EDUCATION

Strong ion approach in blood gas analysis

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Landmark advancements in the clinical diagnosis and treatment of acid base disturbances have included the Henderson-Hasselbalch equation (1916), base excess (1960), anion gap (1970) and the strong ion approach (1983). The Henderson-Hasselbalch equation used the pH value as an overall measure of acid base status, PCO2 as an independent measure of the respiratory component of acid base balance and base excess, and actual bicarbonate concentration or standard bicarbonate as a measure of the metabolic (also called non respiratory) component of acid base balance. However it only provides an estimate of the magnitude of a metabolic acidosis and not the mechanism of its development. Hyperchloremic acidosis is one of many such clinical conditions that have no rational explanation. It is well recognized that the rapid infusion of large quantities of 0.9% NaCl induces acidosis and decreases plasma bicarbonate concentration1.

Stewart proposed that plasma pH was determined by three independent factors; PCO2, the strong ion difference (SID), which is the difference between the charge of plasma strong cations (sodium, potassium, calcium and magnesium) and the anions (chloride, lactate, sulfate, ketoacids, nonesterified fatty acids, fatty acids and many others) and Atot, which is the total plasma concentration of nonvolatile buffers (albumin, globulins, and inorganic phosphate)2. In this context, pH value and bicarbonate concentration are dependent variables and PCO2, SID and Atot are independent variables. Independent variables cannot be affected by changes within the system or by changes in other independent variables. In contrast, dependent variables are influenced directly and predictably by changes in the independent variables. From the three independent factors Stewart developed a complicated polynomial equation that expressed the pH value as a function of eight factors2. Subsequently this was simplified to six factors in 19973. The equation states the pH value is a function of three independent factors (PCO2, SID and Atot) and three constants (S, the apparent dissociation constant for plasma carbonic acid K1 and Ka the effective dissociation constant for nonvolatile buffers in plasma).

$$pH = pK1 + \log \frac{SID - Atot / (1 + 10pka\text{-}pH)}{S\ PCO2}$$

The strong ion approach distinguishes six primary acid base disturbances (respiratory, strong ion, or nonvolatile buffer acidosis or alkalosis) instead of the four primary acid base disturbances (respiratory or metabolic acidosis and alkalosis) differentiated by the traditional Henderson Hasselbalch equation. Acidosis results from an increase in PCO2, nonvolatile buffer concentration (albumin, globulin and phosphate) or from a decrease in SID. Alkalosis results from decrease in PCO2 and nonvolatile buffer concentration or from an increase in SID.

The strong ion approach provides an explanation for the development of hyperchloremic acidosis and therefore a rational treatment for this condition. Normal human plasma SID is 42 meq/l4, whereas the SID of 0.9% NaCl is 0 meq/l because sodium and chloride are both strong ions3. Administration of a large volume of 0.9% NaCl must, therefore decrease plasma SID which will create a strong ion acidosis (assuming that infusion does not cause a change in PCO2, plasma albumin globulin or phosphate concentrations). According to the traditional Henderson Hasselbalch equation hyperchloremic acidosis should be treated with sodium bicarbonate because the bicarbonate concentration was decreased. In contrast, the strong ion approach indicated that hyperchloremic acidosis was caused by the decrease in plasma SID and it is best treated by administering a solution with a high SID, such as sodium bicarbonate (SID 130 meq/l)5.

Clinical guidelines indicate that at a normal pH value (7.4) a 1 meq/l decrease in SID will decrease the pH value by 0.016, a 1 mmHg increase in PCO2 will decrease the pH value by 0.009 and a 1 g/dl increase in total protein concentration will decrease the pH value by 0.039.

A clinically important problem in sick patients is identifying and quantifying the presence of strong anions or cations in plasma that are not routinely measured. Unmeasured strong anion or cation concentration can be quantified by calculating the anion gap6.

In summary the strong ion approach provides the clinician with an improved understanding of complex acid base disturbances and the mechanism of their development. This will help in more targeted treatments of acid base and electrolyte disorders.

REFERENCES

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On Circulation…

"...the one primary and essential object is to supply the brain with an oxygenated circulation. Artificial respiration can be maintained indefinitely with ease; the heart is rather readily started, but unless cerebral anemia be overcome in less than seven minutes the patient passes into the death that knows no awakening". Crile, 1914.

Wake up Safe

Although great strides have been made in anesthesia safety, patients continue to experience unintended harm related to anesthesia and surgical care. We don't know precisely how often these events occur and we don't know their causes. As these events are relatively rare today and a system to report and analyze these events does not exist. Wake up Safe is an initiative designed to fill these gaps in knowledge and to find ways to reduce or eliminate these harmful events.

The Initiative is organized by the Society for Pediatric Anesthesia, the largest professional group for Pediatric Anesthesiologists in the United States. It is a registry of serious adverse events reported on a voluntary basis by participating institutions. Names of individual providers and institutions will not be identified and are confidential. Each institution reports the event and a structured analysis of why the event occurred. From a review of the reports we hope to find ways to improve care of children in the perioperative environment.

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