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Case Report

Biochemistry Section

Undisplayed Bicarbonate ion Concentration in Arterial Blood Gas Analysis

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ABSTRACT

Blood bicarbonate ion concentration ($BcHCO_3^-$) is a vital parameter in the management of acid base disorders. In an arterial blood gas (ABG) analyzer, the $BcHCO_3^-$ is calculated from the values of pH and pCO_2.

We received four samples in a span of one year, from December 2011 to November 2012 for arterial blood gas analysis, in which the $BcHCO_3^-$ was not displayed by the blood gas analyzer. Based on the information available in literature, the formula for calculating the $BcHCO_3^-$ from pH and pCO_2 was obtained and $BcHCO_3^-$ was calculated in all four samples mentioned above. An attempt was made to establish a clinical correlation between laboratory and clinical data of these patients.

All these values of $BcHCO_3^-$ were above the maximum display limit of our blood gas analyzer, which was 60 mmol/L and hence, they were not displayed. All four patients had chronic respiratory disease and they were taking furosemide and / or dexamethasone.

High values of $BcHCO_3^-$, sometimes falling beyond the display range of the ABG analyzer, could be observed in patients of chronic respiratory disease, treated with drugs like furosemide and dexamethasone, that result in bicarbonate retention.

Keywords: Bicarbonate ions, Blood gas analysis, Respiratory acidosis, COPD

INTRODUCTION

Blood bicarbonate ion concentration ($BcHCO_3^-$) is an important investigation in the diagnosis and management of acid-base disorders. It is used to classify a given acid base disorder, assess the degree of compensation, decide the line of treatment and monitor prognosis [1]. In most of the arterial blood gas (ABG) analyzers, the $BcHCO_3^-$ is calculated using the values of pH and partial pressure of carbon dioxide (pCO_2) [2]. However, we observed that for some samples, the ABG analyzer did not display the $BcHCO_3^-$. The objective of this study was to know the reason for this and also to know as to how the $BcHCO_3^-$ could be obtained in such instances. This study was also aimed at knowing the types of patients in whom such a situation could arise.

MATERIAL AND METHODS

We received four samples in a span of one year, from December 2011 to November 2012, for ABG analysis, in which the $BcHCO_3^-$ was not displayed by the ABG analyzer, RL 348 from Siemens Diagnostics Ltd., installed in our laboratory. The operating manual of the ABG analyzer was studied to find out the display range for $BcHCO_3^-$. Similar information was obtained about other models of ABG analyzers.

By using information from literature and by performing mathematical operations, the formula for calculating $BcHCO_3^-$ from pH and pCO_2 was obtained. By using this formula, $BcHCO_3^-$ for the four samples mentioned above was calculated. To verify the correctness of the formula, $BcHCO_3^-$ of 10 other samples falling within the measuring range of the ABG analyzer were also calculated using the formula. These values were compared with the values displayed by the analyzer. Clinical and laboratory data pertaining to the four samples mentioned above was collected from hospital and laboratory records.

RESULTS AND DISCUSSION

$BcHCO_3^-$ can be obtained by calculation from the values of pH and pCO_2 or by measurements using analytical methods. The calculated value is advantageous, as it is not affected by electrolyte exclusion effects and reflects $BcHCO_3^-$ as measured with an ion selective electrode [2]. In most of the ABG analyzers, the $BcHCO_3^-$ is calculated from the measured pH and pCO_2 values. Different ABG analyzers have different upper and lower limits for displaying $BcHCO_3^-$. Values falling beyond the display limits are not displayed by the analyzers, though they may sometimes be encountered in patients. In such instances, laboratory personnel may suspect analyzer malfunction and reporting may be delayed while trying to get the analyzer repaired. To prevent this, it is necessary to know

(1) The formula by which $BcHCO_3^-$ can be calculated from the pH and pCO_2 values and

(2) The types of patients in whom $BcHCO_3^-$ may fall beyond the display range of the ABG analyzer.

(1) The formula, by using which $BcHCO_3^-$ can be calculated from the pH and pCO2 values [2].

The relation between pH, pCO_2, and bicarbonate ion concentration ($cHCO_3^-$) is given by the Handerson-Hasselbalch's equation as follows:

$$pH = 6.103 + \log [cHCO_3^- / (0.0306 \times pCO_2)] \text{ ------- formula 1}$$

Here, $cHCO_3^-$ is expressed in mmol/L, while pCO_2 is expressed in mmHg.

We modified formula 1 by using simple mathematical operations to get the following formula for directly calculating the $cHCO_3^-$:

$$cHCO_3^- \text{ (mmol/L)} = 24.1 \times pCO_2 \text{ (mmHg)}/10^{9\text{-}pH} \text{ ------- formula 2}$$

Another modified form of formula 1 that can be found in literature is as follows [3]:

$$cHCO_3^- = 0.03 \times pCO_2 \times 10^{pH-6.1}$$

The $BcHCO_3^-$ can also be directly obtained on entering pH and pCO_2 values in software programs available on the internet [3]. $BcHCO_3^-$ for ten other samples calculated using formula 2 matched exactly with the values displayed by the analyzer, thus confirming the validity of formula 2. Literature shows that there is no significant difference between $cHCO_3^-$ values obtained by measurements or by

