A Novel Contemporary Perspective Teaching Method for Interpretation of Various Acid base Disorders Citing with Examples

T. Rajini Samuel[1], Balaji Rajagopalan[2], Uma Maheshwari[3]

ABSTRACT

Introduction: The understanding of the basic concepts in Arterial blood gas analysis and interpretation is an essential skill required for all the medical students. Many creative methods of teaching are available for the same yet sometimes it remains a challenging task. Usually, the three main parameters like measured pH, pCO_2 and HCO_3 values are utilized for interpretation of various acid base disturbances. The aim of the current research study was to apply a novel recently published arterial blood gas interpretation method for teaching purposes.

Material and methods: In this newly developed method, the net changes in pH is related to both the changes in respiratory and non-respiratory (metabolic) component affecting the pH. A total of 90 arterial blood gas sample data's were utilized and classified into various groups. The changes in pH due to respiratory and non-respiratory component is calculated and correlated with the net changes in actual pH.

Results: The magnitude and the changes in direction either positive denoting the alkaline effect or negative denoting the acidic effect is very well observed in all the 90 cases and the results are tabulated. The relationship between changes in pH due to respiratory component with pCO_2 and the changes in pH due to non-respiratory component with bicarbonate and standard bicarbonate values were graphically analysed.

Conclusion: The 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, pCO_2 and HCO_3 values.

Keywords: Arterial Blood Gas, Novel Interpretation, Non-Respiratory Hydrogen Ion Concentration

INTRODUCTION

In arterial blood gas (ABG) interpretation, pCO_2 denotes the respiratory component and bicarbonate represents the metabolic component. Many methods exist in literature to guide for ABG interpretation.[1,2,3] The calculated bicarbonate concentration derived from Modified Henderson equation is a variable parameter because it changes with alterations in the values of pCO_2. The enzyme carbonic anhydrase present inside the Red blood cells (RBC) catalyses the reaction of formation of carbonic acid from pCO_2 and water molecules and its dissociation into hydrogen and bicarbonate ions. The hydrogen ions are buffered by non-bicarbonate buffers like albumin, haemoglobin and phosphate buffer system. So, the concentration of bicarbonate changes with pCO_2 values. The measurement of standard bicarbonate helps in solving this problem.[4,5]

Standard bicarbonate is the concentration of bicarbonate in the plasma from blood which is equilibrated with a normal $PaCO_2$ (40 mm Hg) and a normal pO_2 (over 100 mm Hg) at a normal temperature (37°C). The bicarbonate and the standard bicarbonate values are more or less closer, but in the presence of respiratory disturbances, they deviate from each other.[6,7] The calculated hydrogen ion concentration equivalent of standard bicarbonate is called as the 'Non-respiratory hydrogen ion concentration'(NRH).Even before many decades, Non-respiratory hydrogen ion concentration parameter had been suggested as one of the measure of metabolic acid-base disorders but simple formulae to calculate the same was not available at that time.[8]

Recently, the calculation of Non-respiratory hydrogen ion concentration from standard bicarbonate, its relationship with other commonly utilized ABG parameters was published by Rajini Samuel (current research study author).[9,10] The aim of the current research study is to apply this newly developed interpretation method based on the first postulate of the acid base balance theory which states that the net changes in total pH is due to both the changes in respiratory and non-respiratory(metabolic) component affecting the pH.[9,10]

The aim of the current research study was to apply a novel recently published arterial blood gas interpretation method for teaching purposes.

MATERIAL AND METHODS

A total of 90 arterial blood gas (ABG) analysis sample data's were collected from the central clinical laboratory processed by a senior technician using ABG Analyser GEM PREMIER 3000. The main parameters like measured pH, pCO_2, HCO_3

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and standard bicarbonate (Std HCO_3) values were noted. The consistency of the ABG report was checked by using the modified Henderson equation.[11]

Calculation of NRH^+ (Non-Respiratory hydrogen ion concentration)

H^+(Hydrogen ion concentration) = {24 X pCO_2}/ HCO_3

The above equation is based on modified Henderson equation.

NRH^+ - Hydrogen ion concentration at non-respiratory pH (at pCO_2 40 mm of Hg).

