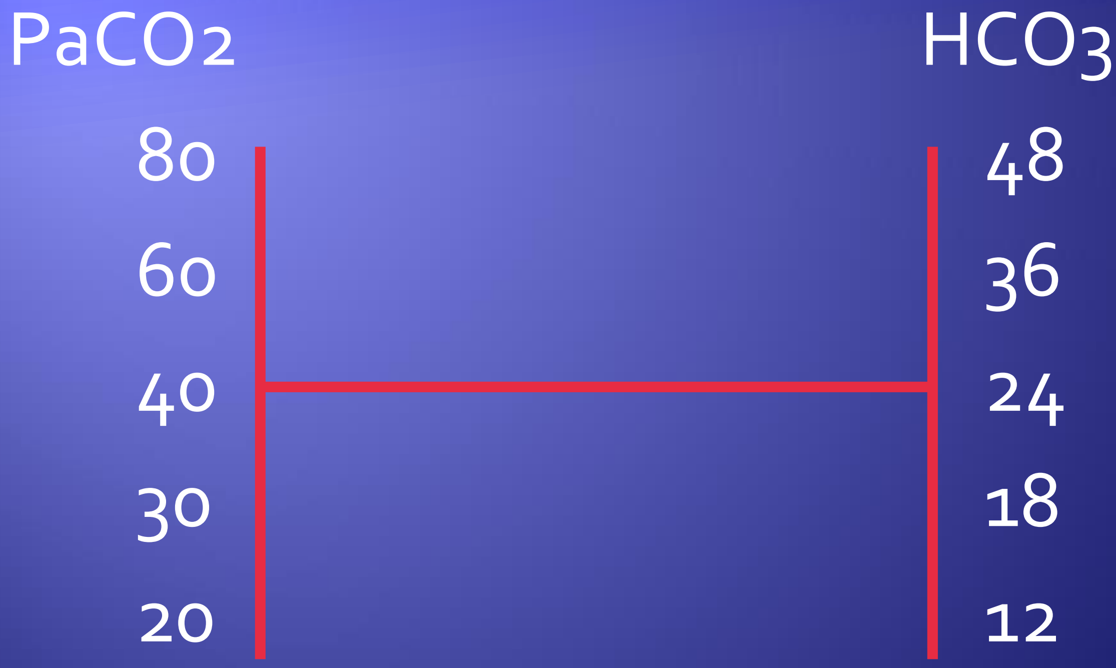
http://nurseslabs.com/8-step-guide-abg-analysis-tic-tac-toe-method/

Romanski method

- Step 1: Evaluate pH
- Step 2: Evaluate respiratory and metabolic components
- Step 3: Determine consistent value
- Step 4: Determine compensation

Larkin, B. G., MS, RN, ACNS-BC, CNS-CP, CNOR, & Zimmanck, E. J., MD. (2015, October). Interpreting Arterial Blood Gases Successfully. Retrieved June 13, 2016, from https://www.aorn.org/websitedata/cearticle/pdf_file/CEA15542-0001.pdf

"H" method



https://prezi.com/lmyewp-he4b2/using-the-h-model-to-interpret-abgs/

Comprehensive approach (Interpretation)

- Uses physiologic rules and mathematical equations in order to apply a proper interpretation to the results