Sample No.	pCO_2 mmHg	Actual pH	Expected pH *	Actual $BcHCO_3$ mmol/L	Expected $BcHCO_3$ * mmol/L	Diagnosis	Factors adding to the rise in $cHCO_3^-$
1	85.3	7.483	7.25	62.29	40.8	Bilateral pulmonary fibrosis with pulmonary hypertension	Dexamethasone
2	102.4	7.448	7.2	69.2	46.8	Congestive Cardiac failure with anasarca with respiratory insufficiency.	furosemide
3	127.7	7.313	7.10	63.2	55.6	COPD†	furosemide
4	122.3	7.409	7.12	75.5	53.8	COPD†.	furosemide

[Table/Fig-1]: Clinical and laboratory data of patients mentioned in the text (n=4)
* Expected values are calculated using baseline values of pH, pCO_2 and $BcHCO_3^-$ as 7.4, 40mmHg, and 25mmol/L respectively.
† COPD: Chronic Obstructive Pulmonary Disease.

calculation [4]. This obviates the need to measure such undisplayed BcHCO3- by another method and the calculated value can be treated as correct.

(2) The types of patients in whom $BcHCO_3^-$ may fall beyond the display range of the ABG analyzer:

Relevant data pertaining to the four samples mentioned above has been presented in [Table/Fig–1]. The value for actual $BcHCO_3^-$ mentioned in the [Table/Fig–1] was not displayed by the analyzer and it was calculated manually using formula 2, which has been given above. As is evident from the table, the calculated $BcHCO_3^-$ values were above 60mmol/L and hence, they were not displayed by our analyzer (RL 348), that has a measuring range of 3-60 mmol/L. All patients mentioned in the [Table/Fig–1] had chronic respiratory disease leading to increased pCO_2 (hypercapnea) and chronic respiratory acidosis. Excess CO_2, on undergoing the following reaction, is converted in the blood to H^+ and HCO_3^-: .

$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

The excess H^+ ions generated are buffered mainly by the protein buffer systems, leaving behind an excess of HCO_3^- ions. This may manifest as metabolic alkalosis, especially immediately following a rise in pCO_2. With passage of time, renal compensation of acidosis will occur and it may fully restore the pH to normal, in spite of high pCO_2 values. During renal compensation, the renal tubular cells promote H^+ ion excretion and bicarbonate retention, thus further increasing the $cHCO_3^-$ values [5]. In chronic compensated respiratory acidosis, the expected rise in $cHCO_3^-$ is 3.5 mmol/L for every 10mm Hg rise in pCO_2, while the expected fall in pH is 0.05 units for every 15 mmHg rise in pCO_2. Using the above information, the expected pH and $BcHCO_3^-$ in our patients were calculated from pCO_2 values [5]. [Table/Fig–1] shows that the actual pH and $BcHCO_3^-$ in our patients were higher than the values expected, due to pure renal compensation, suggesting that an additional factor was causing metabolic alkalosis which was superimposed on compensated respiratory acidosis. There was no record of any intravenous bicarbonate being administered, which could have led to the superimposed metabolic alkalosis. Hospital records of these patients showed administration of furosemide and/or dexamethasone. Furosemide blocks Na^+ and K^+ absorption from the ascending limb of loop of Henle, resulting in a sodium rich fluid reaching the distal convoluted tubule. This stimulates aldosterone secretion that causes loss of K^+ and H^+ in the urine, leading to alkalosis. Similarly, in case of exogenous mineralocorticoid or glucocorticoid administration, K^+ and H^+ ions are excreted by the kidney as a consequence of increased Na^+ reabsorption. Decreased tubular K^+ concentration stimulates ammonia production and thus, renal H^+ excretion as NH_4^+. This is accompanied by enhanced HCO_3^- reabsorption, causing alkalosis [5]. Thus, the superimposed metabolic alkalosis in our patients could have been caused by administration of furosemide and dexamethasone.

The blood concentrations of electrolytes could be traced only for sample 1, as they were requested along with the ABG analysis and were mentioned in the records. They were, Na^+=123mEq/L, K^+=3.1mEq/L and Cl^-=75mEq/L. The anion gap (AG) was calculated by the formula, Na^+- (Cl^-+HCO_3^-) and in this case, it was minus 14.29mEq/L. The delta gap was calculated by the formula, (AG -12) – (24 – HCO_3^-) and in this case, it was 12mEq/L, confirming the presence of metabolic alkalosis [6].

To summarize, $BcHCO_3^-$ may be increased in patients with chronic respiratory disease due to hypercapnoea and renal compensation. Such a rise may be further augmented by treatment with loop diuretics like furosemide and/or glucocorticoids and mineralocorticoids. Sometimes, the raised bicarbonate values may not be displayed by the ABG analyzers, as they may be beyond the display range of the instrument. In such cases, the $BcHCO_3^-$ values may be calculated accurately from the modified form of Handerson –Hasselbalch's equation, which has been given above.

The aim of this article was to draw attention to the fact that whenever $BcHCO_3^-$ is not displayed on the ABG analyzer, the cause may be found in the medical condition of the patient. Hence, instead of suspecting analyzer malfunction, in such situations, it is worthwhile, probing into the patient history, and calculating the $BcHCO_3^-$ manually, so that critical time is saved.

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