THE BALANCE OF ACID AND BASE

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Anyone who draws, analyzes or interprets blood gases, arterial, venous or capillary, understands the importance of acid-base balance. This also includes the pH balance of extra-cellular fluids. Whenever one considers an environment where a particular range of pH is of utmost importance, it is necessary to understand the mechanisms of acid-base balance in the body and the regulatory and compensatory mechanisms therein. These compensatory mechanisms exist in order to attempt to provide homeostasis in the human body. Increasing the respiratory rate and/or depth of respirations, as well as renal retention of bicarbonate ions occur to counteract an acidotic environment. This only holds true if these organs are functioning properly. Many pharmaceutical agents lose their efficacy in an acidotic environment. Organ dysfunction occurs from acid-base imbalance which, in turn, will exacerbate the situation into a continuing spiral of organ failure if not treated. Most of the organs in the human body function optimally at a pH at or near 7.4. Fluctuations in pH can result in neuromuscular weakness, organ dysfunction and reduced drug efficacy and action.

Many clinicians disregard calculated values but much can be gleaned from these values

Elementary chemistry describes pH as a descriptive method used to express small concentrations of acid in solution. Stronger acids have a looser hold on the hydrogen ion than weaker acids and therefore interact in chemical reactions more readily. The scale used is exponential, so small changes in pH describe large changes in acid concentration. Each unit of pH is equal to a ten-fold change in acid concentration. A buffer is a substance undergoes a reversible chemical reaction that resists and thusly minimizes any pH change when mixed with an acid. Buffer systems usually consist of a weak acid, one that holds it's hydrogen ion more tightly, and it's salt. The reaction between acid added to a buffer system results in the formation of the weak acid with the hydrogen ion from the stronger acid reacting with the weaker acid's salt to produce more of the weaker acid. If an alkaline solution is added to a buffer system, the weak acid provides the hydrogen ion, again resisting much of a change in pH as would be expected without the buffer.

Buffer base is a concept first considered in 1948 as an explanation for the non-respiratory component of abnormal acid-base balance. The change in buffer base from normal was known as "deltaBB", an early approximation of base excess. In the 1960's, the Siggaard-Andersen nomogram used this value to further explain the extent of the non-respiratory cause of a patient's abnormal pH. In 1977, Severinghaus tried to modify the nomogram to allow for the estimation of chronic metabolic compensation, with some schools of thought accepting this modification while others dismissed it.

The chemical buffer system classically considered in the human body is the carbonic acid – bicarbonate system. This natural system requires that the body eliminate elements of both sides of the reaction to maintain a proper pH. This buffer system works so well in the body because the chemical by-products of the reaction are carbon dioxide and water. These are easily controlled by the lungs through ventilation and the renal system through micturation. By keeping this chemical equation balanced, pH can be maintained at the appropriate level. Ventilatory response to fluctuations in acid-base balance occurs rapidly, whereas renal response requires several hours to days to respond. The balance of bicarbonate and carbonic acid in this system determines the pH of the blood and extracellular fluid and is normally a 20:1 ratio.

How does one use all of the blood gas results to aid in the differential determination of the mechanisms of acidemia or alkalemia in order to facilitate and optimize treatment? Many clinicians disregard or put much less emphasis on some of the reported results, or do not report it at all, citing insignificance of the calculated values; total CO2, base excess and standard bicarbonate . There is, however, a great deal of information that can be gleaned from these values.

Total CO2 is the sum of the bicarbonate ion and the carbonic acid components of the acid-base equation. In itself, this number is not as pertinent as an adjunctive component when compared with serum bicarbonate. The difference between total CO2 and serum bicarbonate is normally in the 5% range with a higher difference indicative of acidosis and a lower value indicating alkalosis. This ratio can be skewed in patients with chronic compensated situations and can be considered extraneous to this population of patients.

