Quantitative Analysis of Acid Base Disorder

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Resident of Anesthesia and SICU

Objectives

- Idea about history of interpretation (Boston And Copenhagen)
- Understanding Mathematical Concept of Stewart approach
- Quantitative Interpretation of Acid Base disturbances
- Clinical Application of Stewart approach

Story started from HH

- Aim: Maintain pH of solution
- Method : You should have *Buffer*

Method

Classical buffer contains solution of weak acid and conjugate base. Small amounts of acids or bases added are absorbed by buffer and the pH changes only slightly...

Bicarbonate Buffer System

$$[H^+] = K_a \frac{HA}{A^-}$$

HH Equation

$$pH = pK_a + log_{10}[\frac{HCO3^-}{0.03 * PaCO_2}]$$

So...

Simply

$$pH \propto [\frac{HCO3^-}{PaCO_2}]$$

For disturbing H^+ Concentration:

- $HCO3^-$ Increase or Decrease
- $PaCO_2$ Increase Or Decrease

Controllers :*Lungs, Kidney, Liver*

Compensation

$$pH \propto [\frac{HCO3^{-}\uparrow\downarrow}{PaCO_2\uparrow\downarrow}]$$

- CO_2 = Respiratory = Lung
- $HCO3^{-}$ = Metabolic = Kidney

Boston...

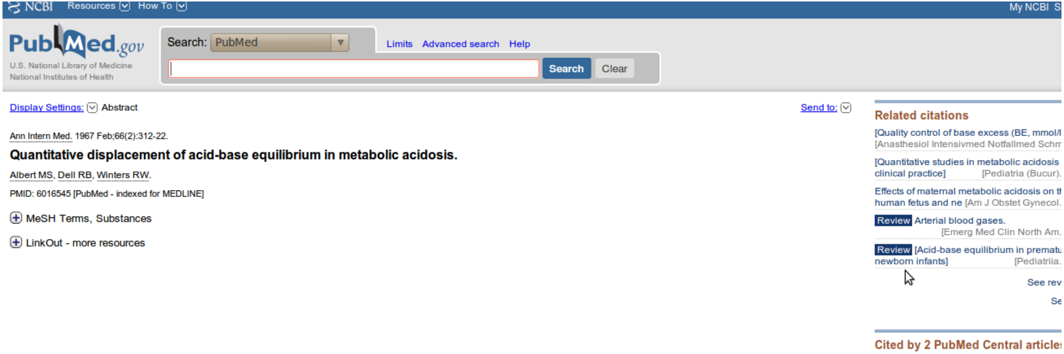
6 types of Disorder

- Acute Respiratory Acidosis
- Chronic Respiratory Acidosis
- Acute Respiratory Alkalosis
- Chronic Respiratory Alkalosis
- Metabolic Acidosis
- Metabolic Alkalosis

Winter Rules

- The rules describe the normal physiological reactions of the human body to one isolated acid-base Disorder
- The clinical question the rules are designed to answer in this situation is, whether the patient's respiratory compensation is within the range to be expected or whether there is an additional component of respiratory disturbance
- Example :: DKA with Respiratory Compensation

Winter rules



Assessing acid-base disorders, Kidney International ..copied from acidbase.org

help and glossary file - Mozilla Firefox

http://www.acidbase.org/phpscripts6/help_text.php?window=yes&help=20

The formulae used in our scripts are based on the version propagated by Horacio J. Adrogué.
(Assessing acid-base disorders, Kidney International advance online publication, 7 October 2009; doi:10.1038/ki.2009.359)
(the prefix "*delta*" indicates that the variable represents the amount the value in question deviates from its normal value.)

1- metabolic acidosis as the primary disturbance, PCO_2 (in mmHg) in relation to $[HC0_3^-]$

delta_$PaCO_2$/delta_$[HCO_3^-]$= 1.2mmHg per mEq/l

2- metabolic alkalosis as the primary disturbance, PCO_2 (in mmHg) in relation to $[HC0_3^-]$

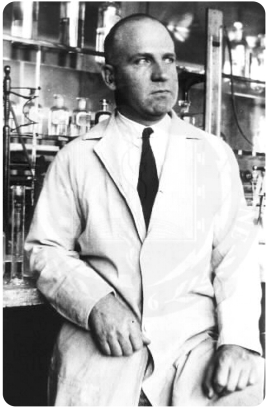
delta_$PaCO_2$/delta_$[HCO_3^-]$= 0.7mmHg per mEq/l

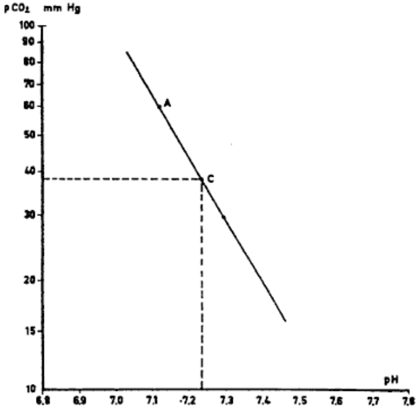
3- respiratory acidosis as the primary disturbance, $[HC0_3^-]$ in relation to PCO_2 (in mmHg)
3a- acute compensation:
delta_$[HCO_3^-]$/delta_$PaCO_2$= 0.1mEq/l per mmHg
3b- chronic compensation:
delta_$[HCO_3^-]$/delta_$PaCO_2$= 0.3mEq/l per mmHg

4- respiratory alkalosis as the primary disturbance, $[HC0_3^-]$ in relation to PCO_2 (in mmHg)
4a- acute compensation:
delta_$[HCO_3^-]$/delta_$PaCO_2$= 0.2mEq/l per mmHg
4b- chronic compensation:
delta_$[HCO_3^-]$/delta_$PaCO_2$= 0.4mEq/l per mmHg

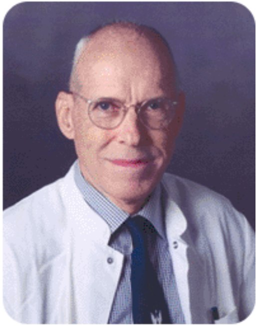
Indepth:

- **In Metabolic Acidosis**
  Anion Gap should be Checked :: High Or Normal ::
- **In Metabolic Alkalosis**
  Type should Be known :: Cl Responsive or Resistant ::




pCO2 mm Hg
100
90
80
70
60
50
40
30
20
15
10
A
C
pH
6.8
6.9
7.0
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8

Siggaard Andersen..The Complete Picture



1960, Ole Seggard Anderson 25 year old, rotating intern, helped to produce an alignment nomogram relating PCO2 and pH to base Excess

More Buffers..