Teaching the Comprehensive Approach

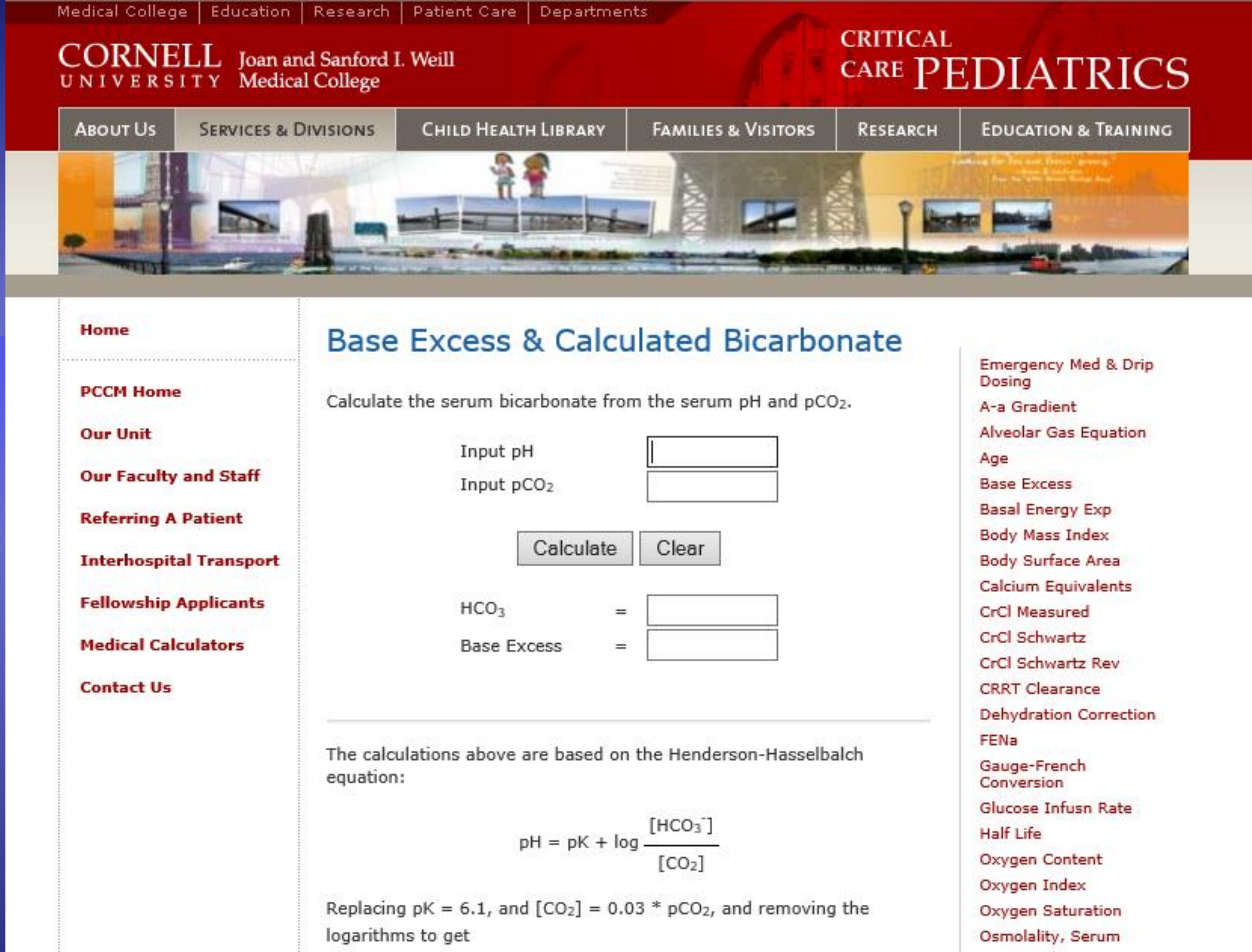
- 1. Basic instruction about the four parts of acid-base physiology (pH, $PaCO_2$, HCO_3, Base) and how to check consistency/inconsistency via H-H equation
- 2. Then we teach one acid-base disorder at a time (including causes) followed by mixed disorders and case studies to put it all together. Always use patient history, electrolytes, and previous ABGs when available.

Comprehensive approach

- 3. Respiratory disorders
  - Apply rules that predict how pH and HCO3 change per given change in PaCO2 in both acute and chronic conditions
- 4. Metabolic disorders
  - Examine anion and bicarbonate gaps
  - Apply rules the predict expected PaCO2 in metabolic acidosis and alkalosis i.e. Winter's and "Point Seven Plus Twenty" rule

Consistency/Inconsistency

- All acid-base data should calculate out according to the Henderson-Hasselbalch equation
- $[HCO_3 \div (PaCO_2 \times 0.03)] \log + 6.1 = pH$



http://www-users.med.cornell.edu/~spon/picu/calc/basecalc.htm

Or just Google: “Cornell base excess”

RULES AND EQUATIONS

Anion Gap

- AG = (Na + K^+) - (Cl +HCO3) or clinical equation…
- AG = Na – (Cl + HCO3)
  - 12 is normal
  - > 20 suggests metabolic acidosis
  - >30 is 100% chance of metabolic acidosis

Bicarbonate Gap

- BG = Δ AG – Δ HCO_3 or clinical shortcut…
- BG = Na – Cl – 36
  - > +6 suggests metabolic alkalosis or compensation for respiratory acidosis
  - < -6 suggests hyperchloremic metabolic acidosis or compensation for respiratory alkalosis

Expected $PaCO_2$ in metabolic acidosis and alkalosis

- Expected $PaCO_2$ in metabolic acidosis (Winter's formula):
  - Expected $PaCO_2 = HCO_3 \times 1.5 + 8$ (+/- 2)
- Expected $PaCO_2$ in metabolic alkalosis: (Point Seven Plus Twenty rule)
  - Expected $PaCO_2 = HCO_3 \times 0.7 + 20$ (+/- 5)

Expected changes in pH and HCO_3 for 10 mmHg Δ in $PaCO_2$ starting at $PaCO_2$ of 40 mmHg

Condition	Acute	Chronic
Respiratory acidosis	pH ↓ by 0.06 HCO_3 ↑ by 1 (hydrolysis)	pH ↓ by 0.03 HCO_3 ↑ by 4
Respiratory alkalosis	pH ↑ by 0.1 HCO_3 ↓ by 2 (hydrolysis)	pH ↑ by 0.03 HCO_3 ↓ by 5

Case 1 - ABG and electrolytes taken from a 55 year old male with aspirin OD:

- pH 7.46
- $PaCO_2$ 19
  - Expected $PaCO_2$ = 27
- HCO_3 13
- Na 146
- Cl 106
- AG = 27
- BG = +4

