Effectiveness of the Stewart Method in the Evaluation of Blood Gas Parameters

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SUMMARY

Objectives

In 1981, Peter A. Stewart published a paper describing his concept for employing Strong Ion Difference. In this study we compared the HCO_3 levels and Anion Gap (AG) calculated using the classic method and the Stewart method.

Methods

Four hundred nine (409) arterial blood gases of 90 patients were collected retrospectively. Some were obtained from the same patients in different times and conditions. All blood samples were evaluated using the same device (ABL 800 Blood Gas Analyzer). HCO_3 level and AG were calculated using the Stewart method via the website AcidBase.org. HCO_3 levels, AG and strong ion difference (SID) were calculated using the Stewart method, incorporating the parameters of age, serum lactate, glucose, sodium, and pH, etc.

Results

According to classic method, the levels of HCO_3 and AG were 22.4±7.2 mEq/L and 20.1±4.1 mEq/L respectively. According to Stewart method, the levels of HCO_3 and AG were 22.6±7.4 and 19.9±4.5 mEq/L respectively.

Conclusions

There was strong correlation between the classic method and the Stewart method for calculating HCO_3 and AG. The Stewart method may be more effective in the evaluation of complex metabolic acidosis.

Key words: Blood gases; Stewart method.

Introduction

Acid-based disorders are frequently seen problems in patients in the intensive care unit. Small changes in blood gases may cause life-threatening events. Therefore, it is essential that values such as pH, HCO_3 and PCO_2 are measured correctly. Although there are several methods currently available for the measurement of blood gas parameters, the basic bicarbonate method described by Henderson is often used.[1] However, in 1981, Peter Stewart published a new calculation method for acid-based disorders. In place of the bicarbonate-based traditional approach used in the diagnosis and treatment of acid-based disorders, Stewart defined several factors that affect H^+ ion concentration in biological solutions.[2] According to the Stewart method, there are three basic independent variables: the strong ion difference (SID) between the strong cation and anion total concentrations, the weak acid concentration, and the partial carbondioxide pressure (PCO_2). Until the 1990s, very little interest was shown in this method described by Stewart. More recently, several researchers have used this method, giving it a place in clinical applications.[3,4]

When looking changes in pH, the Stewart method allows for a more sensitive evaluation compared to traditional methods such as Henderson and Siggard, especially in patients with complex metabolic disorders. In cases caused by multiple factors such as complex metabolic disorders, electrolytes are potentially affected and therefore more information can be obtained with the use of the Stewart. The SID value is calculated with the equation, "*Na+K+Ca+Mg–Cl- Lactate – other strong ions*" The normal SID value is 38-42 mEq/L. A value below this interval indicates metabolic acidosis, and a value above indicates metabolic alkalosis. The Strong Ion Gap (SIG) is a parameter used in place of the Stewart Anion Gap. SIG is an indicator of abnormal ion presence in the plasma (Figure 1). Positive SIG shows the presence of metabolic acidosis. The most important weak acids in the plasma are proteins and phosphates. Of the plasma proteins, the most effective negative-loaded anion is albumin. Changes in the albumin level are of great importance in the calculation of the anion gap.[5]

This study examined arterial blood samples taken from patients undergoing treatment in the intensive care unit, and aimed to determine the consistency of results using the traditional and Stewart methods.

Material and Methods

Blood samples were examined from patients undergoing treatment in the intensive care unit for various diseases. This retrospective, cross-sectional study was conducted at Gülhane Military Medical Academy Intensive Care Unit between May 2010 and July 2010. The study included 409 blood gas samples, some of which were from the same patients on different days or during different disease states. The blood gas results in the study did not define the type or severity of metabolic disorder. The arterial blood gas samples were taken from the patients with an injector, washed with heparin, and transferred to the emergency biochemistry laboratory without delay. All the blood samples were measured with the same device (ABL 800 Blood Gas Analysis Device). Measurements were taken at 37ºC. While pH and PCO_2 were measured directly, the Henderson-Hasselbach method was used to calculate HCO_3. The Siggard-Andersen formula was used to calculate base excess (HCO_3-24.4x[2.3XHbg+7.7] x[pH -7.4])x(1-0.023xHgb).[6] The equation ([Na]+[K])-([Cl] +[HCO_3]) was used for the calculation of the Anion Gap and [measured AG+0.25 X (normal albumin-measured albumin)] the corrected Anion Gap.[7]

The AcidBase.org website was used in the calculation of the blood gas parameters with the Stewart method. Age, gender and comorbidity status of the patient were recorded along with the pH, PCO_2, CL, base excess (BE), sodium and potassium. The values obtained from the emergency biochemistry laboratory for albumin, glucose, urea, lactate, calcium and magnesium were recorded on the same day. After inserting the data into the website, the HCO_3, anion gap, BE, chloride (corrected according to sodium), anion gap (calculated according to albumin), SID and SIG levels were calculated according to the Stewart method. The results were transferred to the computer.