AN IMPROVED CLINICAL METHOD FOR THE ESTIMATION OF DISTURBANCES OF THE ACID-BASE BALANCE OF HUMAN BLOOD

RICHARD B. SINGER[1] AND A. BAIRD HASTINGS

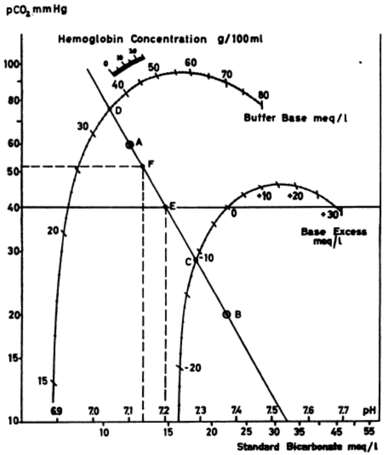
Department of Biological Chemistry, School of Medicine, Harvard University, Boston

INTRODUCTION

The clinical conditions that are associated with disturbances of the acid-base balance of the blood are familiar to many physicians. Some of these, such as diabetic coma and nephritis, are of concern to the internist; while cases of intestinal obstruction with vomiting and of draining gastro-intestinal fistulas must

Singer and Hasting proposed **buffer base** as sum of all blood buffers (anions) including *bicarbonate, proteins, and hemoglobin* in one liter of blood

Seggard Anderson nomogram



- Point A : measured pH at high $PaCO_2$
- Point B : measured pH at low $PaCO_2$
- Point C : the BE "Base Exceess"
- Point D : the Buffer Base

So we Can Define

Base Excess:

The **miliequivalents of strong acid or bases** that is needed to titrate one liters (in vitro) of blood or plasma that has been equlibrated to $pCO2 = 40$ mmhg and to physiological pH of 7.4,at temperature 37 c and full O2 saturation

Buffer Base:

Is the sum of all buffering agents in the blood including **bicarbonate, proteins, and hemoglobin** in one liter of blood

BE calculation And SBE

Van Slayk equation

$$BE = (HCO3 - 24.4 + [2.3 * Hb + 7.7] * [pH - 7.4]) * (1 - 0.023 * Hb)$$

BE calculation And SBE

Van Slayk equation

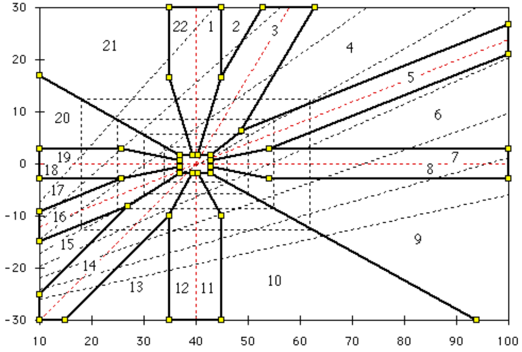
$$BE = (HCO3^{-} - 24.4 + [2.3 \times Hb + 7.7] \times [pH - 7.4]) \times (1 - 0.023 \times Hb)$$

Standard Base Excess

$$SBE = 0.9287 \times (HCO3^{-} - 24.4 + 14.83 \times [pH - 7.4])$$

BE Computing Method

Alan W. Grogono, created java applet for interpretation of acid base disorder using pH, PCO2 and SBE



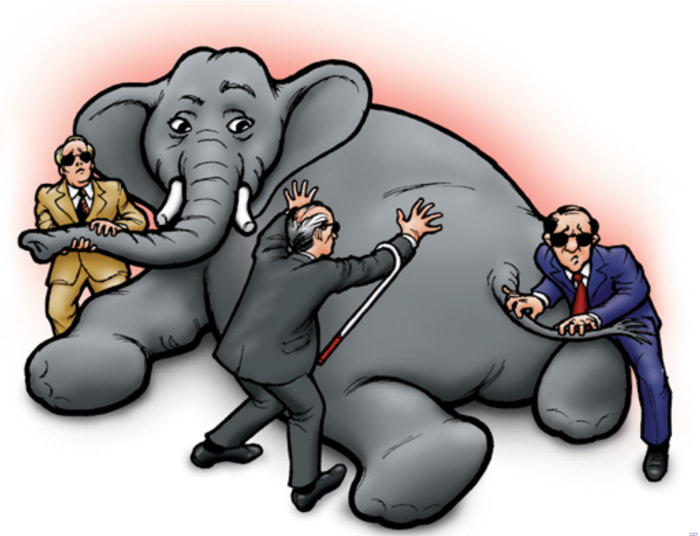
Typical Zones:

- Acute Respiratory Acidosis (7 and 8)
- Chronic Respiratory Acidosis (5)
- Metabolic Alkalosis (3)
- Acute Respiratory Alkalosis (18 and 19)
- Chronic Respiratory Alkalosis (16)
- Metabolic Acidosis (14)

Clinical Example

Running Java Application using AppViewer

Stewart Approach... *Elephant Idea from acidbase.org*



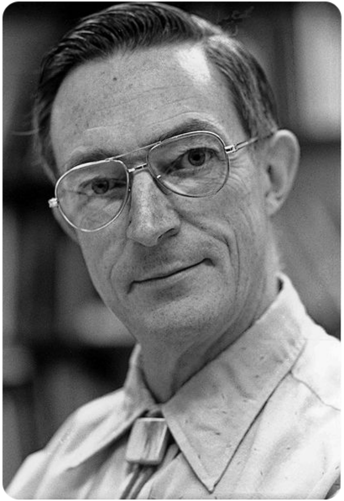
Stewart Approach.. Simply

What is the role of bicarbonate
($HCO3^{-}$)
in
acid-base balance?

The answer is simply:

None!

Peter Stewart (1921-1993)



Do we need other approach

Ok ...look to the following Case -Fencle Case 18-, what is your interpretation...

	18
Measured quantities	
Na^+, mEq/L	140
K^+, mEq/L	4.8
Ca^{2+}, mEq/L	3.4
Mg^{2+}, mEq/L	1.6
Cl^-, mEq/L	103
Pi, mmol/L	0.9
Albumin, g/L	15
pH	7.45
P_{CO_2}, mm Hg	48
Derived quantities	

Chronic obstructive pulmonary disease [COPD], bronchopneumonia, congestive heart failure)

You may think that the solution my be

Post-Hypercarbic Metabolic Alkalosis

Terminologies: Let Us Set New Rules...

- **Neutral Solution :**Solution that its hydrogen ion concentration is equal to hydroxyl ion concentration.

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- **Acidic Solution :**Solution that its hydrogen ion Concentration is greater than hydroxyl ion concentration.

Terminologies: Let Us Set New Rules...

- **Neutral Solution :**Solution that its hydrogen ion concentration is equal to hydroxyl ion concentration.
- **Acidic Solution :**Solution that its hydrogen ion Concentration is greater than hydroxyl ion concentration.
- **Alkaline Solution :** Solution that its hydroxyl ion concentration is greater than its hydrogen ion concentration .

Terminologies..Cont.

Acidic Substance :

- Substance, if added to solution, it brings about an increase in hydrogen ion concentration of solution

Terminologies..Cont.

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Terminologies..Cont.

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- Substance, if added to solution, it brings about an increase in hydrogen ion concentration of solution
- All other independent variables in solution remains constant
- Acids achieve their effect either by dissociating in solution yielding an anion plus Hydrogen ion

Terminologies..Cont.

Base Substance :

- Substance, if added to solution, it brings about an decrease in hydrogen ion concentration of solution

Terminologies..Cont.

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- Substance, if added to solution, it brings about an decrease in hydrogen ion concentration of solution
- All other independent variables in solution remains constant.

Terminologies..Cont.

Base Substance :

- Substance, if added to solution, it brings about an decrease in hydrogen ion concentration of solution
- All other independent variables in solution remains constant.
- Bases achieve their effect either by dissociation to form cation plus hydroxyl group

- **Non-electrolytes :**Substance that does not dissociate are called non-electrolytes..

