Back To Basics Acid-Base Disorders

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Acid-base disorders are commonly encountered in hospitalized patients. Underlying disease processes frequently give rise to acid-base disorders, and understanding these disorders may assist clinicians in diagnosing and treating patients who are affected.

The approach to acid-base disorders is often difficult, both for medical students and practicing physicians. Medical students often memorize the information without truly understanding it. Then, as physicians, they attempt to understand acid-base disorders, rather than relying on memory of the subject matter. Acid-base disorders are often much easier to work through if you do a little review of normal physiology and then put it into practice. This article will review the normal laboratory values and then help review analysis of the abnormal values.

The Normal Physiology

Maintenance of normal physiologic function is closely linked to the maintenance of pH within the normal range. There are two main mechanisms for this balance — respiratory and metabolic. Alveolar ventilation results in excretion of CO_2, while the kidneys control the re-absorption of HCO_3.[1] Respiratory disorders first alter pCO_2, while metabolic disorders affect bicarbonate concentration.[2] Understanding the normal values for each of these components is the initial step to analyzing the problem (Table 1).

A change in the blood hydrogen ion concentration (pH) is referred to as acidemia or alkalemia, while the process that results in the change is either acidosis or alkalosis. A combination of several processes may result in the final pH. The balance between respiratory and renal mechanisms that maintain normal pH is an ongoing process and the time required for compensation varies. The respiratory system provides compensation to metabolic derangements almost immediately, however, the renal compensation response lags by six to 12 hours.[3] These compensatory mechanisms must be considered in order to assess the acid-base condition of patients in a clinical setting.

Summary

Acid-Base Disorders

- Laboratory results are important, but a thorough history and examination of the patient may present some clues to the underlying problem.
- The anion gap is particularly useful in determining the differential diagnosis in patients who present with metabolic acidosis.
- The most common causes of metabolic alkalosis are volume depletion and loss of gastric secretions.

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Clinical Approach to the Patient

There are several steps to take when evaluating a patient with an acid-base disorder. If these steps are followed, the assessment will provide pertinent information to guide treatment and further investigation.

Do a thorough history and physical. Laboratory results are important, but a thorough history and examination of the patient may offer some clues to the underlying problem. The patient may present with a history of insulin-dependent diabetes mellitus (IDDM), which may contribute to a metabolic acidosis. Exacerbation of known chronic obstructive pulmonary disease (COPD) may present as respiratory acidosis. This information helps guide the investigation and treatment of the underlying derangement.

Blood gases and other chemistry.

- Does the pH indicate acidemia or alkalemia?
- Is the cause of the pH imbalance respiratory, metabolic or mixed?
- Is there compensation for the acid-base imbalance?[4]

Acidosis ($pH < 7.35$) and

- $pCO_2 < 35$: The primary problem is acidosis (metabolic) with respiratory compensation.
- pCO_2 35 to 45: Primary metabolic acidosis with no compensation.
- $pCO_2 > 45$: Primary respiratory acidosis

A bicarb of < 24 indicates primary metabolic acidosis. If it is > 28, it is compensated respiratory acidosis.

Alkalosis (pH >7.45) and

- $pCO_2 < 35$: Primary respiratory alkalosis, if $HCO_3 > 28$; there is also primary metabolic acidosis.
- pCO_2 of 35 to 45: Uncompensated primary metabolic alkalosis.
- $pCO_2 > 45$: Metabolic alkalosis with respiratory compensation.[3]

Calculate the expected compensations as indicated in Table 2.

Calculate the anion gap. The anion gap is particularly useful in determining the differential diagnosis in patients who present with metabolic acidosis. These patients may subsequently be divided into two categories — anion gap metabolic acidosis and non-anion gap metabolic acidosis.

Anion gap = Na-(Cl+ HCO_3) and is considered normal if the anion gap is 10+/-4.

The differential diagnosis of anion gap metabolic acidosis is easily remembered by the pneumonic MUDPILES (***M***ethanol; ***U***remia; ***D***iabetic ketoacidosis; ***P***araldehyde; ***I***ron, ***I***soniazid; ***L***actic acidosis; ***E***thanol, ***E***thylene glycol; and ***S***alicylate, ***S***olvents, ***S***tarvation.