This calculated hydrogen ion concentration equivalent of standard bicarbonate represents the 'non-respiratory hydrogen ion concentration'[NRH^+].[9,10]

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

= {24 X 40}/ Std HCO_3 (pCO_2 is 40 mm of Hg)

NRH^+ = 960 / Std HCO_3

Calculation of NRH^+/H^+:

[NRH^+]/ [H^+] = {24 X 40}/ Std HCO_3 /{24 X pCO_2}/ HCO_3

= 40 X {(HCO_3/ Std HCO_3)/ pCO_2}

pH – NRpH = log [NRH^+/ H^+]

pH – NRpH = Log 40 + log (HCO_3/ Std HCO_3) – log(pCO_2)

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

The above equation derived by Rajini Samuel was recently published in a research study. This relation tells us the respiratory influence in causing changes in pH.[9,10]

At pCO_2 40 mm of Hg, pH - NRpH is zero. (Because bicarbonate and standard bicarbonate values are equal; log 1 is zero and log 40 is 1.6).At higher pCO_2 levels (> 40 mm of Hg), the value of [pH – NRpH] is negative which denotes the acidic influence of increased pCO_2.At lower pCO_2 levels (<40 mm of Hg), the value of [pH – NRpH] is positive which denotes the alkaline influence of decreased pCO_2.[9]

The net changes in total pH (Actual pH) includes both the changes in respiratory and non-respiratory (metabolic) component affecting the pH.[9,10]

Δ pH = ΔRpH + ΔNRpH

Group A: Normal cases (10 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.37	43	24.9	24.30	-0.0229	-0.0071	-0.0300
2	7.42	35	22.7	23.90	0.0336	-0.0136	0.0200
3	7.43	35	23.2	24.40	0.0340	-0.0040	0.0300
4	7.4	37	22.9	23.70	0.0169	-0.0169	0.0000
5	7.45	36	25	25.80	0.0300	0.0200	0.0500
6	7.39	38	23	23.60	0.0090	-0.0190	-0.0100
7	7.38	42	24.8	24.60	-0.0197	-0.0003	-0.0200
8	7.4	43	26.6	26.20	-0.0269	0.0269	0.0000
9	7.41	40	25.4	25.40	-0.0021	0.0121	0.0100
10	7.44	38	25.8	26.20	0.0135	0.0265	0.0400
Group B 1: Decreased pH, Increased pCO_2 and Decreased HCO_3 (8 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.02	48	12.4	10.40	-0.0049	-0.3751	-0.3800
2	7.03	75	19.8	16.00	-0.1825	-0.1875	-0.3700
3	7.05	57	15.8	13.40	-0.0843	-0.2657	-0.3500
4	7.06	64	18.1	14.90	-0.1217	-0.2183	-0.3400
5	7.09	49	14.9	13.20	-0.0376	-0.2724	-0.3100
6	7.12	59	19.2	17.00	-0.1180	-0.1620	-0.2800
7	7.15	46	16	15.10	-0.0376	-0.2124	-0.2500
8	7.02	61	15.8	12.50	-0.0836	-0.2964	-0.3800
Group B2: Normal pH, Increased pCO_2 and Increased HCO_3 (5 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.37	73	42.2	35.10	-0.1833	0.1533	-0.0300
2	7.38	50	29.6	27.60	-0.0686	0.0486	-0.0200
3	7.39	64	38.7	33.60	-0.1448	0.1348	-0.0100
4	7.4	69	42.7	36.40	-0.1695	0.1695	0.0000
5	7.41	69	43.7	37.50	-0.1724	0.1824	0.0100
Group B3: Normal pH, Decreased pCO_2 and Decreased HCO_3 (7 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.37	32	18.5	20.10	0.0588	-0.0888	-0.0300
2	7.39	27	16.7	19.30	0.1058	-0.1158	-0.0100
3	7.4	23	13.9	17.50	0.1382	-0.1382	0.0000
4	7.4	30	18.6	20.90	0.0722	-0.0722	0.0000
5	7.41	22	13.9	17.90	0.1477	-0.1377	0.0100
6	7.42	30	19.5	21.90	0.0725	-0.0525	0.0200
7	7.43	31	20.6	22.60	0.0684	-0.0384	0.0300

Table-1: Groups A,B1, B2 andB3 Cases Citing with Examples

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)

RESULTS

A total of 90 arterial 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 pCO_2 is 35-45 mm of Hg and for bicarbonate is 22-26 mEq/L. The various groups are Group A (Normal cases), Group B {Missellaneous cases further divided into Groups B1,B2 and B3), Group C (Metabolic acidosis cases) Group D (Metabolic alkalosis cases) Group E(Respiratory acidosis cases) and Group F (Respiratory alkalosis cases).