- **Non-electrolytes :**Substance that does not dissociate are called non-electrolytes..
- **Strong electrolytes :**electrolytes which are completely dissociated in solution,i.e parent substance disappears when dissolved in water

Example

NaCl if dissolved in water, solution will contain Na^+, Cl^-, H^+, OH^-, water and no NaCl molecules

Weak Electrolytes:

- Substance that partially dissociate when dissolved in water
- The molecules of parent substance as well as the product of dissociation will exist

HA ??

$$[\mathrm{HA}] \Longleftrightarrow H^{+} + \mathrm{A}^{-}$$

For achieving equilibrium,

"The rate of dissociation should equal rate of recombination"

$$[\mathrm{H}^{+}]\times[A^{-}] = \mathrm{K}_{A} \times [HA]$$

Dependant and Intendant Variables

- **Independent Variables:**the variables being manipulated or changed by external maneuvers
- **Dependent variables :** observed result of the independent variable being manipulated

Conversion of mass

The mount of each component substance in any aqueous solution remains constant unless

- Condition 1 : substance is Added Or Removed from solution
- Condition 2 : substance that is Generated Or Destroyed by chemical reaction within the solution .

The Simplest Acid-Base System : Pure water

The Simplest Acid-Base System : Pure water

- Water dissociates into hydrogen and hydroxyl ions. At 37 C
- The dissociation constant is 4.3*10e-16 Eq/Liters.

K_W is highly temperature dependent and very small

So...

$$\mathrm{H_2O} \Longleftrightarrow H^+ + \mathrm{OH}^-$$

$$[\mathrm{H}^+] \times [OH^-] = \mathrm{K}_W \times [H_2\mathrm{O}]$$

$$\mathrm{K'}_W = \mathrm{K}_W \times [H_2\mathrm{O}]$$

$$[\mathrm{H}] \times [OH] = K'_W$$

Cont.

Since water contains Hydrogen and Hydroxyl only

$$H^{+}=OH^{-}$$
$$[H^{+}] \times [H^{+}] = K'_{W}$$

So..

$$H^{+} = \sqrt{K'_{W}}$$

$$OH^{-} = \sqrt{K'_{W}}$$

New Definition for acidic and alkaline solution

- Solution is acid-base neutral if the hydrogen ion concentration is equal to the square root of the K'$_W$.
- A solution is acidic if [H^+] $> \sqrt{(K'_W)}$
- A solution is basic if [H^+] $< \sqrt{(K'_W)}$

Adding strong ions in water

Adding specified amount of NaCl to Water [H_2O], so solution will only contain Na,Cl,H And OH

By application of electrical neutrality

$$Na^{+} - Cl^{-} + H^{+} - OH^{-} = 0$$

$$[H^{+}] \times [OH^{-}] = K'_{W}$$

By substitution of OH^{-} by [K'W] /[H^{+}]

$$H^{+} - (K'_{W}/H^{+}) + Na^{+} - Cl^{-} = 0$$

$$[H^{+}]^{2} + [H^{+}]([Na^{+}] - [Cl^{-}]) - K'_{W} = 0$$

Some Math

the quadratic equation can by solved as

$$[H^+]^2 + [H^+]([Na^+] - [Cl^-]) - K'_W = 0$$

$$[H^+] = -(Na^+ - Cl^-)/2 + \sqrt{((Na^+ - Cl^-)^2/4 + K'_W)}$$

–

- By replacing Na^{+} and Cl^{-} by any strong ions, H^{+} can be obtained
- Difference between **Strong Ions** can be expressed as -Strong Ion Difference- [SID]

SID

$$[H^{+}] = \sqrt{(K'_W + SID2/4) - SID/2}$$

$$[OH^{-}] = \sqrt{(K'_W + SID2/4) + SID/2}$$

Strong Ion Differance

Strong Ion difference

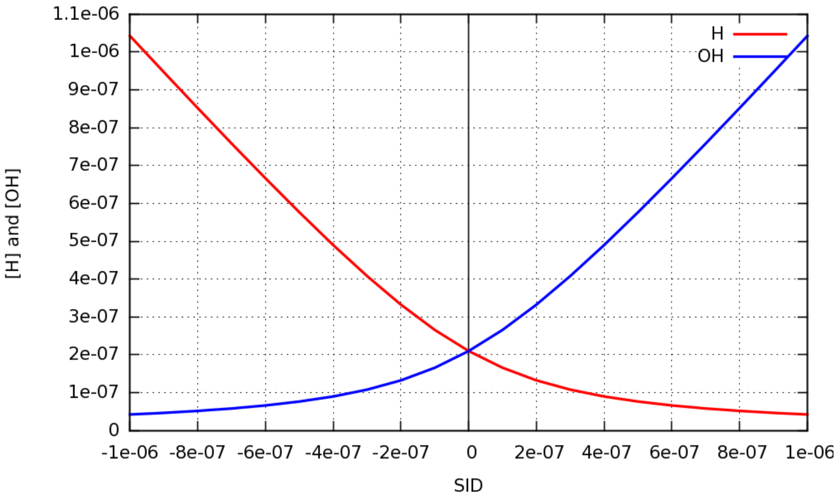
The sum of all strong base cation concentration minus the sum of all strong anion concentration, all expressed in equivalents per Liter

$$SID = \sum StrongBaseCations - \sum StrongAcidAnions$$

In biological solution, SID is almost positive

it is on the order of +40 mEq/Liter. In extra cellular fluids, Na^+ and Cl^+ is the main Strong Ions , the SID is closely to (Na^+ -Cl^-)

SID Graphical Presentation..let the computer plays the game



- **Adding HCL to Water :**

Using traditional approach

Adding H^+ will cause increase of H^+ that mean acidosis

Using Stewart approach

- You are adding a strong anion (Cl^-) without adding a strong cation.The SID decreases. This is a net negative change in charge due to SID.
- To maintain electrical neutrality the solution must liberate H^+, leading to acidosis

- **Production of stomach acid:**

Using traditional approach

Parietal cells secrete HCl into the stomach fluid, increasing its acidity.

Using Stewart approach

- Parietal cells transport a strong anion (Cl^-) from the plasma into the stomach fluid without transporting a strong cation. This decreases the SID in the stomach fluid, which causes it to be more acidic.
- To maintain electrical neutrality, either a positive charge must move with the Cl^- or a negative charge must move opposite it

