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A Novel Graphical Contemporary Perspective ABG Interpretation

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Abstract: *Arterial Blood Gas analyser is one of the most important point of care testing in the management of critically ill patients. Usually, the measured parameters like pH, pCO2and calculated parameters like HCO3and Standard Base Excess values are utilized for interpretation of various acid base disturbances. A novel contemporary perspective interpretation method for Arterial Blood Gas (ABG) was recently developed by the current author in which the net changes in pH is related to both the changes in respiratory and non-respiratory (metabolic) component affecting the pH. The aim of the current study is to represent this perspective ABG interpretation in a four quadrant graphical method for better understanding and correlation. A total of 250 arterial blood gas sample data's were utilized, classified into various groups and the changes in pH due to respiratory and non-respiratory component is calculated for all the cases. The magnitude and the changes in direction either positive denoting the alkaline effect or negative denoting the acidic effect is clearly observed, graphically analysed and correlated in all the acid base disturbances.*

Keywords: *Arterial Blood Gas, Non-Respiratory Hydrogen Ion Concentration, Novel Perspective Interpretation Method, Four Quadrants Graphical Tool*

1. Introduction

Arterial blood gas analyser is one of the most important point of care testing that has immense value in the management of critically ill patients.[I]An increase in the burden of coronary heart disease, diabetes mellitus, chronic obstructive pulmonary diseases (COPD), asthma ,renal failure and trauma patients enhanced the requirement of blood gas analysers due to the rise in the number of patients treated in the emergency department and critical care units but at the same time, the complex and arduous task of interpreting the blood gas analysis report act as a restraining factor for the same.[I-III]

The first postulate of acid base balance theory proposed by the current author (Rajini Samuel) states that the net changes in total pH is due to both the changes in respiratory and non-respiratory(metabolic) component affecting the pH. [III, IV]Based on this concept, a novel ABG interpretation method was developed by the current author correlating the net changes in total or actual pH [Δ pH] with the changes in respiratory [Δ RpH] and non-respiratory (metabolic) component [Δ NRpH] affecting the pH.[II,III] In this current research study, this novel interpretation of Arterial Blood Gas analysis is depicted in a four quadrant graph for better understanding and correlation.

2. Materials and Methods

The measured pH, pCO2, bicarbonate and standard bicarbonate values are noted. The standard base excess or extracellular base excess- cBase (ECF) is calculated using the most commonly used algorithm in ABG analyser.[V,VI]

$$cBase(ECF) = cHCO_3 - 24.8 + 16.2 \times (pH - 7.40)$$

2.1. Newly Derived Ratios

These novel ratios are derived using bicarbonate, standard bicarbonate and carbonic acid values.[V-VIII]

Ratio 1 = HCO_3/Std HCO_3

Ratio 2 = (HCO_3 -Std HCO_3) / H_2CO_3

Ratio 3 = Ratio 1 X Ratio 2

The carbonic acid concentration (mmol/L) was calculated by the given formula.

H_2CO_3=0.03 X pCO_2

2.2. Non-Respiratory Hydrogen Ion Concentration (Nrh+)

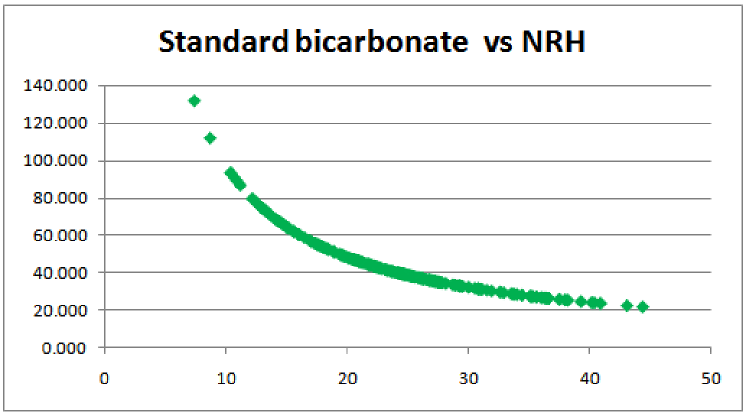
The calculated hydrogen ion concentration equivalent of standard bicarbonate is called the 'non-respiratory hydrogen ion concentration' (Hydrogen ion concentration at non-respiratory pH of pCO_2 40 mm of Hg). [IV, IX]

