ORIGINAL RESEARCH PAPER
Volume - 10 | Issue - 10 | October - 2021 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

APPLICATION OF RATIO BETWEEN NON-RESPIRATORY AND RESPIRATORY pH USING NOVEL ABG INTERPRETATION METHOD

Biochemistry

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ABSTRACT

Arterial blood gas analyser is one of the most important diagnostic test in intensive care unit for the management of emergency conditions. The understanding of arterial blood gas (ABG) analysis and interpretation is a challenging task. The various approaches like physiological and standard base excess are commonly employed in the initial evaluation of acid base status and Stewart's physicochemical approach is used to understand complex acid base disorders. The interpretation of Arterial blood gas analysis data will be an arduous task especially under emergency conditions in which the staffs already overburdened with work will be in stressful situations. This may affect their decision making skills which plays a significant role for the critically ill patients.

In this current research study, a novel arterial blood gas interpretation method is applied which relates the net changes in total pH to both the changes in respiratory and non-respiratory (metabolic) component affecting the pH. This method appears much easier for the initial evaluation of acid base status in cases presenting with different pH, pCO_2, HCO_3 and standard base excess values. The ratio between non-respiratory pH and predicted respiratory pH is calculated for all the cases. The study concludes that the changes in magnitude and direction of these parameters may help in better understanding of acid base disturbances.

KEYWORDS

Novel Arterial blood gas Interpretation, Non-respiratory pH, predicted respiratory pH

INTRODUCTION:

Arterial blood gas analyser is one of the most important diagnostic test in intensive care unit for the management of emergency conditions. The understanding of arterial blood gas (ABG) analysis and interpretation is a challenging task. The various approaches like physiological approach using bicarbonate and the standard base excess approach are commonly employed in the initial evaluation of acid base status. Stewart's physicochemical approach is used to understand complex acid base disorders.[1,2] The interpretation of Arterial blood gas analysis data will be an arduous task especially under emergency conditions in which the staffs already overburdened with work will be in stressful situations. This may affect their decision making skills which plays a significant role for the critically ill patients.

The diagnosis of simple acid base disorders are easy but combined acid base disorders either due to compensatory mechanisms or mixed disorders are often difficult. Mixed acid base disorder indicate the presence of more than one primary disturbances which can be suspected from a lesser or greater than expected compensations.[3] When the compensatory response is significantly different compared to the expected response it will suggest a mixed disorder. In compensatory mechanisms, both bicarbonate and pCO_2 level will change in the same direction (either both will increase or both will decrease). If both are changing in opposite direction then it will suggest a mixed disorder. The compensatory mechanism will try to bring the pH to near normal (closer to normal value). The normal pH with significant variations in bicarbonate and pCO_2 level will suggest a mixed disorder. [4,5]

Once the major primary acid base disorder is identified based on the arterial pH, pCO_2, $[HCO_3^-]$ and standard base excess values, the appropriate compensation rule is chosen to assess the patient's compensatory response. The compensation rules will guide in identifying the presence of a second primary acid base disorder. The metabolic acid base disorders are compensated by respiratory mechanisms. If the measured pCO_2 level is higher than the expected pCO_2 level, then it denotes the presence of respiratory acidosis and if it is lower it denotes the presence of respiratory alkalosis. The respiratory acid base disorders are compensated by renal mechanisms. If the measured $[HCO_3^-]$ value is higher than the expected $[HCO_3^-]$ level then it denotes the presence of metabolic alkalosis and if it is lower it denotes the presence of metabolic acidosis. The difference between the measured and the expected level (either pCO_2 or $[HCO_3^-]$) will indicate the magnitude of the severity.[4-7]

The bicarbonate is a **variable parameter** because it changes with pCO_2 values and this problem is solved by **standard bicarbonate** which 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).[8,9] The hydrogen ion concentration calculated using standard bicarbonate denotes the **'Non-respiratory hydrogen ion concentration'(NRH^+)** which plays an important role in understanding of ABG interpretation.[10,11] The postulates of the acid-base balance theory was published in a previous research study by the current author (Rajini Samuel). In this theory, the net changes in actual pH is correlated with the changes in pH due to respiratory and non-respiratory component.[11,12] The relationship between changes in pH due to respiratory component with pCO_2 and the changes in pH due to non-respiratory component with standard base excess is very well correlated. In this present study, the ratio between non-respiratory pH and the predicted respiratory pH is calculated and the study concludes that it changes in various acid base disorders.