Normal Anion Gap Metabolic Acidosis:

- Gastrointestinal loss (GI), loss of HCO_3 (*i.e.*, diarrhea, enterostomies);
- Renal loss of HCO_3 (*i.e.*, renal tubular acidosis [RTA], early renal failure); or
- Other (*i.e.*, dilution, addition of hydrogen chloride [HCl] acid).[5]

Metabolic alkalosis. The most common causes of metabolic alka-

Table 1

The Normal Physiology

	Normal	Acidosis	Alkalosis
pH	7.35 to 7.45	< 7.35	> 7.45
pCO_2	35 to 45 mmHg	> 45 mmHg	< 35 mmHg
HCO_3	21 to 28 meq/L	< 22 meq/L	> 28 meq/L

Adapted from: Mays D: Turn ABG's into child's play. RN Jan 1995; 58(1):36-40.

Table 2

Expected Compensations

Acid-Base Disorder	Compensation Formula
Metabolic acidosis	Change in $PaCO_2$ = 1.2 x change in HCO_3
Metabolic alkalosis	Change in $PaCO_2$ = 0.6 x change in HCO_3
Acute respiratory acidosis	Change in HCO_3 = 0.1 x change in $PaCO_2$
Chronic respiratory acidosis	Change in HCO_3 = 0.35 x change in $PaCO_2$
Acute respiratory alkalosis	Change in HCO_3 = 0.2 x change in $PaCO_2$
Chronic respiratory alkalosis	Change in HCO_3 = 0.5 x change in $PaCO_2$

Adapted from Fall P: A stepwise approach to acid-base disorders. Postgrad Med 2000; 107(3):249-63.

Acid-Base Disorders

Case Study

A 45-year-old male with known azotemia presents to your office with increased weakness and pruritus. His mucous membranes appear dry. He is sent for laboratory investigation and the following results are obtained:

- Na 135 mmol/L
- K 5.4 mmol/L
- Cl 101 mmol/L
- HCO_3 12 mmol/L
- BUN 62.5 mmol/L
- Cr 1679 mmol/L
- Ph 7.32
- PCO_2 24 mmHg

Question:

What is your analysis of these results?

losis are volume depletion and loss of gastric secretions. These may be divided into two groups, as follows:

Saline Responsive (urine Cl < 10 mEq/L):
- GI: Vomiting, nasogastric (NG) suction, diarrhea;
- Diuretic therapy;
- Cystic fibrosis (CF).

Saline-Resistant (urine Cl > 10 mEq/L):
- Primary: Aldosteronism; or
- Secondary: Chronic heart failure (CHF), cirrhosis, ascites, malignant hypertension.

Respiratory acidosis. This can present in acute and chronic forms as follows:

Acute:
- Central nervous system (CNS) depression;
- Paralysis of respiratory muscles; and/or
- Airway obstruction or respiratory failure.

Chronic:
- COPD; and/or
- Extreme obesity or other body habitus abnormalities.

Respiratory alkalosis.
Hyperventilation is a very common cause of an acute respiratory alkalosis. The contributing factors to hyperventilation include:
- Early shock;

- Early sepsis;
- Pregnancy; and
- Early salicylate poisoning.[3]

Calculate the osmolal gap. The osmolal gap is also useful in diagnosing patients who present with anion gap metabolic acidosis.
- Osmolal gap = Measured serum osmolality – calculated serum osmolality;
- Calculated = (2 x Na) + blood urea nitrogen (BUN) + glucose; and
- N = 10 osm/L to 20 osm/L.

The pneumonic MADGAS represents the differential diagnosis of an elevated osmolal gap (***M***ethanol; ***A***lcohols; ***D***ye [IVP]; ***G***lycerol; ***A***cetone; ***S***orbitol)

Discussion of Case

From an acid-base point of view, analysis of the patient's laboratory work reveals the following:
- pH acidosis;
- PCO_2 < 35; therefore the patient has primary metabolic acidosis;
- Respiratory compensation is adequate: 1.2x12=14.4= expected change in $PaCO_2$; and
- Anion gap=135–(101+12)= 22 (*i.e.*, increased).

Therefore, this patient has a simple, compensated, increased anion gap metabolic acidosis.[5]

Conclusion

The evaluation of acid-base disorders requires a systematic approach. There are a few basic principles that must be followed to assist in the analysis of blood gases:
- Don't panic;
- Obtain an adequate history and examine the patient; and
- Don't forget the formulas from medical school are important. Write them down somewhere accessible. CME

References
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Suggested Readings
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