NRH^+ = {24 X pCO_2}/ Std HCO_3

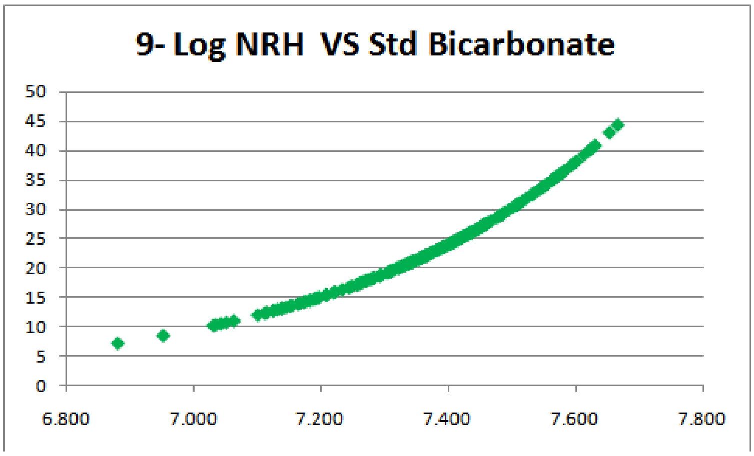
= {24 X 40}/ Std HCO_3 (pCO2 is 40 mm of Hg)

NRH^+ = 960 / Std HCO_3; NRpH = 9 – log [NRH^+]

The relation between NRH^+ and standard bicarbonate shown in the graph 1 clearly depicts that the shape of the graph is rectangular hyperbola and as NRH^+ increases, the standard bicarbonate decreases and vice versa. The relation between non-respiratory pH and standard bicarbonate is shown in the graph 2.



Graph1. *X axis: Std Bicarbonate VS Y axis: NRH^+*



Graph2: *X axis: 9- Log NRH VS Y axis: Std Bicarbonate*

2.3. Net Changes in Total PH

The net changes in Total pH (Actual pH) includes both the changes in respiratory and non-respiratory (metabolic) component affecting the pH.[IV,X,XI]

Δ pH = ΔRpH + ΔNRpH

Δ pH = [pH - 7.4] (net changes in Total or Actual pH)

Δ NRpH = [NRpH - 7.4] (changes due to Non-respiratory component)

Δ RpH = [pH - 7.4] - [NRpH - 7.4]

Δ RpH = [pH – NRpH] (changes due to Respiratory component)

2.4. Calculation of Δrph(Ph –Nrph)

The derivations are already published in previous research articles by the current author.[III,IV]

ΔRpH(pH – NRpH)= log 40 + log {(HCO_3/ StdHCO_3)/ pCO_2}

(the value of log 40 is 1.6)

ΔRpH(pH – NRpH) =1.6 + log (HCO_3/Std HCO_3) - log(pCO_2) or

ΔRpH(pH –NRpH)= 1.6 + log{ (HCO_3/Std HCO_3)/ pCO_2}

3. Results

A total of 250Arterial Blood Gas sample data's were utilized and classified into various acid-base disorder groups based on their normal ranges. The normal reference for arterial blood pH is 7.35 to 7.45, for pCO2 is 35-45 mm of Hg and for bicarbonate is 22-26 mEq/L ormmol/L. The various groups are tabulated in the tables 1 and2. The net changes in total or actual pH [Δ pH (pH - 7.4)] denoting both the changes in respiratory [Δ RpH(pH – NRpH)] and non-respiratory(metabolic) component [Δ NRpH(NRpH - 7.4)] affecting the pH were applied for all the cases for different acid-base disorder groups.

Table1. *Normal and Respiratory Acid-base Disorder Groups*

Groups	Type of Acid Base Disorder	Number of Cases
Group I	**Normal:**	**25 cases**
Group II	**Respiratory acidosis**	**32 cases**
	Respiratory acidosis 1(pCO_2> 45≤ 60 mm of Hg)	11 cases
	Respiratory acidosis 2(pCO_2> 60≤ 80 mm of Hg)	14 cases
	Respiratory acidosis 3(pCO_2> 80 mm of Hg)	7 cases
Group III	**Respiratory alkalosis**	**53 cases**
	Respiratory alkalosis 1: pCO_2 31 to 34 mm of Hg	16 cases
	Respiratory alkalosis 2: pCO_2 26 to 30 mm of Hg	22 cases
	Respiratory alkalosis 3: pCO_2 21 to 25 mm of Hg	8 cases
	Respiratory alkalosis 4: pCO_2 ≤ 20 mm of Hg	7 cases