Adding weak electrolytes

Some Math.. BE Patient Plz

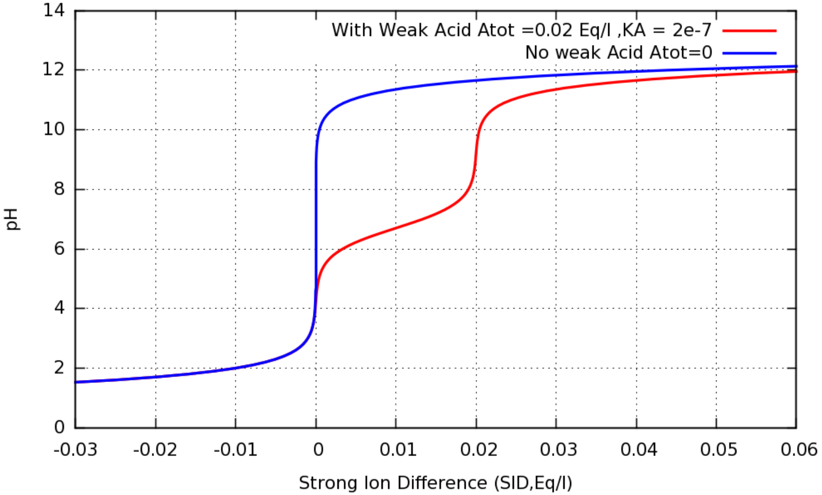
$$HA \Longleftrightarrow H^+ + A^-$$

$$[H^+] + [OH^-] + [SID] + [A^-] = 0$$

$$[H^+]^3 + KA + [SID] * [H^+]^2 + K_A * ([SID] - [A_{TOT}]) - K'_W * [H^+] - K_A * K'_W = 0$$

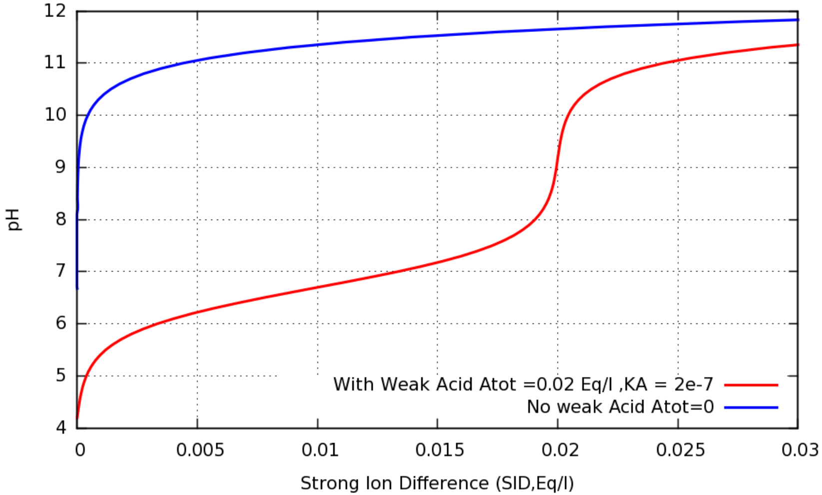
- **By using computer programming languages H$^+$ value could be obtained from the previous equation.**

A_{TOT}



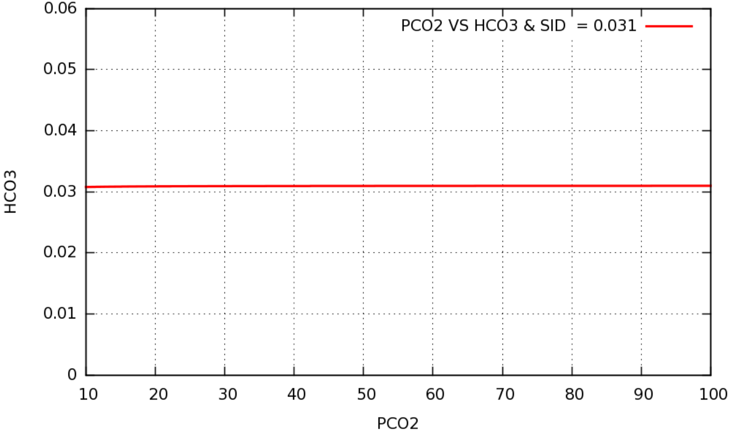
With Weak Acid Atot =0.02 Eq/l ,KA = 2e-7
No weak Acid Atot=0
pH
14
12
10
8
6
4
2
0
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
Strong Ion Difference (SID,Eq/l)

A_{TOT} Zoom


12
11
10
9
8
7
6
5
4
pH
0
0.005
0.01
0.015
0.02
0.025
0.03
Strong Ion Difference (SID,Eq/l)
With Weak Acid Atot =0.02 Eq/l ,KA = 2e-7
No weak Acid Atot=0

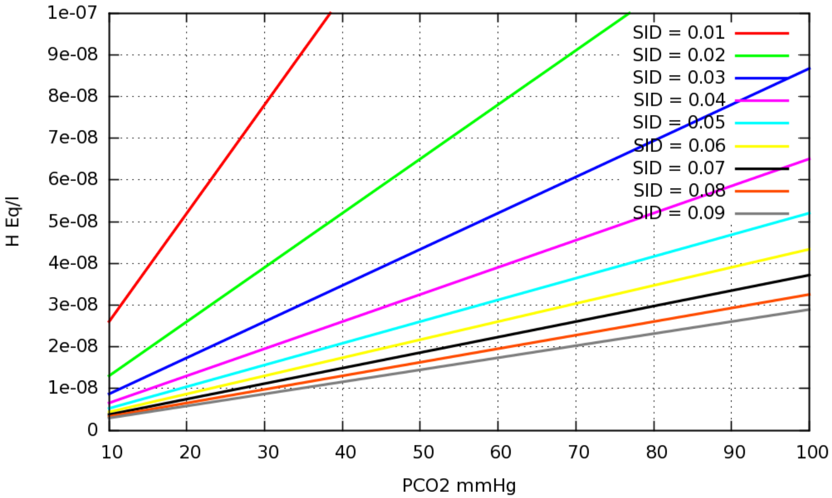
Adding CO2

....



PCO2 VS HCO3 & SID = 0.031
0.06
0.05
0.04
0.03
0.02
0.01
0
HCO3
10
20
30
40
50
60
70
80
90
100
PCO2

H,CO2 And SIDs



H,CO2 And SIDs

After plotting of H and CO2 relationship with known SID

- SID could be evaluated by known H (using pH meter) and known $PaCO_2$, after that, the value of OH^-, $CO3^{--}$ and $HCO3^-$ could be calculated if needed

H,CO2 And SIDs

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- H^+ depends only on SID and $PaCO_2$ only

H,CO2 And SIDs

After plotting of H and CO2 relationship with known SID

- SID could be evaluated by known H (using pH meter) and known $PaCO_2$, after that, the value of OH^-, $CO3^{--}$ and $HCO3^-$ could be calculated if needed
- H^+ depends only on SID and $PaCO_2$ only
- H^+ does not depend on $HCO3^-$, $HCO3^-$ was important historically as it could be calculated from known value of CO_2 and H^+

The Complete Picture

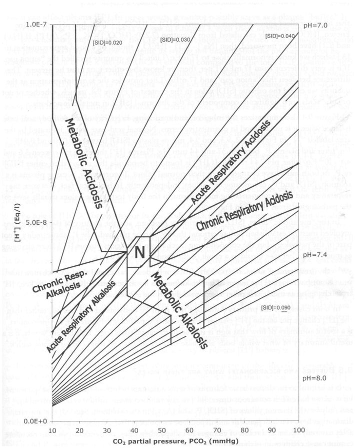
All Dependant Variables

SID + H^+ + $HCO3^-$ - A^- -$CO3^{--}$ - OH^-=0

Simple... :)

$$H^4 + KA + SID * H^3 + KA * (SID) - ATOT) - (KC * PC + K'W) * H^2 - KA * (KC * PC + K'W + K3 * KC * PC * H - KA * K3 * KC * PC = 0$$

The Complete Picture... Cont.

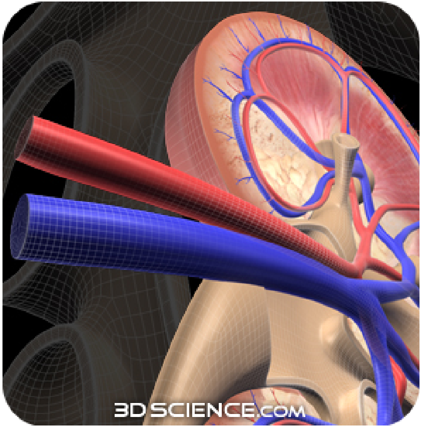


Acid-base Balance

Set of mechanisms by which parts of the body, notably **lungs**, **kidneys**, and **gastrointestinal** track control the composition of circulating blood plasma, so its H^+ generally within range from 2*10e-7 to 1*10e-7 Eq/L or pH 7.7 to 7.0

Lungs.. CO_2 regulator

Kidney...



