ASSESSMENT OF THE ACID BASE BALANCE IN THE BLOOD

It is important to analyze blood for abnormal quantities of acids or bases which can cause changes in pH, e.g. lactic acid level in lactic acidosis or to quantitate part of the acid or base, e.g. Cl^- level in pyloric obstruction. Some of these investigations are not routinely available and in most clinical situations are unnecessary as the chemical cause can be deduced from other clinical evidence. Most clinical disturbances can be understood by deciding if the blood pH has changed and whether or not CO2 or other acid or base changes are the primary cause. When there is more than one possible chemical cause for a change in pH and management of the possible chemical causes differ, it will be essential to chemically differentiate the possibilities, e.g. some cases of diabetic acidosis where either lactic or keto-acids may be involved.

The definition of the acid-base balance requires knowledge of at least three parameters:
1. Acidity or alkalinity of the blood; for normal arterial blood pH ranging from 7.35 to 7.45. The pH is the unit of measure for the concentration of free hydrogen ions in a solution. A decrease of pH below 7.35 defines the state of acidosis (due to the increased of the P_{CO2} or the concentration of other acids or a decrease of the bicarbonate); an increase of the pH above 7.45 reflects an alkalosis (due to the decrease of the P_{CO2} or the amount of bicarbonate).
2. The carbonic acid concentration in arterial blood, expressed generally in the form of CO_2 partial pressure; pCO_2 normal is between 40 ± 2 mmHg. It is called the respiratory component.

$$[H_2CO_3] \text{ m mol / l} = pCO_2 \times 0.03$$

An increase or a decrease in pCO_2 means breathing intervention in the acid base balance; when pCO_2 is the primary change, a decrease to below 38 mmHg indicates respiratory alkalosis, while an increase to over 42 mmHg indicates respiratory acidosis.
3. The metabolic component of the acid base balance; the most common indicator is plasma bicarbonate, whose normal value in blood is of 23-27 mmol / l (mEq / l). Increase of the plasma bicarbonate indicates a metabolic alkalosis and decrease metabolic acidosis. Since blood contains other buffer systems other parameters for the metabolic component were proposed: buffer base (BB), base excess (BE) and others.

Knowing two of these parameters the third can be calculated based on Hasselbach Henderson equation:

$$pH = 6.1 + \log [HCO_3^-] / [H_2CO_3]$$

Exploration of acid-base balance can be done by:
a. assessment of the blood pH by colorimetric or electrometrical methods
b. assessment of alkaline reserve (AR) by manometric or volumetric method Van Slyke. Alkaline reserve is the amount of carbon dioxide in ml or cm ³ at 0 ° C and 760 mmHg that is contained in 100 ml of plasma balanced with CO_2 equal with pCO_2= 40 mmHg (alveolar air). Normal: 50-70 vol%.

$$\text{Total } CO_2 \text{ (mmol / l)} = \text{RA (vol \%) / 2.24}$$

c. assessment of the alkaline functions of plasma (bases buffer) by titration with acid.
d. assessment of parameters Astrup with Astrup microquipment.

Determination of Astrup parameters

Astrup microquipment includes a thermostabilised microtonometer that allows balancing of two blood samples at two different pCO_2, a glass capillary electrode for determining pH, a calomel reference electrode, a pH meter and an ultra thermostat for maintaining constant temperature. Radial, brachial or femoral arteries can be punctured. The syringe may be pre-packaged and contain a small amount of heparin. The air is removed from the syringe, as bubbles of air can dissolve into the sample and cause inaccurate results. The blood is mixed with the heparin. The sample is immediately transported to the laboratory. If it cannot be immediately analyzed, it has to be cooled in an ice bath to slow the metabolic processes which can cause alteration in the results.

Capillary blood, obtained by collecting blood in capillary heparinised test tubes by a puncture of the finger can also be used. The collection of blood samples should be done at least 30 minutes before the therapeutically administration of oxygen.

Determination of acid-base balance parameters is done using Siggard Andersen diagram based on the inverse relationship between pH and logarithm of blood pCO_2. Three pH measurements using whole blood are necessary. One reading is that of the unaltered blood as received from the patient (pHa). The other two readings are of blood equilibrated in a tonometer at 37°C with different CO_2-O_2 mixtures. The chosen CO_2 tensions are such that one is approximately 20 mm of mercury and the other approximately 60 mm of mercury. The former is lower and the latter higher than the normal blood tension. The two points are plotted on a pH vs log pCO_2 graph and a straight line is drawn through the points. The two pH values measured by balancing the blood are signed up on the A axis and trace/draw two perpendiculars. The axis B, where we note the values corresponding pCO2 raises other two perpendiculars. The four perpendiculars will meet in two points A and B, the union representing a straight balancing line. It is linear relationship between log pCO_2 and pH of whole blood sample analyzed.