Table2. *Metabolic Acid-base Disorder and Missellaneous Groups*

Groups	Type of Acid Base Disorder	Number of Cases
Group IV	**Metabolic acidosis**	**47 cases**
	Metabolic acidosis 1(HCO_3>18≤ 22 mmol/L)	10 cases
	Metabolic acidosis 2(HCO_3> 15≤ 18 mmol/L)	12 cases
	Metabolic acidosis 3(HCO_3> 10≤ 15 mmol/L)	17 cases
	Metabolic acidosis 4(HCO_3 ≤ 10 mmol/L)	8 cases
Group V	**Metabolic alkalosis**	**34 cases**
	Metabolic alkalosis 1(HCO_3>40 mmol/L)	12 cases
	Metabolic alkalosis 2(HCO_3> 30 ≤ 40 mmol/L)	12 cases
	Metabolic alkalosis 3(HCO_3> 26≤ 30 mmol/L)	10 cases
Group VI	**Missellaneous further divided into Sub-groups**	**59 cases**
	Missellaneous1: Decreased pH ,increased pCO_2 with decreased HCO_3	11 cases
	Missellaneous 2: Normal pH, increased pCO_2 with Increased HCO_3	20 cases
	Missellaneous 3: Normal pH, Decreased pCO_2& Decreased HCO_3	28 cases

From the normal reference level of pH, the normal level of Δ pH (pH - 7.4) is calculated as ± 0.05. If the Δ pH is < -0.05, it denotes acidic pH and if the Δ pH is > +0.05, it denotes alkaline pH. Then the value of Δ pH is compared with the values of Δ RpH (more negative for respiratory acidosis and more positive for respiratory alkalosis) and Δ NRpH (more negative for metabolic acidosis and more positive for metabolic alkalosis).ΔNRpH (NRpH-7.4) is calculated using the relation, {Δ pH = Δ RpH + Δ NRpH} where this Δ pHis calculated using the measured pH.

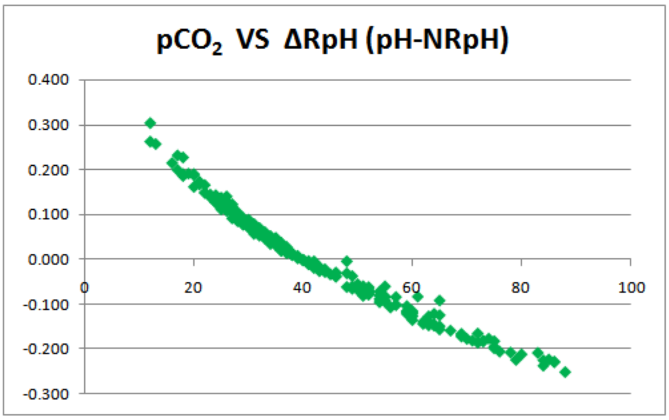
4. Discussion

The standard bicarbonate values are used to calculate the 'Non-respiratory hydrogen ion concentration'(NRH)which are used to derive an equation denoting the respiratory influence of pCO2 in causing changes in pH that plays a key role in the understanding of this novel perspective Arterial Blood Gas interpretation.[III]The magnitude and direction (positive or negative) of the changes in the parameter ΔRpH (pH-NRpH) denotes the respiratory influence in causing changes in PH[III,IV]

PH –NRpH = log 40 + log (HCO3/Std HCO3) - log (pCO2)

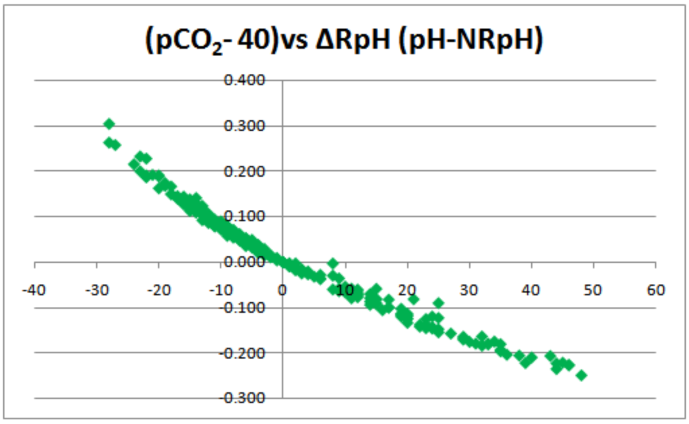
From the above relation it is very clear that, at pCO2 40mm of Hg, the value of [pH – NRpH] is zero. (Standard bicarbonate and bicarbonate values are equal at pCO2 40 mm of Hg; log1 is zero). At higher pCO2 levels (> 40 mm of Hg), the value of [pH – NRpH]is negative which denotes the acidic influence of increased pCO2.At lower levels of pCO2 values (<40 mm of Hg), the value of [pH – NRpH] is positive which denotes the alkaline influence of decreased pCO2.[III,IV]