Lung And Kidney

- **Acute Respiratory Acidosis** = PCO_2 up briefly, so plasma H^+ is up
- **Acute Respiratory Alkalosis** = PCO_2 down briefly, so plasma H^+ is down
- **Chronic Respiratory Acidosis** = PCO_2 up -sustained- , SID up , H^+ up slightly
- **Chronic Respiratory Alaklosis** = PCO_2 down -sustained-, SID down, H^+ down slightly

- **Prolonged Vomiting**

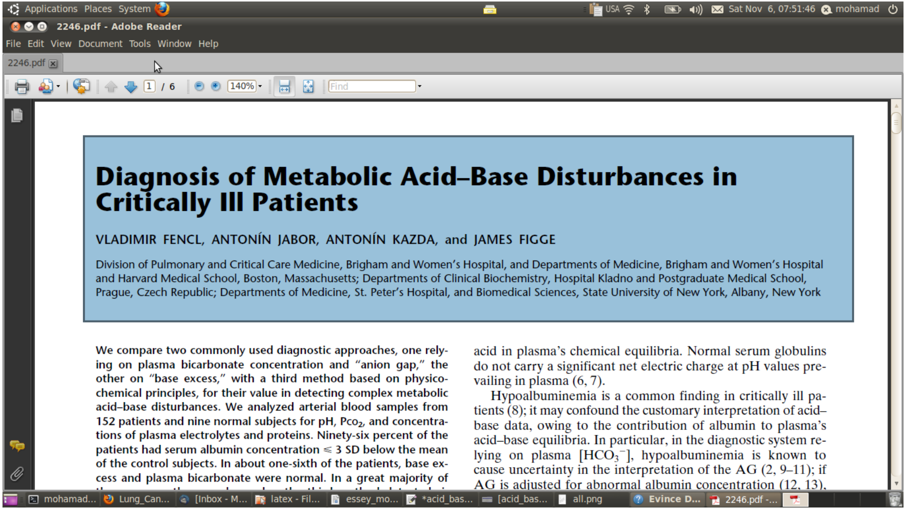
Stomach Rule as Example for regulation and disturbances

- Lowered plasma Cl^- level "Hypocholermia"
- Elevated SID = Metabolic Alkalosis
- Above normal PCO_2 = Respiratory acidosis
- Moderately lowered H^+ = Elevated pH

Some Questions

- How can we Calculate SID.
- How could we Calculate A_{TOT}
- pH affection by each variables

Fencle !!



Diagnosis of Metabolic Acid–Base Disturbances in Critically Ill Patients

VLADIMIR FENCL, ANTONÍN JABOR, ANTONÍN KAZDA, and JAMES FIGGE

Division of Pulmonary and Critical Care Medicine, Brigham and Women's Hospital, and Departments of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts; Departments of Clinical Biochemistry, Hospital Kladno and Postgraduate Medical School, Prague, Czech Republic; Departments of Medicine, St. Peter's Hospital, and Biomedical Sciences, State University of New York, Albany, New York

We compare two commonly used diagnostic approaches, one relying on plasma bicarbonate concentration and "anion gap," the other on "base excess," with a third method based on physicochemical principles, for their value in detecting complex metabolic acid–base disturbances. We analyzed arterial blood samples from 152 patients and nine normal subjects for pH, P_{CO_2}, and concentrations of plasma electrolytes and proteins. Ninety-six percent of the patients had serum albumin concentration ≤ 3 SD below the mean of the control subjects. In about one-sixth of the patients, base excess and plasma bicarbonate were normal. In a great majority of

acid in plasma's chemical equilibria. Normal serum globulins do not carry a significant net electric charge at pH values prevailing in plasma (6, 7).

Hypoalbuminemia is a common finding in critically ill patients (8); it may confound the customary interpretation of acid–base data, owing to the contribution of albumin to plasma's acid–base equilibria. In particular, in the diagnostic system relying on plasma $[HCO_3^-]$, hypoalbuminemia is known to cause uncertainty in the interpretation of the AG (2, 9–11); if AG is adjusted for abnormal albumin concentration (12, 13).

SID

Definition

$$SID = \sum StrongBaseCations - \sum StrongAcidAnions$$

- Na^{+},K^{+},Mg^{+} and Ca^{+} is strong cations
- Cl^{-} And XA^{-} -Unknown Anions- is Strong Anions

How Can We Get XA^{-} ??

Solution :: You Have two SIDs

Presentation of SID

d equally; this increases or reduces the SID by the same de-
a × C − a × A = a × D; concentrational alkalosis and dilu-
re are not to be confused with "contraction alkalosis" and
ie latter terms have been used in reference to supposed acid–
nd increase in extracellular fluid volume, respectively. How-
o not, by themselves, change any of the variables that deter-
e extracellular volume is expanded by infusion of NaCl saline,
sults (20, 21).
is and hypochloremic alkalosis.
lactate, keto acids in "metabolic acidosis" *sensu strictiori*; for-
cations), and sulfate and other anions in chronic renal failure
organic acids are at least three orders of magnitude lower
atible with life; therefore, they are always > 99.9% dissoci-
anions can be included in the definition of the SID); unlike
t include inorganic phosphate (which here is evaluated sepa-
of the nonvolatile weak acids).
in severe extracellular volume loss, such as in cholera (22).
is clinically insignificant: the normal value of [Pi] (~ 1 mmol/
1 to have an appreciable acid–base effect.

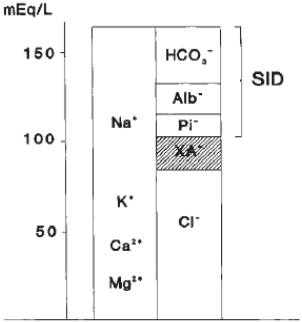


Figure 1. Electroneutrality in blood plasma: sum of positive charges equals the sum of negative charges, as indicated by equal heights of the columns representing cations and anions. Omitted (as insignificant on the scale shown) are ions having micromolar or nanomolar concentrations in plasma (OH^-, CO_3^{2-}, and H^+). Alb^- and Pi^- are negative electric charges displayed by serum albumin and inorganic phosphate, respectively. XA^- = unidentified strong anions; SID = strong ion difference.

SIDe.. Introduction

$$SID = [HCO3^-] + [A_{TOT}]$$

$$SID = [HCO3^-] + [Alb] + [Pi]$$

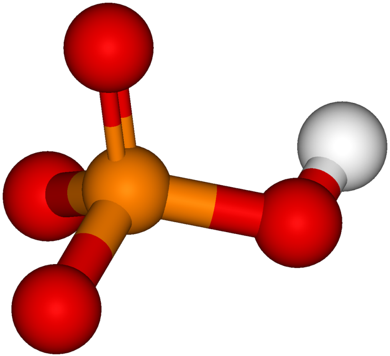
A_{TOT}

Albumin Effect

$$[Alb] = [Alb] \times (0.123 \times pH - 0.631)$$

$$Alb = 2.8 * \times Alb \text{ g/dl}$$

Inorganic Phosphate



Phosphorus

$$[Pi] = [Pi] \times (0.309 \times pH - 0.469)$$

Effective Strong Ion Difference

SIDe

$$SIDe = HCO3^{-} + 2.8 \times alb + Pi$$

$$SIDe = HCO3^{-} + 2.8 \times alb + 2$$

Apparent Strong Ion Difference

SIDa

$$SIDa = [Na^{+} + K^{+} + Mg^{++} + Ca^{++}] - [Cl^{-}]$$

Presentation of SID

d equally; this increases or reduces the SID by the same de-
a × C − a × A = a × D; concentrational alkalosis and dilu-
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ıe latter terms have been used in reference to supposed acid–
ıd increase in extracellular fluid volume, respectively. How-
ɔ not, by themselves, change any of the variables that deter-
ɛ extracellular volume is expanded by infusion of NaCl saline,
sults (20, 21).
is and hypochloremic alkalosis.
(lactate, keto acids in "metabolic acidosis" *sensu strictiori*; for-
cations), and sulfate and other anions in chronic renal failure
organic acids are at least three orders of magnitude lower
ıatible with life; therefore, they are always > 99.9% dissoci-
anions can be included in the definition of the SID); unlike
t include inorganic phosphate (which here is evaluated sepa-
of the nonvolatile weak acids).
in severe extracellular volume loss, such as in cholera (22).
is clinically insignificant: the normal value of [Pi] (~ 1 mmol/
ı to have an appreciable acid–base effect.