MATERIALS AND METHODS:

The project was done under Sri Balaji Vidhyapeeth (SBV) Short Term Studentship (STS) program conducted for the students. The student investigator for the project "Application of ratio between Non-Respiratory and Respiratory pH Using Novel ABG Interpretation Method" is Ms.Vanisri, Final year M.B.B.S Student, who is guided by Dr. Rajini Samuel. Arterial blood gas samples of patient's admitted in emergency and intensive care units were analysed using ABG Analyser GEM PREMIER 3000 by a senior technician.Strict precautions were taken to avoid pre-analytical errors and the consistency of the ABG report was checked using Modified Henderson Equation.[13,14] 185 arterial blood gas sample data's were utilized. The main parameters like measured pH, pCO_2, HCO_3, standard HCO_3(Std HCO_3) and standard base excess(SBE) values were noted. The **Boston Method** (bicarbonate-based 6 bedside rules) or the **Copenhagen Method** (four SBE-based bedside rules) can be applied to assess compensation.[6,7,15]

Six Bicarbonate-Based Bedside Rules:

Rule for Acute Respiratory Acidosis: The $[HCO_3]$ will increase by 1 mmol/l for every 10 mmHg elevation in pCO_2 above 40 mmHg.
Expected $[HCO_3] = 24 + \{(\text{Actual } pCO_2 - 40) / 10\}$

Rule for Chronic Respiratory Acidosis: The $[HCO_3]$ will increase by 4 mmol/l for every 10 mmHg elevation in pCO_2 above 40 mmHg.

Expected $[HCO_3] = 24 + 4\ \{(\text{Actual } pCO_2 - 40) / 10\}$

Rule for Acute Respiratory Alkalosis: The $[HCO_3]$ will decrease by 2 mmol/l for every 10 mmHg decrease in pCO_2 below 40 mmHg.
Expected $[HCO_3] = 24 - 2\ \{(40 - \text{Actual } pCO_2) / 10\}$

Rule for a Chronic Respiratory Alkalosis:
The $[HCO_3]$ will decrease by 5 mmol/l for every 10 mmHg decrease in pCO_2 below 40 mmHg.
Expected $[HCO_3] = 24 - 5\ \{ (40 - \text{Actual } pCO_2) / 10 \}$ (range: +/- 2)

Rule for a Metabolic Acidosis:
Expected $pCO_2 = 1.5 \times [HCO_3] + 8$ (range: +/- 2)

Rule for a Metabolic Alkalosis:
Expected $pCO_2 = 0.7\ [HCO_3] + 20$ (range: +/- 5)

Four SBE-Based Bedside Rules:
Acute Respiratory Acidosis or Alkalosis:
An acute change in pCO_2 will not change the Standard Base Excess. If there is any change in SBE then it cannot be due to acute respiratory acid-base disturbances and it must be of metabolic origin.[15]

Chronic Respiratory Acidosis or Alkalosis:
Expected change in SBE will be 0.4 times the change in pCO_2.
$SBE = 0.4 \times (pCO_2 - 40)$

Metabolic Acidosis:
Compensatory change in pCO_2 will be proportional to the SBE.
Expected $CO_2 = 40 + SBE$

Metabolic Alkalosis:
Compensatory change in pCO_2 will be proportional to 0.6 times the SBE.
Expected $CO_2 = 40 + (0.6 \times SBE)$