It is very clear that Δ RpH value is negative for increased pCO2 (> 40 mm of Hg) and positive for decreased pCO2 (<40 mm of Hg) which are clearly shown in the graph 3. Their relationship is not strictly proportional, because the respiratory influence of pCO2 in changing pH through bicarbonate is a variable one (ratio HCO3/ Std HCO3) depending on the acute or chronic conditions or compensations. [III]

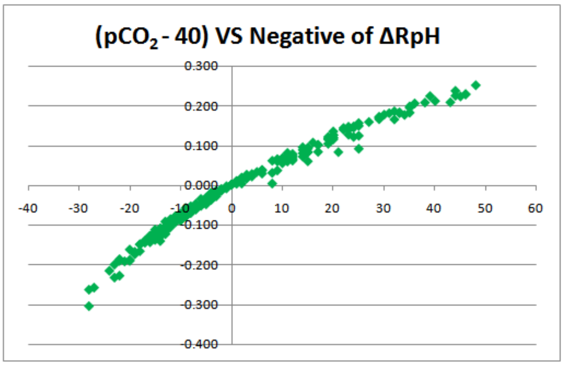


Graph3: *X axis: pCO_2VS Y axis: ΔRpH (pH-NRpH)*

The values of ratio 2 or ratio 3 are negative for pCO2 lesser than 40 mmHg and positive for pCO2 greater than 40 mmHg.[V-VIII]The value of Δ RpH is more negative for respiratory acidosis and more positive for respiratory alkalosis(shown in the graphs 3 & 4) which is opposite to the values of ratio 2 or ratio 3.Similarly, the negative value of Δ RpH is more positive for respiratory acidosis and more negative for respiratory alkalos is which is similar to the values of ratio 2 or ratio 3 (shown in the graph 5).

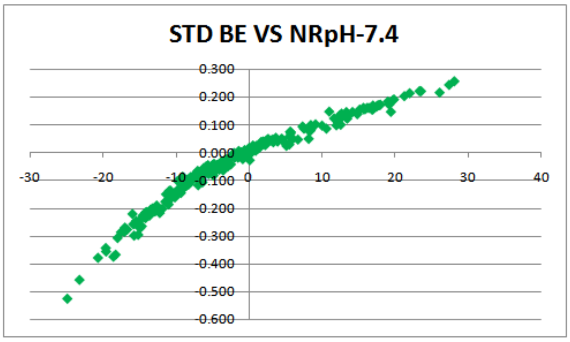


Graph4. *X axis: (pCO_2- 40) VS Y axis: ΔRpH (pH-NRpH)*



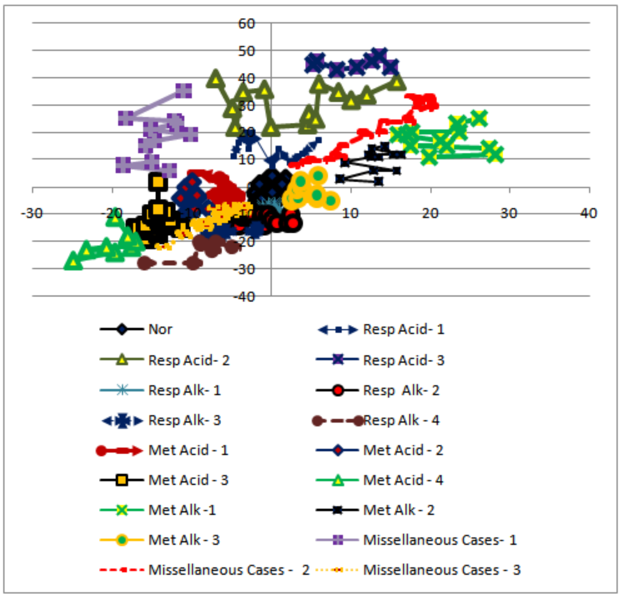
Graph5. *X axis: (pCO_2- 40) VS Y axis: Negative of ΔRpH (pH-NRpH)*

The low non-respiratory hydrogen ion concentration (NRH+) or a high non-respiratory pH is seen in metabolic alkalosis which is related to a higher value (more positive) of base excess. Base deficit (lower or more negative value of base excess) is related to a higher non-respiratory hydrogen ion concentration (NRH+) or a low non-respiratory pH which is seen in metabolic acidosis cases.[IV] The relation between standard Base Excess and the parameter Δ NRpH (NRpH-7.4) is shown in the graph 6.The value of Δ NRpHis more negative for metabolic acidosis and more positive for metabolic alkalosis which is similar to the standard base excess.