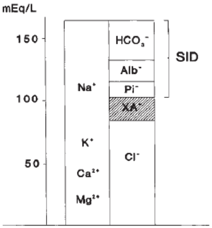


Figure 1. Electroneutrality in blood plasma: sum of positive charges equals the sum of negative charges, as indicated by equal heights of the columns representing cations and anions. Omitted (as insignificant on the scale shown) are ions having micromolar or nanomolar concentrations in plasma (OH^-, CO_3^{2-}, and H^+). Alb^- and Pi^- are negative electric charges displayed by serum albumin and inorganic phosphate, respectively. XA^- = unidentified strong anions; SID = strong ion difference.

$$XA^- = SIDa - SIDe = SIG$$

$$[XA^-] = ([Na^+] + [K^+] + [Ca^{++}] + [Mg^{++}]) - [Cl^-] - SID$$

Respiratory..... Non Respiratory

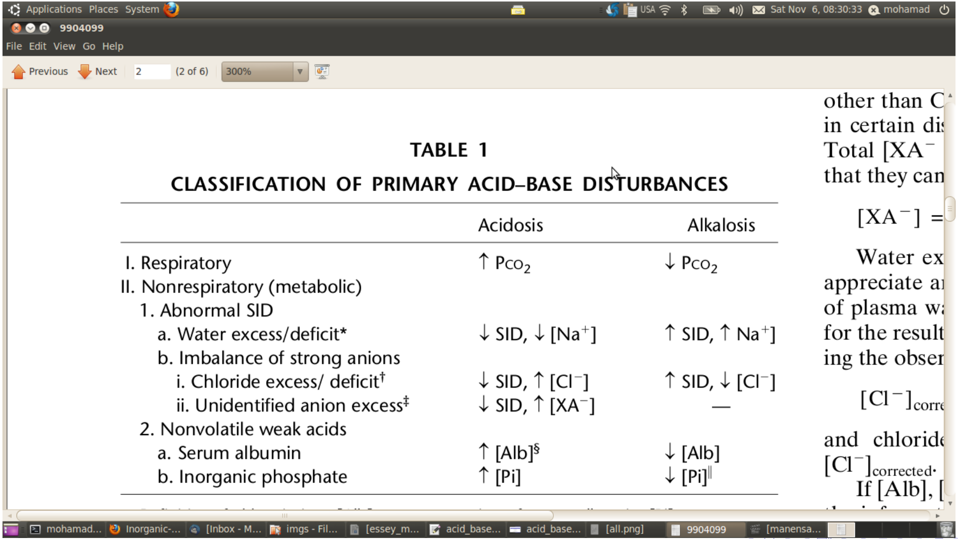


TABLE 1

CLASSIFICATION OF PRIMARY ACID–BASE DISTURBANCES

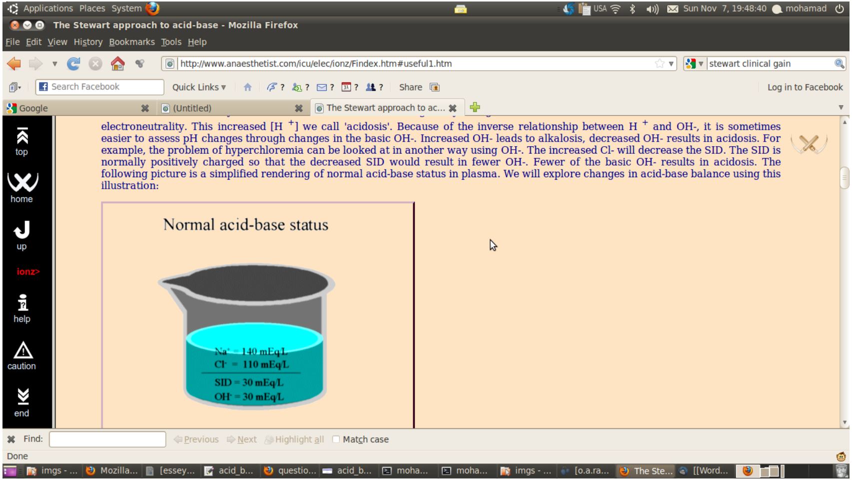
	Acidosis	Alkalosis
I. Respiratory	↑ P_{CO_2}	↓ P_{CO_2}
II. Nonrespiratory (metabolic)		
1. Abnormal SID		
a. Water excess/deficit*	↓ SID, ↓ $[Na^+]$	↑ SID, ↑ $Na^+]$
b. Imbalance of strong anions		
i. Chloride excess/ deficit†	↓ SID, ↑ $[Cl^-]$	↑ SID, ↓ $[Cl^-]$
ii. Unidentified anion excess‡	↓ SID, ↑ $[XA^-]$	—
2. Nonvolatile weak acids		
a. Serum albumin	↑ [Alb]§	↓ [Alb]
b. Inorganic phosphate	↑ [Pi]	↓ [Pi]‖

Factor affecting H ion Concentration.

Independent Variable

- **PaCO2**
- **A**$_{TOT}$ presented by Albumin And Pi
- **SID** which is affected by water deficit/excess Cl deficit or excess
- **XA**$^{-}$

SID in clinical practice



SID In Clinical practice

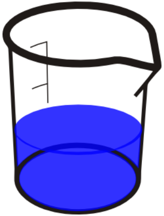
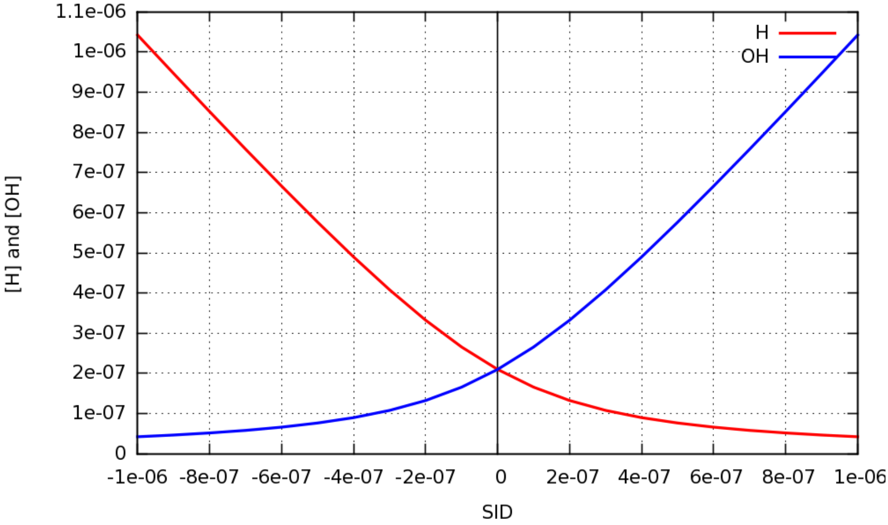


Figure: Beaker Model For simulation of body fluid content

- Na^{+}: 140 mE/L
- Cl^{-} : 110 mEq/L
- SID = 30

Relation between H^+ and SID



SID Change

Three mechanisms by which SID will change :

