Approach to Metabolic Acidosis in the Emergency Department

Mike Rice, MD, Bashar Ismail, MD, M. Tyson Pillow, MD, MEd*

KEYWORDS

• Metabolic acidosis • Acid-base disorders • Anion gap • Non-anion gap

KEY POINTS

- The approach that encompasses all acid-base derangements is to think of these disorders as a process, treat the underlying cause, and treat the patient, not the numbers.
- In thinking of acid-base disorders as a process, it is important to understand normal acid-base regulation in the body.
- Many different acids, pathologic abnormalities, and metabolic processes can contribute to the metabolic component of acid-base alterations.

INTRODUCTION

Several obstacles make it difficult to understand acid-base disorders in the emergency department (ED): (1) understanding of basic principles, which is frequently obscured by rote memorization of equations; (2) the perceived requirement to know intermediary metabolism; (3) the arbitrary and interchangeable use of "CO_2" to mean bicarbonate and/or P_{CO_2}; (4) the fact that patients rarely present with the primary complaint of "I have acidosis." It is also easy to get the impression that all laboratory tests will give exact, unwavering answers, and that calculations using these results will yield precise numbers that lead to the only correct answer.[1] Rather than thinking about acid-base disorders as numbers and arrows on a chart, each disturbance should be thought of as a *process*. The goal, with few exceptions, is therefore to identify and treat the underlying cause, not just the numbers.

In thinking of acid-base disorders as a process, it is important to understand the normal process of acid-base regulation in the body. Put simply, the body's goal is to eliminate the large burden of acid generated in the creation and storage of energy required for cellular metabolism. The pH is maintained between 7.35 and 7.45 by several intricate processes between the renal and respiratory systems (**Box 1**).

Baylor College of Medicine, Houston, TX, USA
* Corresponding author. Section of Emergency Medicine, Ben Taub General Hospital, Baylor College of Medicine, 1504 Taub Loop, Houston, TX 77030.
E-mail address: tysonpillow@gmail.com

Emerg Med Clin N Am 32 (2014) 403–420
http://dx.doi.org/10.1016/j.emc.2014.01.002 emed.theclinics.com

Box 1
The carbonic acid buffer system

$$\underset{\text{Proton}}{H^+} + \underset{\text{Bicarbonate Ion}}{HCO_3^-} \leftrightarrow \underset{\text{Carbonic Acid}}{H_2CO_3} \leftrightarrow \underset{\text{Water}}{H_2O} + \underset{\text{Carbon Dioxide}}{CO_2}$$

If the concentration of each component remains unchanged, then simple calculations will tell you the ratios of one component to another, based on the pKa. From this, one can easily calculate the pH. If the concentration of any component changes, a new and different equilibrium will be reached, along with a different pH.

Respiratory Physiology

The lung expels 15,000 mmol of CO_2 per day in the healthy state. This rate is approximately 150 times more than the amount of acid excreted by the kidneys. Ventilation, therefore, serves as a primary compensatory mechanism.

Renal Physiology

The kidneys play an integral role in several other vital aspects of acid-base balance. Intricate biochemical reactions in the nephron facilitate the following: (1) maintenance of buffer capacity in blood; (2) excretion of inorganic acids, which the respiratory system is incapable of handling; (3) regeneration of lost bicarbonate ion; (4) the ability to increase H^+ excretion on a long-term basis, thereby giving the kidneys the ability to repair nonrenal causes of metabolic acidosis; (5) free proton excretion, although very limited in amount, which occurs only in the kidneys.

Pathophysiology

Metabolic acidosis is perhaps the most common derangement in acid-base encountered in the ED. It is a metabolic disturbance producing an increase in $[H^+]$ or a decrease in $[HCO_3^-]$. Although they are often used interchangeably, “acidosis” is separate from “acidemia,” which is a serum pH lower than 7.35 (**Box 2**).

Metabolic acidosis can be produced by 3 major mechanisms:

1. Increased acid formation
2. Decreased acid excretion
3. Loss of bicarbonate

Box 3 shows a list of common diagnoses based on these mechanisms. Most commonly, however, the diagnoses are grouped in terms of those that create elevated anion gaps (AG) and those that do not.

APPROACH TO ACID-BASE DISORDERS

It is again important to emphasize that interpretation of acid-base status must be done in the context of the patient.[2] Another first step is to confirm the consistency of the

Box 2
Definition of pH (with Henderson-Hasselbalch equation)

$$pH = -\log[H+] = pK_a + \log_{10}([A^-]/[HA])$$