Graph6. *X axis: Std Base Excess VS Y axis: NRpH-7.4*

A graphical tool constructed using standard base excess (STD BE) in the x axis and the parameter (pCO2- 40 mm of Hg) in the y axis clearly demarcates the various acid-base disturbances which is clearly shown in the graph 7.[II,V,XII]Normal Cases are seen around the centre of the graph with various acid-base disorders plotted in the 4 quadrant graph will occupy any of the 4 quadrant which is tabulated in the table 3. Simple acid base disorders are located towards Single Axis(either x axis or y axis) and Combined acid base disturbances (compensations or mixed disorders) are seen in between them (between x axis and y axis).



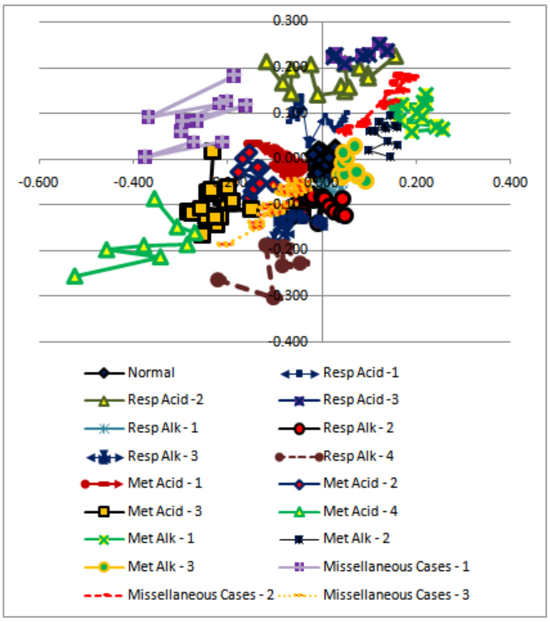
Graph7. *Graphical Tool - X axis: STD BE VS Y axis: pCO_2-40mm of Hg*

Table3. *Acid Base Disorders in a Four Quadrant Graphical Tool*

PLOTTED AREA	Quadrant in the Graphical Tool			
	1st quadrant: both x axis and y axis are positive	**2nd quadrant :** x axis positive and y axis negative	**3rd quadrant** : both x axis and y axis are negative	**4th quadrant:** x axis negative and y axis positive
Towards X: Axis	Metabolic Alkalosis	Metabolic Alkalosis	Metabolic Acidosis	Metabolic Acidosis
Towards Y: Axis	Respiratory Acidosis	Respiratory Alkalosis	Respiratory Alkalosis	Respiratory Acidosis
In Between Them	Metabolic Alkalosis and Respiratory Acidosis	Metabolic Alkalosis and Respiratory Alkalosis	Metabolic Acidosis and Respiratory Alkalosis	Metabolic Acidosis and Respiratory Acidosis

5. Novel ABG Interpretation Method

A four quadrant graphical tool can be constructed similar to the previously published graphical tool (constructed using standard base excess and ratio 2 or ratio 3) using different parameters (Δ NRpHin the x: axis and the negative of [Δ RpH] in the y: axis) which is shown in the graph 8. A novel ABG interpretation method was developed by RajiniSamuel correlating the net changes in total or actual pH [Δ pH] with the changes in respiratory [Δ RpH] and non-respiratory (metabolic) component [Δ NRpH] affecting the pH.[III]



Graph8. *Graphical Tool - X axis: Δ NRpH VS Y axis: Negative of Δ RpH*

The value of Δ NRpH is more negative for metabolic acidosis and more positive for metabolic alkalosis which is similar to the standard base excess. Similarly, the negative value of Δ RpH is more positive for respiratory acidosis (increased pCO2) and more negative for respiratory alkalosis (decreased pCO2) which is similar to the ratio 2 or ratio 3 values. If changes in both the components (ΔNRpH & ΔRpH) are involved, it may denote combined acid base disturbances (either compensatory mechanisms or mixed acid base disorders). If the changes in pH due to metabolic and respiratory component are equal but opposite, then the net change is zero because it is cancelled out each other.[II,III]

The graphical representation will serve as an aiding tool for better ABG interpretation.[XIII,IVX]The application of this novel ABG interpretation in a four quadrant graphical method in this study concludes that it is much easier to observe the changes in magnitude and direction in various acid base disturbances which will help in better understanding of cases presenting with different pH, pCO2 and HCO3 values.

6. Conclusion

Arterial blood gas interpretation has immense clinical value in critically ill patients. This novel contemporary perspective method of Arterial Blood Gas (ABG) interpretation depicted in a four quadrant graphical method appears to be much simpler, easier and may serve as a supporting tool for teaching purposes.

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