Base excess or base deficit is an indication of the amount of anionic compound and hydrogen ion in the patient's blood compared to the "normal" level for that patient. The value of base excess can also be described as the amount of acid needed to actualize a normal pH of 7.4. In specific terms, base excess is defined as the amount of acid needed to bring 1 liter

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that may be developed by the home care company or obtained from a number of healthcare organizations such as the American Lung Association (ALA) or the AARC. Additional material that may be of value is available over the internet but source and validity should be checked before they are used for patient education. The COPD disease process, breathing techniques and exercises, respiratory-related medications, activities of daily living (ADLs) and nutrition are some of the program-specific educational topics that should be covered by the RT during patient visits.

Ongoing follow-up visits by the RT helps to insure that the DM program for patients with chronic lung disease will achieve its stated goals and objectives. However, state law often requires a physician or healthcare provider prescription authorizing these RT visits. Most physicians or healthcare providers will welcome patient reports generated during the home visits and will use them to follow-up on the overall status and progress of their patients. These reports should include a patient assessment plus a medication profile and patient history. The unfortunate part of DM programs, especially for COPD patients, is the lack of recognition and reimbursement by insurance payors. It is recommended that any home care company offering a DM program to their chronic lung patients plan on conducting follow-up patient surveys to demonstrate program effectiveness, especially in terms of treatment compliance, patient emergency department (ED) visits and hospitalizations. Data obtained from this type of study is useful in showing the effectiveness of RT involvement in the home and may one day lead to reimbursement for RT services in the home setting.

Recent studies prove the value and effectiveness of these services in terms of patient compliance, quality of life, improvement in respiratory-related symptoms, reduction in ED visits and hospitalizations due to cardiopulmonary related causes. The reasons for these positive patient outcomes is a result of the education received by the patient along with a better understanding of the need for using the home oxygen and aerosol treatments as prescribed. Patients also know what to look for when their condition adversely changes and when to contact their physician or healthcare provider. The result is better patient care and a reduction in overall medical expenditures for patients with COPD. Based on CMS data in 2006, the average cost of caring for a COPD in the hospital is just under $24,000. In conclusion, home care companies and related professional organizations must continue to promote DM programs as a way to control healthcare costs and to deliver the best home care possible.

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of blood to it's normal pH if the academia is purely a metabolic dysfunction, assuming a normal PCO2 of 40 mmHg. These basic chemicals consist not only of bicarbonate but include other buffers in the body as phosphates, hemoglobin and sulfates, to name a few. Intuitively, base excess means a metabolic alkalosis and a base deficit means a metabolic acidosis. It is important to understand that this is a calculated value and not a direct measurement. Base deficit can also be used to direct bicarbonate therapy. Using the equation whereby the base deficit is multiplied by 10% of the patient's body weight in kilograms will result in the amount of bicarbonate needed to neutralize an equivalent amount of fluid, blood or extracellular fluid, in a compartment of one tenth the patient's body.

Another calculated value that can help shed some light on the metabolic component of acid-base imbalance is the standard bicarbonate level. This value represents the bicarbonate ion concentration in the fluid corrected to a normal PCO2 of 40 mmHg and, in much the same way as base excess, describes the metabolic component of a patient's acid-base balance. As described previously, this value in conjunction with the total CO2 can give information about pH.

As we know, oxygen also affects acid-base balance by combining with and thereby lessening the buffering capacity of hemoglobin. Conversely, acidotic environments affect the oxygen saturation of hemoglobin. This concept is of great importance because of the Hendersen-Hasselbeck concept. Acidemia "shifts the curve to the left" means that there is a lower affinity of oxygen to hemoglobin at a given oxygen level in arterial blood. This in turn means that there is a greater release of oxygen into the capillaries where there is a higher acid concentration. Alkalemia causes the hemoglobin to hold the oxygen more tightly and increases the hemoglobin's oxygen carrying capacity.

The human body is an amazing machine that contains many intricate mechanisms to maintain normal function. A great many methods to help a clinician differentiate the causative factors of chemical imbalance within their patients have been and continue to be discovered, fine-tuned and utilized to best treat our patients.