Equation Relating Stewart's parameters and Non-Respiratory Hydrogen ion:
$SIDa - (A^{-}tot + SIG) = \{960 / NRH^{+}\} \times HCO_3 / Std\ HCO_3$
The equation relating the Stewart's parameter and the non-respiratory hydrogen ion(**NRH^{+}**) concentration was derived by the current author (Rajini Samuel).The above equation will help in understanding the mixed metabolic acid base disorders.Strong ion difference is inversely proportional but the total concentration of dissociated weak acids (A^{-} or A^{-}_{tot}) and the Strong ion gap (SIG) is directly proportional to the non-respiratory hydrogen ion concentration.[16]

Calculation of NRH^{+} (Non-Respiratory hydrogen ion concentration):
$NRH^{+} = \{24 \times pCO_2\} / Std\ HCO_3$
$NRH^{+} = \{24 \times 40\} / Std\ HCO_3$ (where pCO_2 is 40 mm of Hg)
$NRH^{+} = 960 / Std\ HCO_3$

Novel ABG Interpretation Method:
The net changes in total pH (actual pH) includes both the changes in respiratory and non-respiratory (metabolic) component affecting the pH.[11,12,17,18]
$\Delta pH = \Delta RpH + \Delta NRpH$
$pH - 7.4 = \Delta RpH + NRpH - 7.4$

Calculation of ΔRpH (pH-NRpH):
$pH - NRpH = \text{Log } 40 + \log (HCO_3 / Std\ HCO_3) - \log(pCO_2)$
$[pH - NRpH] = 1.6 + \log\{ (HCO_3 / Std\ HCO_3) / pCO_2\}$

The above **equation** derived by **Rajini Samuel** tells us the respiratory influence in causing changes in pH. The value of **ΔRpH** at pCO_2 40 mm of Hg is zero.(Because bicarbonate and standard bicarbonate values are equal; log 1 is zero and log 40 is 1.6). The value of **ΔRpH** is **negative** at **higher pCO_2** levels (> 40 mm of Hg), which denotes the **acidic influence** of increased pCO_2 and the value is positive at **lower pCO_2** levels (<40 mm of Hg) which denotes the **alkaline influence** of decreased pCO_2. [11,12,17,18]

Predicted Respiratory pH (PrRpH):
$PrRpH = 7.4 + \Delta RpH$

Non-Respiratory pH (NRpH):
$NRpH = \Delta NRpH + 7.4$

The changes in **magnitude** and **direction** (positive or negative) of non-respiratory pH parameter is due to the accumulation of acids other than carbonic acid or bases. The value is **negative** for **acidic** effect and **positive** for **alkaline** effect. [11,12]

RESULTS:

The normal reference for arterial blood **pH** is 7.35 to 7.45, for **pCO_2** is 35-45 mm of Hg, for **bicarbonate** is 22-26 mEq/L or mmol/L and for **Standard Base Excess** is **-** 2 to **+** 2 mmol/L. A **total** of **185** Arterial Blood Gas sample data's were utilized and classified into various acid-base disorder groups based on their normal reference ranges namely normal cases (**23**), respiratory acidosis (**14**), respiratory alkalosis (**46**), metabolic acidosis (**42**), metabolic alkalosis (**31**) and miscellaneous cases (**29**). The miscellaneous group is further divided into 3 Sub-groups (**1st** : Decreased pH, increased pCO_2 with decreased HCO_3, **2nd** : Normal pH, increased pCO_2 with Increased HCO_3 and **3rd** : Normal pH, Decreased pCO_2 & Decreased HCO_3). The concentration of non-respiratory hydrogen ion concentration was calculated from standard bicarbonate values for all the 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**] denoting both the changes in **respiratory** [**Δ RpH**] and **non-respiratory** (metabolic) component [**Δ NRpH**] affecting the pH were applied for all the cases.