The respiratory and non-respiratory (metabolic) component affecting the pH was calculated for all the cases. 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 is applied for all the cases and the results are tabulated in table 1(for Group A and Group B), table 2 (Group C and Group D) and table 3 (for Group E and Group F).

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 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

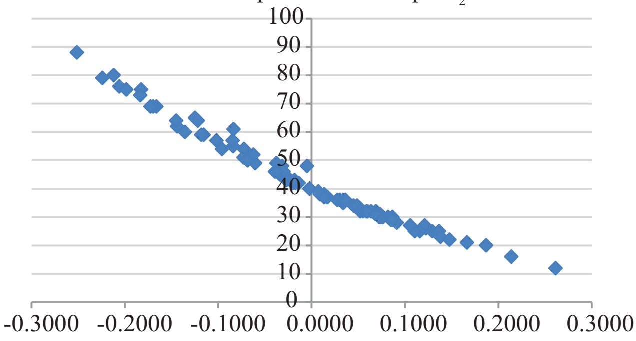

Figure-1: Δ RpH VS pCO_2

Group C: Metabolic acidosis cases (15 cases)							
S.NO	**pH**	**pCO_2**	**HCO_3**	**Std HCO3**	**Δ RpH**	**NRpH - 7.4**	**pH-7.4**
1	7.27	16	7.3	11.10	0.2139	-0.3439	-0.1300
2	7.31	21	10.6	13.70	0.1664	-0.2564	-0.0900
3	7.23	25	10.5	12.80	0.1160	-0.2860	-0.1700
4	7.3	28	13.8	15.90	0.0913	-0.1913	-0.1000
5	7.13	29	9.6	10.80	0.0864	-0.3564	-0.2700
6	7.23	30	12.6	14.10	0.0740	-0.2440	-0.1700
7	7.32	32	16.5	18.20	0.0523	-0.1323	-0.0800
8	7.35	32	17.7	19.40	0.0550	-0.1050	-0.0500
9	7.36	25	14.1	17.40	0.1107	-0.1507	-0.0400
10	7.15	42	14.6	14.40	-0.0173	-0.2327	-0.2500
11	7.22	45	18.4	17.60	-0.0339	-0.1461	-0.1800
12	7.23	40	16.8	16.80	-0.0021	-0.1679	-0.1700
13	7.25	36	15.8	16.40	0.0275	-0.1775	-0.1500
14	7.28	37	17.4	18.00	0.0171	-0.1371	-0.1200
15	7.36	37	20.9	21.80	0.0135	-0.0535	-0.0400
Group D: Metabolic alkalosis cases (15 cases)							
S.NO	**pH**	**pCO_2**	**HCO_3**	**Std HCO3**	**Δ RpH**	**NRpH - 7.4**	**pH-7.4**
1	7.43	42	27.9	27.30	-0.0138	0.0438	0.0300
2	7.44	44	29.9	28.90	-0.0287	0.0687	0.0400
3	7.45	39	27.1	27.20	0.0073	0.0427	0.0500
4	7.47	36	26.2	26.80	0.0339	0.0361	0.0700
5	7.48	43	32	30.90	-0.0183	0.0983	0.0800
6	7.51	36	28.7	29.20	0.0362	0.0738	0.1100
7	7.44	49	33.3	31.10	-0.0605	0.1005	0.0400
8	7.44	59	40.1	35.30	-0.1155	0.1555	0.0400
9	7.45	52	36.1	31.90	-0.0623	0.1123	0.0500
10	7.46	51	36.3	33.50	-0.0727	0.1327	0.0600
11	7.48	55	41	36.00	-0.0839	0.1639	0.0800
12	7.49	65	49.5	40.40	-0.1247	0.2147	0.0900
13	7.5	46	35.9	34.00	-0.0391	0.1391	0.1000
14	7.53	46	38.4	35.60	-0.0299	0.1599	0.1300
15	7.57	54	49.5	43.10	-0.0723	0.2423	0.1700