- Arrow method: partially compensated respiratory alkalosis.
- Actual interpretation is metabolic acidosis with respiratory OVER compensation (respiratory alkalosis)

Case 2 - 66 year old male with chronic hypercapnia ($PaCO_2$ 75-85) and NG tube

- pH 7.45
- $PaCO_2$ 79
- HCO_3 53
  - Expected HCO_3 for this degree of chronic hypercapnia is 40
- Na 144
- Cl 79
- AG = 12
- BG = +29

- In spite of clinical scenario, stepwise methods classify these values as compensated metabolic alkalosis
- Actual interpretation is chronic hypercarbia AND metabolic alkalosis

Case 3 - 36 year old female presents to the ED with pain and anxiety

- pH 7.58
- $PaCO_2$ 22
- HCO_3 19.9
- Base -1.7

Also, in single acid-base disorders, a base excess/deficit in the normal range would rule out partial compensation.

- Arrow: partially compensated respiratory alkalosis
- Actual interpretation is acute respiratory alkalosis. HCO_3 dropped from hydrolysis.

Case 4 – 71 year old end-stage COPD with suspected pneumonia. His steady-state values are normally 7.31/73/36/+9. ABGs in the ED are:

- pH 7.43
- $PaCO_2$ 53
- HCO_3 34
- Base +9

- Stepwise methods (because they don't consider history) classify these values as compensated metabolic alkalosis
- Actual interpretation is acute hypocapnia superimposed on chronic respiratory acidosis.

Case 5 - A adult male patient is brought to the ER has the following ABG on a nasal cannula at 2 l/m:

- 3:49 am
- pH 6.83
- $PaCO_2$ 139
- PaO_2 138
- HCO_3 22
- Base -10

- Arrow: acute respiratory acidosis
- Actual interpretation: mixed respiratory and metabolic acidosis

Case 5 continued - A second ABG is taken 23 minutes later while the patient is being manually ventilated:

- 3:49 am
- pH 6.83
- $PaCO_2$ 139
- HCO_3 22
- Base -10

- 4:12 am
- pH 7.19
- $PaCO_2$ 45
- HCO_3 17
- Base -10

Good work by the respiratory therapist!!!

Also, good example of hydrolysis.

Case 6 – 23 year old man being evaluated in the ED for severe pneumonia. Respiratory rate is 38 and he is using accessory muscles.

- pH 7.29
- $PaCO_2$ 55
- HCO_3 26
- Base -1
- PaO_2 47
- Na 154
- Cl 100
- AG 28
- BG +18

- Stepwise: acute respiratory acidosis
- Actual interpretation: respiratory acidosis + metabolic acidosis + metabolic alkalosis
- Note in this situation that base is normal from competing metabolic acidosis and alkalosis

Case 7 – 24 year old DKA

- pH 7.17
- $PaCO_2$ 17
- HCO_3 6
- Base -20

- Stepwise: partially compensated metabolic acidosis
- Actual interpretation: maximally and appropriately compensated metabolic acidosis.

Last two digits rule and Winter's indicate maximal compensation in this patient.

Case 8 – 18 year old female, previously healthy, opioid OD

- pH 7.19
- $PaCO_2$ 60
- HCO_3 22

- Stepwise: acute respiratory acidosis
- Actual interpretation: mixed respiratory and metabolic acidosis. Base is -5

- If acute, HCO_3 should be 26 from hydrolysis
- HCO_3 is lower than it should be from the metabolic acidosis

Case 9 – 64 year old woman admitted to the ED with renal failure and vomiting

- pH 7.40
- $PaCO_2$ 38
- HCO_3 23
- Na 149
- K^+ 2.8
- Cl 100
- Creatinine 8.7 mg/dl
- AG 26
- BG +13

- Stepwise: normal
- Actual interpretation: coexistent metabolic acidosis and metabolic alkalosis.

Case 10 – Previously healthy, 56 year old man in the recovery room following cholecystectomy

- pH 7.22
- $PaCO_2$ 70
- HCO_3 27.7
- Base +0.5

- Stepwise: partially compensated respiratory acidosis
- Actual interpretation: acute respiratory acidosis. HCO_3 elevated from hydrolysis. Base is normal. If truly partially compensated, there would be a base excess.

Case 11 – Patient with chronic hypercapnia and hypokalemia

- pH 7.40
- PaCO2 60
- HCO3 36

- Stepwise: compensated respiratory acidosis OR compensated metabolic alkalosis. Could not distinguish with pH 7.40
- Actual interpretation: primary respiratory acidosis AND primary metabolic alkalosis. Base is +11.

If this were a single metabolic alkalosis the PaCO2 would only compensate 45 according to the “Point Seven Plus Twenty” rule. HCO3 is higher from primary metabolic alkalosis.

Conclusion/Summary

- A proper acid-base diagnosis is vital to guide treatment decisions at the bedside
- Many patients have very complex acid-base disturbances
- Stepwise methods such as the arrow method OVER simplify acid-base interpretation
- We owe it to our students to give them all the tools to properly interpret arterial blood gases!