In the study, the samples were also separated into 3 groups according to the sodium level (hyponatremia, hypernatremia and normonatremia). In each group, the chloride level was re-calculated according to the sodium level using the equation (*[Cl] corrected=[Cl] measuredx([Na] normal/[Na] measured*). The difference between the chloride level measured with the blood gas device and the corrected chloride level was examined in each group.

Statistical Analysis

The statistical analyses were applied using SPSS (version 13) software. Descriptive statistics (mean±SD, minimum, maximum) were calculated for the obtained data. Consistency between the results obtained with the blood gas device and the results with the Stewart method was evaluated using Intraclass Correlation Analysis (ICC). In addition, the direct relationship of the differences was examined with a simple regression model and Pearson correlation analysis. A value of $p < 0.05$ was accepted as statistically significant.

Results

A total of 409 arterial blood gas samples were examined from 90 patients being treated in the intensive care unit.
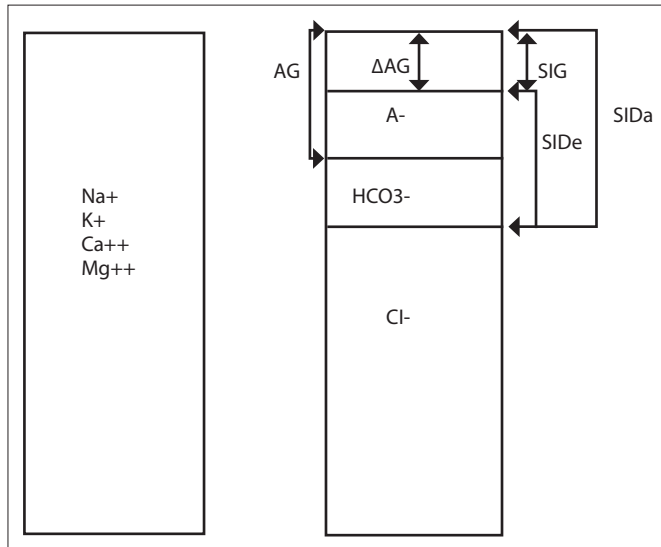
Figure 1. The Liquid-buffer system.

The mean age of the patients was 70.1±19.0 years and 47.3% were male (no of samples=201). Mean pH value was 7.37±0.1 and mean albumin level was 2.8mg/dl.

Using the traditional method, mean HCO_3 was measured as 22.4±7.2 mEq/L and mean BE as 2.86±8 mEq/L. Mean Anion Gap was determined as 20.09±4.4 mEq/L, and mean corrected Anion Gap according to albumin as 24.04±4.5 mEq/L (p<0.001).

Using the Stewart method, the mean HCO_3 was measured as 22.6±7.4 mEq/L and mean BE as 2.1±7.7 mEq/L. Mean Anion Gap was determined as 19.91±4.5 mEq/L, and mean corrected Anion Gap according to albumin as 23.84±4.5 mEq/L (p<0.001).

In all the results a statistically significant difference was seen between the Stewart method and the Henderson method (p<0.001) (Table 1). There was a high correlation between the Stewart method and the Henderson method in all the results (p<0.001). The mean strong ion difference (SID) calculated with the Stewart method was 48.33±5 mEq/L. There

was a strong correlation between SID and AG and corrected AG (p<0.001 for all values).

The mean chloride of all the samples was 101.44±7.2 mEq/L. In the hyponatremia group (n=79), the mean measured chloride level was 94.49±5 mEq/L, the mean corrected chloride was 100.7±4.7 mEq/L, and the mean corrected chloride level according to the absolute sodium level was 103.6±4.9 mEq/L (p<0.001).

In the hypernatremia group (n=80), the mean measured chloride level was 109.33±6 mEq/L, the mean corrected chloride level was 102.2±5 mEq/L, and the mean corrected chloride level according to the absolute sodium level was 100.9±5 mEq/L (p<0.001).

In the normonatremia group (n=250), the mean measured chloride level was 101.09±5.4 mEq/L, the mean corrected chloride level was 101.08±5 mEq/L, and the mean corrected chloride level according to the absolute sodium level was 101.75±7.4 mEq/L (p=0.174) (Table 2).

Discussion

In this study, a high rate of correlation was observed between the Stewart method and the traditional method in all the results. A statistically significant difference was determined between the HCO_3 results of both methods, but the difference was not at the level of clinical significance. HCO_3 was measured by calculating ($[HCO_3]=SID–(k1[Alb]+k2[Pi])=SID – [Atot]$) with the Stewart method and

$$pH = 6.1+\log \frac{[HCO_3]}{0.03 \times pCO_2}$$ with the Henderson method.