Table-2: Group C and Group D cases Citing with Examples

Group E: Respiratory acidosis (11 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.07	80	23.2	18.80	-0.2118	-0.1182	-0.3300
2	7.15	69	24	20.30	-0.1661	-0.0839	-0.2500
3	7.17	76	27.7	23.30	-0.2057	-0.0243	-0.2300
4	7.22	60	24.6	22.30	-0.1355	-0.0445	-0.1800
5	7.27	88	40.4	32.60	-0.2513	0.1213	-0.1300
6	7.31	54	27.2	25.00	-0.0958	0.0058	-0.0900
7	7.33	79	41.7	35.20	-0.2240	0.1540	-0.0700
8	7.34	48	25.9	23.10	-0.0316	-0.0284	-0.0600
9	7.35	57	31.5	27.80	-0.1016	0.0516	-0.0500
10	7.19	62	23.7	21.2	-0.1440	-0.0660	-0.2100
11	7.28	75	35.2	29.5	-0.1983	0.0783	-0.1200
Group F: Respiratory alkalosis (19 cases)							
S.NO	pH	pCO_2	HCO_3	Std HCO3	Δ RpH	NRpH - 7.4	pH-7.4
1	7.44	12	8.2	14.90	0.2614	-0.2214	0.0400
2	7.44	25	17	20.10	0.1293	-0.0893	0.0400
3	7.45	29	20.2	22.80	0.0850	-0.0350	0.0500
4	7.44	30	20.4	22.70	0.0765	-0.0365	0.0400
5	7.45	30	20.9	23.30	0.0757	-0.0257	0.0500
6	7.45	33	22.9	24.50	0.0522	-0.0022	0.0500
7	7.47	20	14.6	18.90	0.1869	-0.1169	0.0700
8	7.48	26	19.4	22.40	0.1226	-0.0426	0.0800
9	7.46	29	20.6	23.10	0.0879	-0.0279	0.0600
10	7.48	30	22.3	24.50	0.0820	-0.0020	0.0800
11	7.46	32	22.8	24.50	0.0636	-0.0036	0.0600
12	7.46	32	22.8	24.70	0.0601	-0.0001	0.0600
13	7.48	34	25.3	26.70	0.0451	0.0349	0.0800
14	7.53	25	20.9	24.30	0.1366	-0.0066	0.1300
15	7.56	27	24.2	27.00	0.1211	0.0389	0.1600
16	7.49	30	22.9	24.90	0.0865	0.0035	0.0900
17	7.51	31	24.7	26.80	0.0732	0.0368	0.1100
18	7.49	32	24.4	25.90	0.0689	0.0211	0.0900
19	7.49	34	25.9	27.10	0.0489	0.0411	0.0900

Table-3: Group E and F Cases Citing with Examples

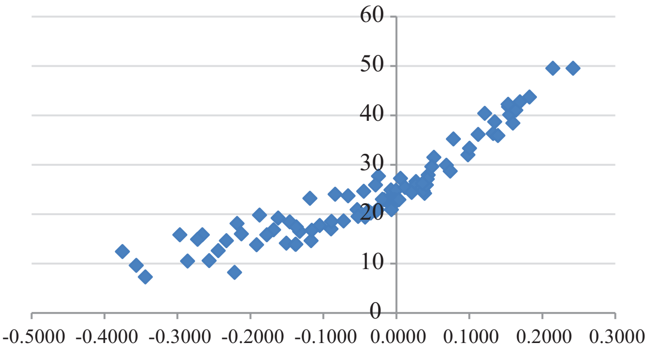

Figure-2: NRpH - 7.4 VS HCO_3

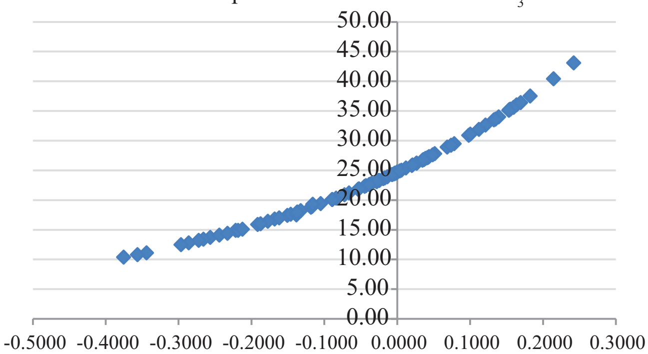

Figure-3: NRpH - 7.4 VS Std HCO_3

(more negative for metabolic acidosis and more positive for metabolic alkalosis).

The graphical relationship of Δ RpH with pCO_2, Δ NRpH with HCO_3 and standard bicarbonate were analysed and shown in the figures 1,2 and 3 respectively.