The normal level of **Δ pH (pH - 7.4)** is calculated as ± **0.05** from the normal reference level of pH. If the Δ pH is lesser than (or more negative) **-0.05**, it denotes **acidic pH** (**< -0.05**) and if the Δ pH is greater than (or more positive) **+0.05**, it denotes **alkaline pH (> +0.05)**. The total change in actual pH value (**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).[11,12] The ratio and the difference between non-respiratory pH and predicted respiratory pH was calculated for all the cases.The relationship of the metabolic and the respiratory component of this novel method is graphically analysed and shown in the graphs (**figure 1 to 9**). The results are tabulated and **few examples** (**70 cases**) are shown in the **table 1** (normal(**10**) and Respiratory acid base disorder cases(**15**)), **table 2** (Metabolic acid base disorder cases(**25**)) and **table 3** (Missellaneous acid base disorder cases(**20**)) for different acid-base disorder groups.

RESULTS:

Table 1: Normal Cases And Respiratory Acid Base Disorder Cases

S. NO	pH	HCO3	STD HCO3	pCO_2	pH-7.4	Δ RpH	ΔNRpH	STD BE
1	7.4	22.9	23.7	37	0	0.017	-0.017	-1.90
2	7.42	23.4	24.2	36	0.02	0.029	-0.009	-1.08
3	7.39	23	23.6	38	-0.01	0.009	-0.019	-1.96
4	7.45	25.7	26.3	37	0.05	0.022	0.028	1.71
5	7.43	25.9	26.1	39	0.03	0.006	0.024	1.59
6	7.38	24.8	24.6	42	-0.02	-0.020	0.000	-0.32
7	7.4	26.6	26.2	43	0	-0.027	0.027	1.80
8	7.44	25.8	26.2	38	0.04	0.014	0.026	1.65
9	7.37	23.8	23.7	41	-0.03	-0.011	-0.019	-1.49
10	7.41	26	25.5	41	0.01	-0.004	0.014	1.36
11	7.23	23.5	21.4	56	-0.17	-0.108	-0.062	-4.05
12	7.31	27.2	25	54	-0.09	-0.096	0.006	0.94
13	7.36	29.4	27	52	-0.04	-0.079	0.039	3.95
14	7.35	31.5	27.8	57	-0.05	-0.102	0.052	5.89
15	7.19	23.7	21.2	62	-0.21	-0.144	-0.066	-4.50
16	7.28	35.2	29.5	75	-0.12	-0.198	0.078	8.46
17	7.33	41.7	35.2	79	-0.07	-0.224	0.154	15.77
18	7.3	41.3	33.8	84	-0.1	-0.237	0.137	14.88
19	7.45	21.5	23.7	31	0.05	0.066	-0.016	-2.49
20	7.47	24	25.2	33	0.07	0.060	0.010	0.33
21	7.44	17.7	20.9	26	0.04	0.113	-0.073	-6.45
22	7.53	25.1	27.2	30	0.13	0.088	0.042	2.41
23	7.45	16	20.1	23	0.05	0.139	-0.089	-7.99
24	7.49	16.8	20.8	22	0.09	0.165	-0.075	-6.54
25	7.55	14.9	20.5	17	0.15	0.231	-0.081	-7.47

 PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

Table 2: Metabolic Acid Base Disorder Cases

S.NO	pH	HCO3	STD HCO3	pCO_2	pH-7.4	Δ RpH	ΔNRpH	STD BE
1	7.34	19.4	20.5	36	-0.06	0.020	-0.080	-6.37
2	7.36	20.9	21.8	37	-0.04	0.013	-0.053	-4.55
3	7.31	15.6	17.6	31	-0.09	0.056	-0.146	-10.66
4	7.35	17.7	19.4	32	-0.05	0.055	-0.105	-7.91
5	7.25	15.8	16.4	36	-0.15	0.028	-0.178	-11.43
6	7.28	11.3	14	24	-0.12	0.127	-0.247	-15.44
7	7.23	10.5	12.8	25	-0.17	0.116	-0.286	-17.05
8	7.3	13.8	15.9	28	-0.1	0.091	-0.191	-12.62
9	7.26	13.9	15.5	31	-0.14	0.061	-0.201	-13.17
10	7.15	14.6	14.4	42	-0.25	-0.017	-0.233	-14.25
11	7.13	4.3	7.3	13	-0.27	0.256	-0.526	-24.87
12	7.27	7.3	11.1	16	-0.13	0.214	-0.344	-19.61
13	7.14	5.8	8.6	17	-0.26	0.198	-0.458	-23.21
14	7.24	9.4	12.1	22	-0.16	0.148	-0.308	-17.99
15	7.13	9.6	10.8	29	-0.27	0.086	-0.356	-19.57
16	7.53	42.6	38.2	51	0.13	-0.060	0.190	19.91
17	7.59	49.9	44.4	52	0.19	-0.065	0.255	28.18
18	7.48	41	36	55	0.08	-0.084	0.164	17.50
19	7.5	44.5	39.3	57	0.1	-0.102	0.202	21.32
20	7.45	41.7	36.4	60	0.05	-0.119	0.169	17.71
21	7.48	32	30.9	43	0.08	-0.018	0.098	8.50
22	7.44	33.3	31.1	49	0.04	-0.061	0.101	9.15
23	7.47	37.1	33.7	51	0.07	-0.066	0.136	13.43
24	7.49	39.6	35.6	52	0.09	-0.070	0.160	16.26
25	7.45	38.2	34.4	55	0.05	-0.095	0.145	14.21

Table 3: Missellaneous Acid Base Disorder Cases

S. NO	pH	HCO3	STD HCO3	pCO_2	pH-7.4	Δ RpH	ΔNRpH	STD BE
1	7.15	16	15.1	46	-0.25	-0.038	-0.212	-12.85
2	7.12	19.2	17	59	-0.28	-0.118	-0.162	-10.14
3	7.37	27.7	26.5	48	-0.03	-0.062	0.032	2.41
4	7.38	29	27.2	49	-0.02	-0.062	0.042	3.88
5	7.38	29.6	27.6	50	-0.02	-0.069	0.049	4.48
6	7.41	32.2	29.3	52	0.01	-0.075	0.085	7.56
7	7.4	33.3	29.2	55	0	-0.083	0.083	8.50
8	7.4	36.5	32.6	59	0	-0.122	0.122	11.70
9	7.41	38	32.9	60	0.01	-0.116	0.126	13.36
10	7.39	38.7	33.6	64	-0.01	-0.145	0.135	13.74
11	7.42	41.5	36.3	64	0.02	-0.148	0.168	17.02
12	7.4	42.7	36.4	69	0	-0.170	0.170	17.90
13	7.39	44.2	36.6	73	-0.01	-0.181	0.171	19.24
14	7.42	16.1	18.8	26	0.02	0.118	-0.098	-8.38
15	7.4	18.6	20.9	30	0	0.072	-0.072	-6.20
16	7.43	20.6	22.6	31	0.03	0.068	-0.038	-3.71
17	7.37	18.5	20.1	32	-0.03	0.059	-0.089	-6.79
18	7.4	19.8	21.7	32	0	0.055	-0.055	-5.00
19	7.41	20.3	22.2	32	0.01	0.056	-0.046	-4.34
20	7.39	20	21.7	33	-0.01	0.046	-0.056	-4.96

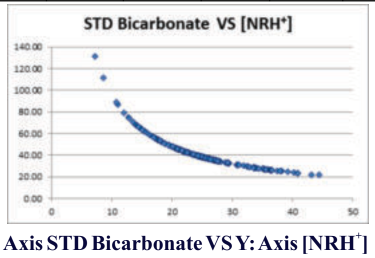

Figure 1: X: Axis STD Bicarbonate VS Y: Axis [NRH+]