- Change in water content of plasma
- Change in Chloride concentration
- Increase concentration of unknown anions (XA^-)

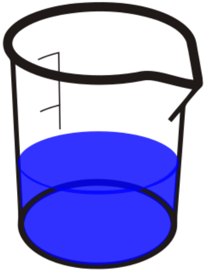
Change in water content of plasma

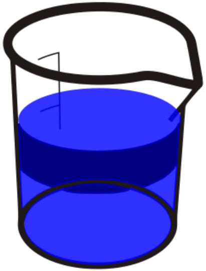
Concept:

Adding or removing the free water concentrations will cause change of electrolytes concentration which will cause:

- Dilutional Acidosis
- Concentrational Alkalosis

Adding Free Water





- Na^+ : 140 mE/L
- Cl^- : 110 mEq/L
- SID = 30

- Na^+ : 140/2 = 70
- Cl^- : 110/2 =55
- SID^- : 30/2=15

Clinical Application : TURP Syndrome :

- Management of hyponatremia of TRRP syndrome focused on treating using normal or hypertonic saline .
- Analysis of this treatment reveals that this may not be the best method of managing this problem

Clinical Application : TURP Syndrome :

Taking 1 liter from the previous resultant example

- Na^+ : 70 meq/l
- Cl^- : 55 meq/l
- SID : 15

Normal Saline electrolyte concentration :

- Na^+ : 154 mEq/l
- Cl^- : 154 mEq/l
- SID : 0

Resultant solution

Na^+ : (150+70)/2 :=112

Cl^-: (55+154)/2: 105

SID=112-105=7

The result will be :

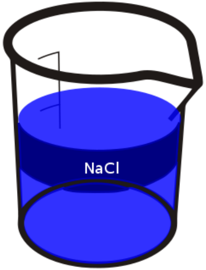
- Correction of hyponatremia
- Decrease in SID which will cause further acidosis

So

- A more appropriate treatment might be with sodium bicarbonate . Here, sodium ions are administered with $HCO3^-$.
- The bicarbonate is conveniently expired through the lungs leaving the Na^+ to increase the SID.

HyperCholermic Metabolic Acidosis

- Adding one liter of normal Saline to normal one Liter of Plasma:



Normal Saline Na^+, Chloride and SID

- Na^+ : 154 mEq/l
- Cl^- : 154 mEq/l
- SID : 0

Final Solution

- Na^+ : (140+154)/2 =147
- Cl^-: (110+154)/2=132
- SID=147-132=15

HyperCholermic (Metabolic) Acidosis

So

- SID is decreased so acidosis is developed.
- More appropriate Fluid for maintenance of SID: Lactated Ringer

Lactated Ringer SID:

Cations: 137 meq/l   **Cl**$^-$: 109 meq/l

Final Solution SID

Cations: (140+137)/2 139   **Cl**$^-$: (110+109)/2 110   **SID**=139-110=29

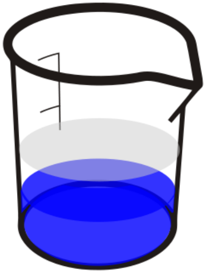
Contractional Alkalosis

- In case of volume restriction or diuretic therapy

The resultant Solution

- Na^{+} : 140*2 mq/ L = 280
- Cl^{-} : 110*2 mq/ L = 220
- SID=280-220=60

Correction of contraction alkalosis could be done using free water administration in the form of**hypotonic saline**



In case in volume depletion, with consideration of half volume depletion

Hypochloremia and Metabolic Alkalosis

Gastrointestinal abnormality, in case of vomiting or naso gastric tube suction

Cl Loss

- Na^+ : 140 mq/l
- Cl^- : 95 mq/l
- SID =45

Treatment Using normal Saline

- Na^+:(140+154)/2 =147 mq/l
- Cl^-:(95+154)/2= 125mq/l
- SID=147-125=22

Problem With Volume...

K^{+}, Mg^{++}

If volume expansion will be problematic ; then potassium, calcium or magnesium chloride can be administered, Alternative Solution, Cl^{-} Administration could be done using HCL

XA and SID

- SID can also be affected by the presence of organic acids such as lactate or ketoacids, because these negatively charged molecules , it will decrease SID, they result in an acidosis.
- Treatment is usually focused on stopping the production of acid. Resolution of the abnormal H^+ can also be achieved by increasing the SID using NaHCO3

Crystalloids And Colloids

- Saline
- Lactated Ringer
- Albumin
- hetastarch

Just think of **SID** and **ATOT**

Intraoperative Fluid Management

Critical Care April 2005 Vol 9 No 2 Morgan

Review

Clinical review: The meaning of acid–base abnormalities in the intensive care unit – effects of fluid administration

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BE again

Simply

- For Non-Respiratory Component, each Independent Variable -SID And A_{TOT}- Deviation will be reflected to BE
- New BE = SBEc = Corrected Base excess = Buffer Base = complete version of the -van Slyke equation-

SBEc=[HCO3$^-$]-24.4+8.3$\times Alb \times 0.15 + 0.29 \times Phos \times 0.32 * (pH - 7.4)$

Algorithm

Quantitative Analysis Of Acid Base

- History,Anticipate,Proceed
- Check pH againet 7.4 value
- global deviation can be concluded from deviation of BE and CO_2 from Normal
- Respiratory Component -**CO_2 analysis** -Acidosis Or Alkalosis-
- Non-Respiratory Component -**SID And A_{TOT}**.
- Na^+, Cl^- deviation calculation
- SID, SIDe, SIDa, SIG
- Albumin
- Winter Rules

History

Step 1

- Very important
- Get Idea about possible possible deviation of acid base
- Always remember .... you are treating patient not the ABG paper :)

Step 2

- pH less than 7.4 = Acidosis irrespective to its origin -
- pH more than or equals = Alkalosis irrespective to its origin -

PaCO2

Step 3

- Normal Range : 35:45 mmHg
- More than 45mmHg = respiratory Acidosis -may be primary or compensatory -
- Less than 35mmHg = respiratory Alkalosis -may be primary or compensatory -

Non Respiratory elements

Step 4

- SBEc will give you idea about total Metabolic elements deviation
- SID And A_{TOT}
- SID = Na^{+}-Cl^{-} effect And XA effect
- A_{TOT} = for simplicity : Albumin effect

Na-Cl

Step 5

- How much Na^+ deviate from normal range ”140 mEq/l”.
- Amount of deviation to Cl^- value ”105 mEq/L as mean”.

SID And A_{TOT}

Step 6

- SIDe=Albumin gm/dl $\times$2.8 $+$ $HCO3^{-}$+2
- SIDa=Na^{+}+K^{+}+6 - Cl^{-}
- XA^{-}=SIDa-SIDe - Normal Value in Critically ill patient 2-8 mEq
- Albumin Effect = 2.8 $\times Albumingm/dL$

Deviations

Step 6 Cont.