DISCUSSION

In the traditional method, the changes (either increase or decrease) in the values of pCO_2 and bicarbonate concentration are correlated with the measured pH values.[1] Simple acid base disorder is easy to understand but the compensatory mechanisms and the presence of more than one disorder (mixed disorder) is sometimes very difficult to understand. Also, the bicarbonate is a variable one and may not indicate the true metabolic status.[6]

The non-respiratory hydrogen ion concentration calculated from standard bicarbonate by a newly derived formulae represent the non-respiratory(metabolic) component.[9,10]

This newly developed ABG interpretation method by Rajini Samuel 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 appears to be easier and simpler but numerous future studies by other researchers are needed to confirm the same. The value of Δ NRpH is more negative for metabolic acidosis and more positive for metabolic alkalosis. Similarly, the value of Δ RpH is more negative for respiratory acidosis and more positive for respiratory alkalosis.[9] If changes in both the components are involved, it may denote a combined acid base disturbances (either compensatory mechanisms or mixed acid base disorders). If the changes in pH due to metabolic and respiratory component is equal but opposite, then the net change is zero because it is cancelled out each other. At present, there is no clear cut-off normal values for these components since it is a newly derived recently published parameter.

From the figure 1, it is very clear that Δ RpH value is negative for increased pCO_2 (> 40 mm of Hg) and positive for decreased pCO_2 (<40 mm of Hg). The graph is not strictly proportional, because the respiratory influence of pCO_2 in changing pH through bicarbonate is a variable one (ratio HCO_3/ Std HCO_3) depending on the acute or chronic conditions or compensations.[9]

The figure 2, clearly shows that [Δ NRpH (NRpH - 7.4)] is negative for decreased bicarbonate and positive for increased bicarbonate values but it has poor correlation because bicarbonate is a variable one affected by pCO_2 values.

The figure 3, clearly depicts the correlation between Δ NRpH (NRpH - 7.4) and standard bicarbonate. The non-respiratory hydrogen ion concentration [NRH^+] is calculated from standard bicarbonate concentration, so the correlation is obviously seen in this graph.

The current research study provides a novel contemporary perspective method for ABG interpretation which may serve as a supporting tool for teaching purposes especially for nursing and junior medical students.

CONCLUSION

Arterial blood gas interpretation plays a significant role in emergency situations yet it remains a challenging task. The study concludes that this newly developed interpretation method for arterial blood gas analysis may guide us in correlating the changes in acid base status in various acid base disorders to overcome this difficult task.

REFERENCES

1. Pramod Sood, Gunchan Paul, and Sandeep Puri Interpretation of arterial blood gas Indian J Crit Care Med, 2010; 14: 57–64.
2. Barnette, L. & Kautz, D.D. Creative ways to teach arterial blood gas interpretation. Dimensions of Critical Care Nursing (DCCN), 2013; 32: 84-87.
3. Doig AK, Albert RW, Syroid ND, Moon S, Agutter JA. Graphical arterial blood gas visualization tool supports rapid and accurate data interpretation Comput Inform Nurs, 2011; 29: 53-60
4. Jørgensen K, Astrup P. Standard bicarbonate, its clinical significance, and a new method for its determination. Scand J Clin Lab Invest 1957;9:122-132
5. Schwartz WB, Relman AS. A critique of the parameters used in the evaluation of acid-base disorders: whole-blood buffer base and standard bicarbonate compared with blood pH and plasma bicarbonate concentration. New Engl J Med 1963;268:1382-1388.
6. Samuel R. A Graphical Tool for Arterial Blood Gas Interpretation using Standard Bicarbonate and Base Excess. Indian J Med Biochem, 2018; 22: 85-89.
7. Rajini Samuel T Application of standard bicarbonate/ carbonic acid ratio in arterial blood gas analysis International Journal of Clinical Biochemistry and Research, 2018;5:314 – 320.
8. J. T. Suero The Usefulness Of Non-Respiratory Hydrogen Ion Concentration And Its Relationship To The Traditional Acid-Base Parameters Clin. Biochem, 1969;2: 177-185.
9. Rajini Samuel T Application and Inter-Relationship of Non-Respiratory Hydrogen Ion Concentration in Acid-Base Balance Theory International Journal of Clinical Chemistry and Laboratory Medicine (IJCCLM), 2018; 4: 1-13.
10. Rajini Samuel A graphical representation for aiding arterial blood gas interpretation using non-respiratory and respiratory pH wjpmr, 2018;4:192-202
11. Rajini Samuel, Ilanchezian, Balaji Rajagopalan Application of Modified Henderson Equation In ABG Interpretation Int. J. Pharm. Sci. Rev. Res, 2016; 37: 169-177.

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