In the calculation of HCO_3, enzymatic direct measurement methods were also used. However, in previous studies, a high correlation was seen between the enzymatic direct measurement and the calculation method. Therefore, from a cost perspective, the use of the calculation method is recommended.[8] Additionally, in a study by Story and Paustie, it was suggested that a difference between HCO_3 measure-

Table 1. Comparison of Stewart and traditional methods in terms of pH, HCO_3, AG, BE and SID

Parameters	Traditional method	Stewart method	P
pH	7.37±0.1	7.37±0.1	NS
HCO3 (mEq/L)	22.4±7.2	22.6±7.4	<0.001
AG (mEq/L)	20.09±4.4	19.91±4.5	<0.001
BE (mEq/L)	-2.86±8	-2.1±7.7	<0.001
SID (mEq/L)		48.33±5	

AG: Anyon Gap; BE: Base Excess; SID: Strong Ion Differences; NS: Non significant.

Table 2. Corrected chloride levels determined according to serum sodium levels

	Serum chloride level (mEq/L)	Corrected serum chloride level (mEq/L)	P
Hyponatremia (n=79)	94.49±5	100.7±4.7	<0.001
Normonatremia (n=250)	101.09±5.4	101.08±5	0.174
Hypernatremia (n=80)	109.33±6	102.2±5	<0.001

ment methods of more than 1mEq/L is significant.[9] In the current study, the difference between the HCO_3 levels of the Henderson and Stewart methods was less than 1mEq/L. Therefore, the use of either method in the calculation of HCO_3 will not affect the clinical result.

The Anion Gap is used to predict the difference between strong anions and cations and organic and inorganic acids that cannot be measured in the plasma. The Anion Gap may be inaccurately low in the case of hypoalbuminemia. In hypoalbuminemia, there is an alkalinization effect that may result in anions that cannot be measured. Therefore, especially in patients with hypoalbuminemia, it is recommended that albumin correction is applied for the measurement of the Anion Gap.[6,10] In the current study, there was a clinical and statistically significant difference in the albumin-corrected Anion Gap measured by the Henderson and Stewart methods. In addition, a high correlation was observed between SID and the corrected Anion Gap in the Stewart method. The use of both methods is recommended in the evaluation of metabolic disorders. However the more reliable data is obtained from the use of SID than from several parameters, especially in patients with complicated metabolic acidosis.

BE is used in calculations of metabolic acid-based disorders. BE below -2 is considered metabolc acidosis. In the Stewart method of calculating the BE value, the albumin value is used.[2] In the current study, a clinical and statistically significant difference was seen between the BE measurements made with the two different methods. It has been observed in measurements made using the Van Skyle method in particular, that the BE result is affected by the albumin level. This difference between the two methods is thought to be due to low albumin levels in intensive care patients. In a study by Fencl, it was determined that the BE value is misrepresentative in patients with a low albumin level and correction is necessary according to albumin.[9] An experimental study by Morgan et al measured the accuracy of the Van Skyle method in BE measurement. It was shown that despite no statistically significant difference in the BE value in different PCO_2 levels, the BE value was affected by changes in the lactate level.[11] This result demonstrated that in the evaluation of respiratory acid-based disorders, there is no need to measure

BE, as the BE value is not affected despite changes in PCO_2. In the current study, as no differentiation was made between metabolic and respiratory disorders, the effect of PCO_2 on the B value could not be determined.

Changes in plasma free fluid result from abnormal sodium concentration and cause dilutional acidosis and concentrational alkalosis. The change in the plasma free fluid causes change in SID. When dilution or concentration occurs in plasma free fluid, correction of the measured chloride level is necessary.[6] The corrected chloride value is used in the strong ion formula. In the current study, the patients were separated into 3 groups according to the sodium level. When intra-group comparisons were made of the chloride levels, it was necessary to correct the chloride level in those with an abnormal sodium value. However, in those with a normal sodium level, it was not necessary to apply chloride correction to calculate SID or the Anion Gap. This result was also an indicator of the accuracy of the formula applied for chloride correction.

In conclusion, the results of this study showed a high correlation between the Stewart method and the traditional Henderson-Hesselbach method for evaluating acid-based disorders. Both methods can be used with similar accuracy in acid-based disorders. However, in patients with complex metabolic acidosis, the Stewart method is thought to provide more sensitive information. In metabolic acidosis with hypoalbuminemia, the evaluation of the Anion Gap after correction according to albumin is more accurate. In addition, it has been shown that SID and AG should be calculated after correction of the chloride level in cases of abnormal serum sodium values.

Conflict of Interest

The authors declare that there is no potential conflicts of interest.

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