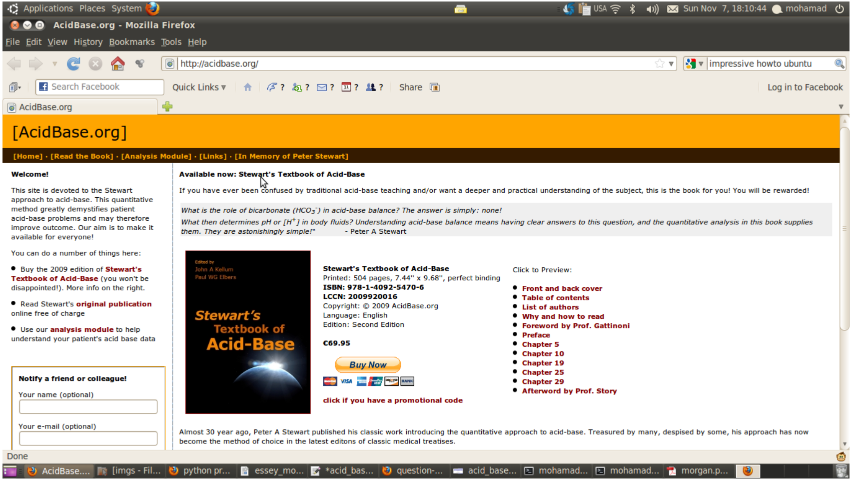
- Na^+, Cl^- , Albumin, XA^- from its normal range indicates deviation SBEc from its normal Range
- Example : Na^+ deviation , HyperChloremic Acidosis , Unknown Anion Acidosis , Hypoalbuinemic Alkalosis ,.......

Winter Rules

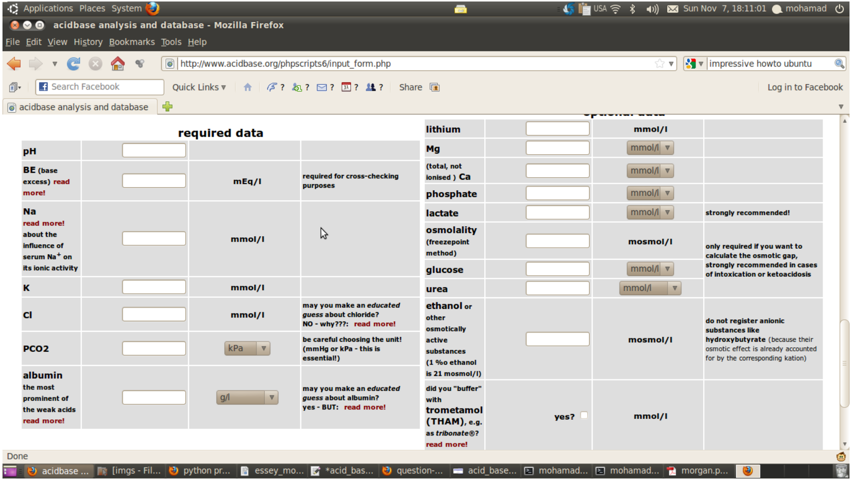
Step 7

- For Assessment of Compensation

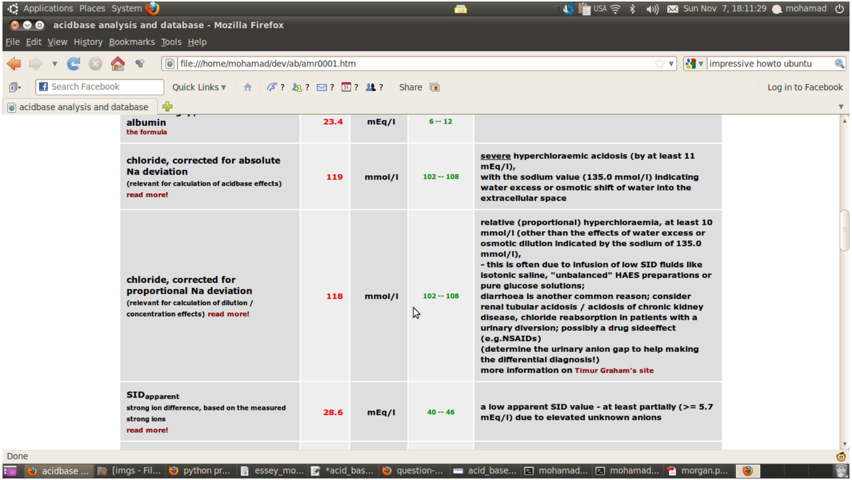
Quantitve analysis Computing Method



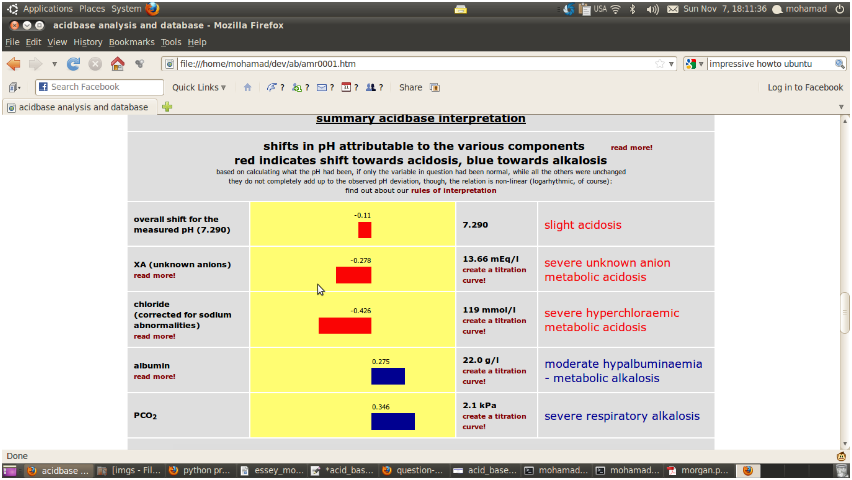
Quantitve analysis Computing Method



Quantitve analysis Computing Method



Quantitative analysis Computing Method

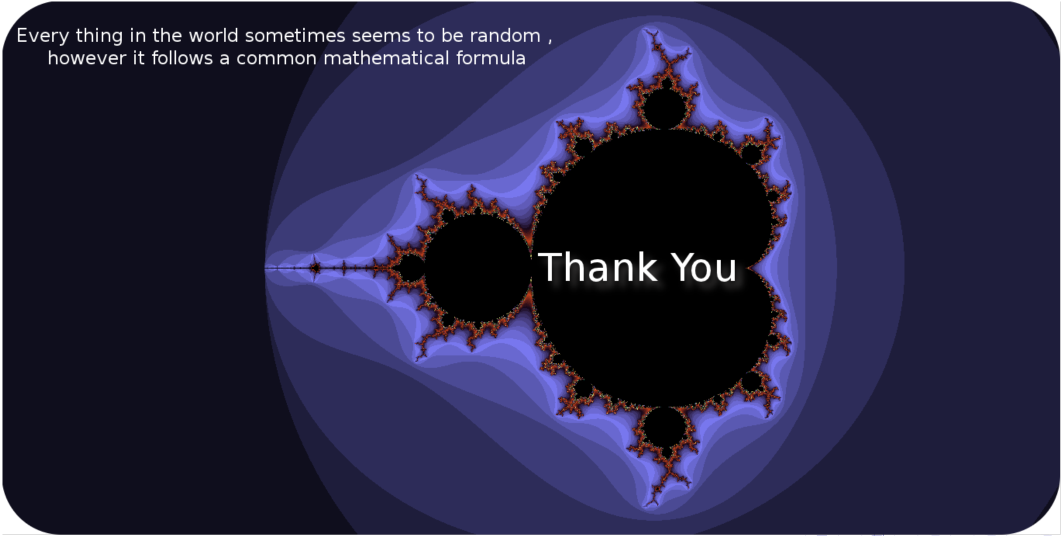


Any Questions

Summary

- It was long way for developing vision for quantitative analysis of pH deviation
- Boston and bicarbonate Buffers
- Copenhagen and BE
- Stewart, Dependent, And Independent variables

Thank You :)


Every thing in the world sometimes seems to be random , however it follows a common mathematical formula
Thank You