Using Willie’s acid-base box for blood gas analysis

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Many years ago, I was asked to evaluate a method developed by Dr. William T. Lipscomb for teaching blood gas analysis of acid-base status. Dr. Lipscomb was a Professor in the Department of Physiology of the University of Nebraska College of Medicine during my graduate student days and served as a teaching mentor to myself and several other graduate students for our first physiology lectures. Dr. Lipscomb went on to teach anatomy and physiology at Coastal Georgia Community College for 18 yr and after retiring and served as Secretary for the Glynn Environmental Coalition until his death in 2005. Glynn Environmental Coalition named a science award in his honor as he was a much-loved teacher.

When I first examined this approach, it seemed much too simplistic for medical students, but I decided to try it in my lectures. First, I present the standard Henderson-Hasselbalch equation and apply this to some simple patient problems but then reexamine the patient cases using Willie’s acid-base box. Invariably, some of the students find it silly at first, but every single year I have some more senior students who come back to this method. For example, a recent second-year medical class tackling acid-base cases in a course titled “Evidence-Based Medicine” contacted me to review “Willie’s box.” Even third-year medical students have found the method useful to prepare for an Internal Medicine Shelf exam. Also, students have e-mailed me after exams attesting that this method was helpful in securing correct answers on various board-style tests. Before dismissing this method, give it a try, as I’m sure many of your students will enjoy it and benefit in the long run.

The box is constructed using three of the parameters of standard arterial blood gas analysis: pH, bicarbonate, and CO₂. Therefore, it depicts the Henderson-Hasselbalch equation in a simple visual form that requires no calculations. The top value depicts the pH with the normal range of 7.35–7.45 and is considered inside the box. Anything below that range is outside the box and identifies acidosis, whereas any value above the range is outside the box to the right and depicts alkalosis. The middle line represents the metabolic component of the acid-base system, which is measured clinically as bicarbonate. I took the liberty of broadening the normal range for this value from Dr. Lipscomb’s original to account for the immediate changes in bicarbonate that result from CO₂ conversion to bicarbonate by buffering from hemoglobin (1).

The first case (Fig. 1) shows a patient who is experiencing an acute asthma attack with the following blood gas values: pH = 7.27, bicarbonate = 26 meq/l, and CO₂ = 60 mmHg. Willie’s acid-base box is then used to reexamine this patient case. The pH is outside the box and identifies acidosis, whereas the bicarbonate value is outside the box to the right and depicts alkalosis. The middle line in the box represents the metabolic component of the acid-base system, which is measured clinically as bicarbonate. This is depicted by the box being filled with the value of 28 meq/l.

The box is then used to reexamine the patient case from Fig. 1. The pH is outside the box and identifies acidosis, whereas the bicarbonate value is outside the box to the right and depicts alkalosis. The middle line in the box represents the metabolic component of the acid-base system, which is measured clinically as bicarbonate. This is depicted by the box being filled with the value of 28 meq/l.

The second case (Fig. 2) shows a patient suffering from chronic obstructive pulmonary disease. The blood gas values are pH = 7.35, bicarbonate = 22 meq/l, and CO₂ = 60 mmHg. Willie’s acid-base box is then used to reexamine this patient case. The pH is inside the box and identifies normality, whereas the bicarbonate value is outside the box to the right and depicts alkalosis. The middle line in the box represents the metabolic component of the acid-base system, which is measured clinically as bicarbonate. This is depicted by the box being filled with the value of 28 meq/l.

The third case (Fig. 3) shows a patient in cardiopulmonary arrest. The blood gas values are pH = 7.35, bicarbonate = 45 meq/l, and CO₂ = 35 mmHg. Willie’s acid-base box is then used to reexamine this patient case. The pH is inside the box and identifies normality, whereas the bicarbonate value is outside the box to the right and depicts alkalosis. The middle line in the box represents the metabolic component of the acid-base system, which is measured clinically as bicarbonate. This is depicted by the box being filled with the value of 35 meq/l.

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acid-base box for this patient is shown in Fig. 1. In this example, the pH value of 7.27 is below the normal range and is plotted by the circle outside the box on the left. The bicarbonate concentration of 26 meq/l is within the normal range and, thus, is plotted inside the box. Finally, the partial pressure of CO₂ is 60 mmHg is plotted outside the box to the left. The marks outside the box now name the patient’s condition, in this case, as “respiratory acidosis.”

In the second case (Fig. 2), blood gas values are shown from a patient with chronic obstructive pulmonary disease: pH = 7.33, bicarbonate = 31 meq/l, and CO₂ = 60 mmHg. Willie’s acid-base box for this patient is shown in Fig. 2. In this example, the pH value of 7.33 is below the normal range and is plotted by the circle outside the box on the left. The bicarbonate concentration of 31 meq/l is above the normal range and, thus, is plotted outside the box on the right. Finally, the partial pressure of CO₂ of 60 mmHg is plotted outside the box to the left, as in the previous example. In this case, where all three marks are outside the box, the side with most outside values names the patient’s condition, whereas the side with only one mark depicts the compensation, namely, respiratory acidosis with metabolic compensation. With chronic obstructive pulmonary disease, the blood bicarbonate value appears much different from that in the acute asthma attack because there has been sufficient time for the kidneys to respond to the acidosis by reabsorbing bicarbonate and increasing acid excretion, primarily in the form of ammonium ions (1). Through this mechanism, the kidneys generate new bicarbonate and increase blood bicarbonate levels. This brings the patient’s pH back toward the normal range, although still somewhat low compared with normal.

The final example (Fig. 3) shows a patient in cardiopulmonary arrest with the following representative blood gas values: pH = 7.02, bicarbonate = 19 meq/l, CO₂ = 80 mmHg, and O₂ = 30 mmHg. Willie’s acid-base box for this patient is shown in Fig. 3. In this example, the pH value of 7.33 is below normal, the bicarbonate concentration below normal, and CO₂ is above normal. Thus, in this case, all three marks are outside the box and on the left side. Since the side with the most marks names the patient’s condition, we would identify this as a combination metabolic and respiratory acidosis. This condition makes sense for two reasons: first, the patient in cardiopulmonary arrest will retain CO₂ (respiratory acidosis), but also the very low O₂ will lead to anaerobic metabolism and a buildup of lactic acid (metabolic acidosis).

This method works well with almost all but the most complex acid-base problems and should be of benefit to both medical and nursing students. I have enjoyed using it because it receives positive feedback from the students and honors a dedicated and caring physiology teacher.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

REFERENCE