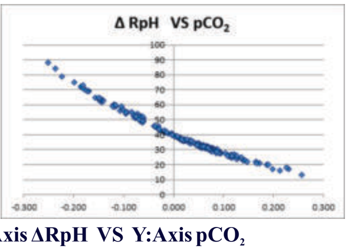

Figure 2: X: Axis ΔRpH VS Y:Axis pCO_2

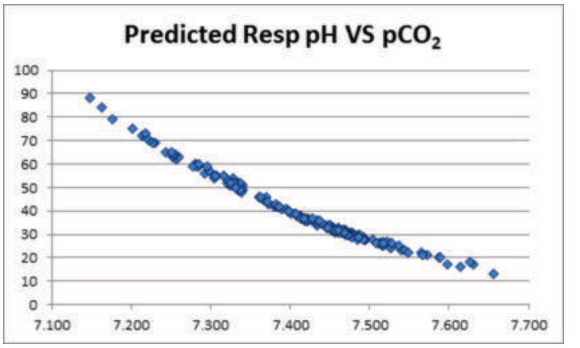

Figure 3: X: Axis Predicted Respiratory pH VS Y: Axis pCO_2

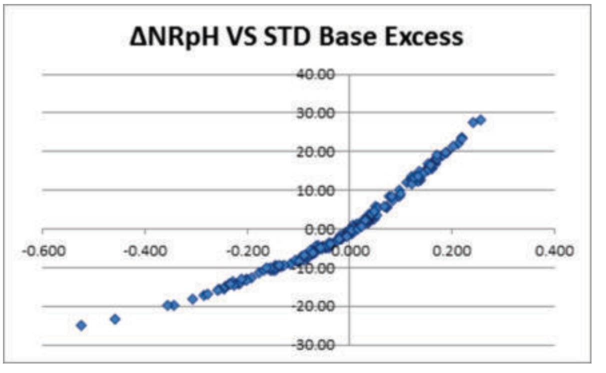

Figure 4: X: Axis ΔNRpH VS Y: Axis STD Base Excess

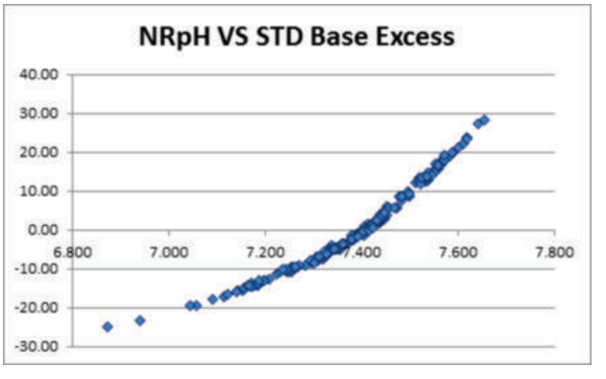

Figure 5: X: Axis NRpH VS Y: Axis STD Base Excess

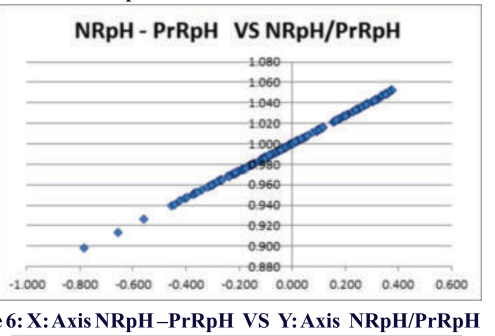

Figure 6: X: Axis NRpH –PrRpH VS Y: Axis NRpH/PrRpH

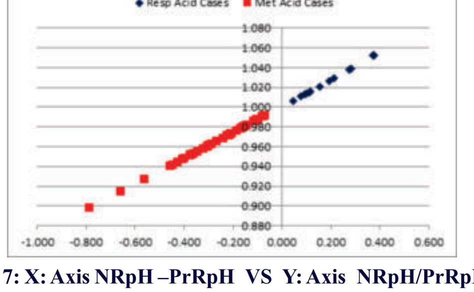

Figure 7: X: Axis NRpH –PrRpH VS Y: Axis NRpH/PrRpH for Respiratory and Metabolic Acidosis cases

 PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr

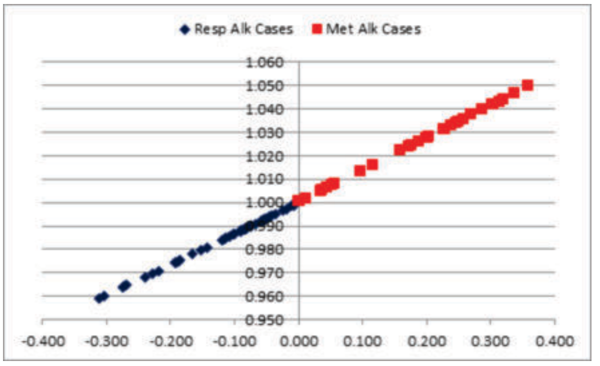

Figure 8: X: Axis NRpH –PrRpH VS Y: Axis NRpH/PrRpH for Respiratory and Metabolic Alkalosis cases

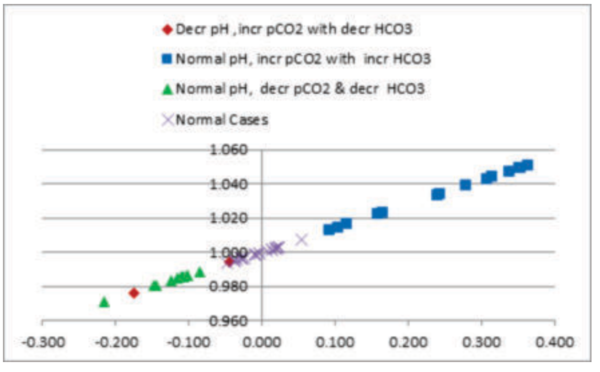

Figure 9: X: Axis NRpH –PrRpH VS Y: Axis NRpH/PrRpH for Normal and Missellaneous Cases

DISCUSSION:

A novel ABG interpretation method developed by **Rajini Samuel** (current author) was applied in this research study. This is based on 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. This interpretation method appears to be easier and simpler which correlates 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. The value of **Δ NRpH** is more negative for metabolic acidosis and more positive for metabolic alkalosis. Similarly, the value of **ΔRpH** is more negative for respiratory acidosis and more positive for respiratory alkalosis. The changes in both the components may denote either compensatory mechanisms or mixed acid base disorders. The net change is zero if the changes in pH due to metabolic and respiratory component is equal but opposite because it gets cancelled out each other. The clinical history and compensation rules can be applied to identify the mixed disorders. [11,12,17,18]

The relationship between standard bicarbonate and non-respiratory hydrogen ion concentration (NRH^+) is clearly shown in the **figure 1**. The respiratory component **Δ RpH** and **Predicted Respiratory pH (PrRpH)** correlates well with the pCO_2 parameter which are clearly depicted in the **figure 2** and **3** respectively. From these **figures**, 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 metabolic component **ΔNRpH** and non-respiratory pH(**ΔNRpH+ 7.4**) directly correlates with the standard base excess parameter which are clearly depicted in the **figure 4** and **5**.The parameter **ΔRpH (pH-NRpH)** is decreased(negative) in Respiratory acidosis and increased(positive) in Respiratory alkalosis. Similarly, the parameter **NRpH** is decreased in Metabolic acidosis and increased in Metabolic alkalosis. [11,12]

The **figure 6,7,8** and **9** clearly shows that the difference (**NRpH - PrRpH**) and the ratio (**NRpH / PrRpH**) between non-respiratory pH and Predicted Respiratory pH has a linear relationship. The ratio and the difference between non-respiratory pH and predicted respiratory pH is calculated for all the cases and it changes in various acid base disorders. The **ratio** is **greater than one** (or their **difference** is **positive**) for **respiratory acidosis** and **metabolic alkalosis** cases and the **ratio** is **lesser than one** (or their **difference** is **negative**) for **respiratory alkalosis** and **metabolic acidosis**.The understanding of the novel ABG parameters like Non-Respiratory pH and predicted Respiratory pH and their relationship with the changes in pH plays a significant role to overcome the arduous task in the interpretation of arterial blood gas analysis reports especially for junior staffs.