With balancing line and diagram are determined Astrup parameters:

1. the dissolved **pCO_2** in blood (respiratory factor) is projected pH_a value stated on axis A on the balancing line, point C and it will be projected on the axis B which read the current value of pCO_2.
2. **Actual bicarbonate (BA)** (respiratory and metabolic factor) is determined by projecting point C on line balancing (which is PHA) from left to right and at an angle of 45 degrees to the axis C, where the read value in mEq / l.
3. **Bicarbonate standard (BS)** or alkaline reserve (metabolic factor) represent the content in HCO_3^- of the plasma when blood is fully saturated with O_2 and standard conditions of pCO_2 (40 mmHg) and temperature (37 ° C); it appreciates the ability of blood to fix CO_2 as bicarbonate, is read at the point of intersection of line balancing and the axis C, in mEq / l.
4. **The buffer basses (BT)** metabolic factor is defined as the sum of buffer anion concentration in the blood and expressed in mEq / l; it read the diagram D in point where balancing line crosses the the scale.
5. **Bases excess (BE)**, metabolic factors, indicating the excess or deficit of bases; it reads the value where the balancing line intersects the axis E. The positive value means excess of bases or non-volatile acid deficiency, while a negative value base deficit or an excess of non-volatile acids.
6. **CO_2 total** (respiratory and metabolic factor) is the amount of carbonic acid and bicarbonate. It is calculated as:

$$\text{Total } CO_2 \text{ (mmol / l)} = (pCO_2 \times 0.03) + BA$$

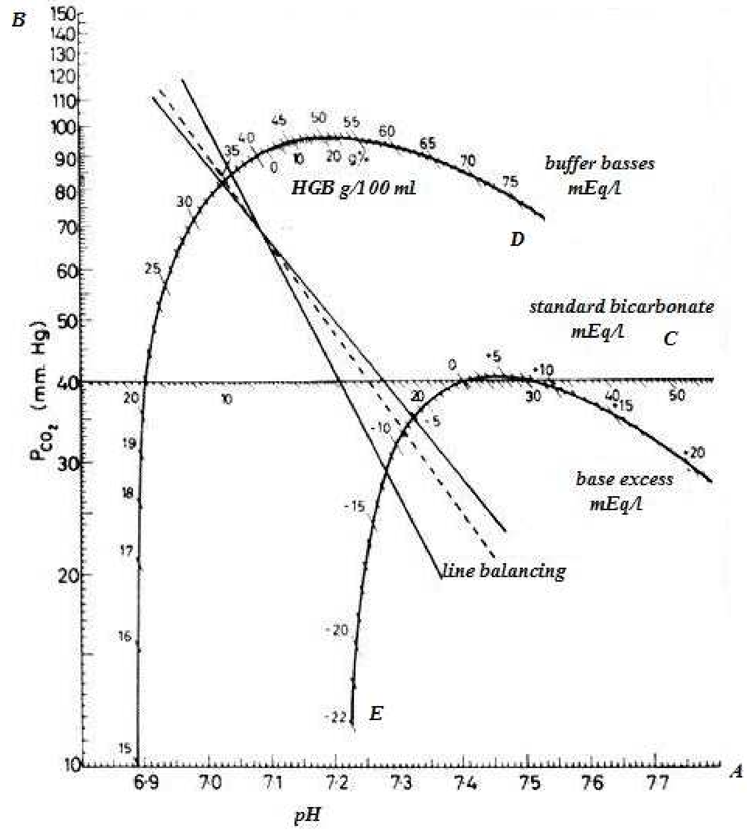

Figure Andersen Siggard nomogram

NORMAL VALUES

pH = 7.35 ÷ 7.45
pCO_2 = 38 ÷ 42 mmHg
BA = 23 ÷ 27 mmol / l (mEq / l)
BT = 46 ÷ 52 mEq / l
BS = 23 ÷ 27 mmol / l (mEq / l)
BE = - 2 ÷ 2 mEq / l
Total CO_2 = 24 ÷ 28 mmol / l

Other parameters

- pO_2 in the arterial blood is 80-100 mmHg. It represents partial pressure of oxygen dissolved in arterial blood.
- SaO_2 saturation of arterial blood in oxygen represents the percentage of hemoglobin wich is saturated with oxygen. The content in oxygen of the arterial blood can be calculated according to the following formula:

$$\text{Oxygen content} = SaO_2 \times HGB \times 1{,}34 + pO_2 \times 0.003$$

INTERPRETATION

Pathological changes of acid-base balance can be classified according to the ratio of bicarbonate and carbonic acid. The decrease of this ratio leads to acidosis and alkalosis if it increased. If the decrease is due to the bicarbonate variation it is called metabolic acidosis, if this change is caused by the increase of carbonic acid it is called respiratory acidosis. These disorders may be compensed or uncompensated.

Table Changes in acid-base balance

Condition		pH	pCO_2 (mmHg)	HCO_3^- (mEq/l)	HCO_3^-/H_2CO_3
Normally		7,35-7,45	38-42	23- 27	18- 22
Metabolic acidosis	compensed	7,35-7,40	<38	<22	18- 22
	uncompensed	<7,35	≤ 40	< 22	<18
Respiratory acidosis	compensed	7,35-7,40	> 42	> 27	18- 20
	uncompensed	<7,35	> 42	≥24	< 18
Metabolic alkalosis	compensed	7,40- 7,45	>42	> 27	20- 22
	uncompensed	>7,45	≥40	> 27	> 22
Respiratory alkalosis	compensed	7,40- 7,45	< 38	< 22	20- 22
	uncompensed	>7,45	< 38	≤ 24	> 22