CONCLUSION:

The ratio between non-respiratory pH and the predicted respiratory pH changes in various acid base disorders. The study concludes that this newly developed ABG interpretation method may help in the initial evaluation of acid base balance disorders that directly correlates changes in pH with the respiratory and metabolic component of the arterial blood gas.

REFERENCES:

1. PramodSood, Gunchan Paul, and SandeepPuri Interpretation of arterial blood gas Indian J Crit Care Med, 2010 Apr-Jun; 14(2): 57–64
2. Rajini Samuel A Graphical Representation for Aiding Arterial Blood Gas Interpretation Using Non-Respiratory and Respiratory pH World Journal of Pharmaceutical and Medical Research, 2018,4(12), 192-202
3. Rajini Samuel T Application of standard bicarbonate/carbonic acid ratio in arterial blood gas analysis International Journal of Clinical Biochemistry and Research, April - June, 2018;5(2):314 – 320
4. Cosimo Marcello Bruno and Maria Valenti Acid-Base Disorders in Patients with Chronic Obstructive Pulmonary Disease: A Pathophysiological Review Journal of Biomedicine and Biotechnology,2012; Article ID 915150:1-8
5. Nicholette M Oosthuizen Approach to acid-base disorders – a clinical chemistry perspective CME 2012, 30 (7): 230-234
6. Gavin M. Joynt, Gordon Y. S. Choi, Chapter:Blood gas analysis in the critically illOxford Textbook of Critical Care (2 ed.)Publisher:Oxford University Press, 2016DOI:10.1093/med/9780199600830.003.0072
7. Anaesthesia MCQ: Acid-Base Physiology. 9.3 Bedside Rules for Assessment of Compensation
8. Jørgensen. K, andAstrup. P "Standard bicarbonate, its clinical significance, and a new method for its determination." Scandinavian Journal of Clinical & Laboratory Investigation 9.2 (1957):122-32.
9. Samuel R. A Graphical Tool for Arterial Blood Gas Interpretation using Standard Bicarbonate and Base Excess. Indian J Med Biochem, 2018; 22(1): 85-89.
10. SueroJ.TThe Usefulness Of Non-Respiratory Hydrogen Ion Concentration And Its Relationship To The Traditional Acid-Base Parameters Clin. Biochem.1969; 2, 177-185
11. 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(3): 1-13
12. Rajini Samuel T, BalajiRajagopalan, Uma Maheshwari. A novel contemporary perspective teaching method for interpretation of various acid base disorders citing with examples. International Journal of Contemporary Medical Research 2019;6(3):C10-C14
13. Rajini Samuel, Ilanchezian, BalajiRajagopalan Application of Modified Henderson Equation In ABG Interpretation Int. J. Pharm. Sci. Rev. Res, 2016; 37(2): 169-177
14. Rajini Samuel, ChennapatnamSindhura, BalajiRajagopalan A Study to assess The Consistency of the ABG report By Modified Henderson Equation International Journal of Scientific Research,2021;10(5):39-44
15. Deranged Physiology. Assessment of compensation: Boston and Copenhagen methods. 01/08/2020
16. Rajini Samuel T, An Applied Equation Inter-Relating Stewarts's Parameter and NonRespiratory Hydrogen Ion Concentration in Arterial Blood Gas International Journal of Clinical Chemistry and Laboratory Medicine 2019, 5(1) : 23-28
17. Rajini Samuel T. Book: Novel Graphical Tools – ABG Interpretation 2019 Mahi Publication, ISBN NUMBER : 978-93-89339-22-2
18. Rajini Samuel T. Chapter Who Is Balancing: Is It RBC or Acid-Base Status? Intech Open Publisher; pages 1-15 DOI: http://dx.doi.org/10.5772/intechopen.84768