Basics of interpretation of ABG

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The structural integrity of intracellular enzymes is essential for survival. Proton activity at enzymatic sites of action in cytosol and organelles must be tightly controlled.

In critically ill patients it is impractical to directly monitor the intra cellular sites. So the clinicians track the extracellular data from tests on arterial blood. We know that plasma pH exceeds intra cellular pH by 0.6 pH units.

Systemic arterial pH is maintained between 7.35 to 7.45 by intra & extracellular chemical buffering together with respiratory & renal regulatory mechanisms. The arterial CO_2 tension is controlled by CNS & respiratory system while plasma HCO_3^- is controlled is controlled by kidneys so as to stabilize arterial pH.
Henderson-Hasselbatch equation –

$$pH = 6.1 + \log \frac{HCO_3^-}{Pa\,CO_2 \times 0.0301}$$

This equation tells us about metabolic & respiratory components that regulate systemic pH. Usually the CO_2 production & excretion are exactly matched. The $PaCO_2$ is not regulated by CO_2 production but is primarily controlled by neutral respiratory factors in normal circumstances. It means hypercapnia is due to hypoventilation & not due to increased CO_2 production. In simple words, rise or fall in $PaCO_2$ means either of two problems:

1) Hypoventilation due to neurological or lung problems
2) Compensatory changes in response to primary change in HCO_3^-.

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Kidneys regulate HCO_3^- in plasma.

In this review report we will see how to approach an ABG report. We will see how to interpret the values and numbers. Detail discussion on etiology, clinical features & management is out of scope of this article.

Validity of ABG report
Always note that ABG report may not be correct. This is due to improper calibration of machine. If the report is not valid, then the interpretation may be wrong.

Example
A 54 year old male, diabetic presented with respiratory distress. pH 7.20, $PaCO_2$ – 30 , PaO_2 – 108 ,HCO_3^- 15. Apparently it looks like metabolic acidosis.

But if we put the values in simplified Henderson's equation:

$$\frac{[H+][HCO_3^-]}{[PaCO_2]} = 24$$

If you put values in above equation , you will come to know that values in the ABG report are wrong. H+ ion concentration is measured by many machines directly. Otherwise one approximate mono gram is given below. From pH value you can calculate [H+] value and can use in this formula.

$$\frac{[H+][HCO_3^-]}{[PaCO_2]} = 24$$

e.g. In DKA

pH = 7.20
$PaCO_2$ = 30
HCO_3^- = 15

$$\frac{60 \times 15}{30} = 30$$

ABG is Incorrect

pH	Substract from	H+
6.8		160
6.9		130
7.0	100	100
7.1	90	90
7.2	80	60
7.3	80	50
7.4	80	40
7.5	80	30
7.6	85	25
7.7	90	20
7.8	95	15

ABG gives us important informations about :-

1) oxygenation status
2) ventilation status
3) acid-base status

Oxygenation status:

Look at FiO_2

Before interpreting, check FiO_2. PaO_2 & O2 saturation is dependent on FiO_2.

When there is normal $PaCO_2$, normal gas exchange & ventilation & perfusion, then PaO_2 is usually 4-5 times of FiO_2.

Means FiO_2 of 21% gives PaO_2 of 80-100 mm Hg. Normal PaO_2 at higher FiO_2 indicates hypoxemia.

Is the PaO_2 lower than expected?

Calculate (A-a)pO_2 gradient.

$PaO_2 = FiO_2(PB-PH_2O)- PaCO_2/ R$

Where, PaO_2 is alveolar arterial tension.

FiO_2 is concentration of O_2 in inspired air.

PB is barometric pressure which 760 at sea level

PH_2O is pressure of water vapor in inspired gas (usually 47)

$PaCO_2$ is arterial CO_2

R is respiratory coetient, for normal balanced diet it is usually 0.8

Normally the gradient is less than 10- 15 mm Hg. This gradient can tell us the reason for hypoxemia in a particular patient.

ACIDOSIS OR ALKALOSIS

The pH of arterial blood gas measurement identifies the disorder. Normal arterial blood pH is = 7.40 ± 0.05.

Acidemic – pH <7.35

Alkalemic – pH >7.45

IS THE PRIMARY DISTURBANCE RESPIRATORY OR METABOLIC?

1) Respiratory disturbance primarily alters arterial $PaCO_2$(normal value 40, range 35-45)
2) Metabolic disturbance alters the serum HCO_3- (normal value 24, range 22-26)
3) In simple acid base disorder, $PaCO_2$ & HCO_3- move in same direction.
4) In simple metabolic disorder , $PaCO_2$ & HCO_3- moves in same direction of pH
5) In simple respiratory disorder, $PaCO_2$ & HCO_3- moves in opposite direction of pH.
6) In mixed disorder, $PaCO_2$ & HCO_3- can move in any direction, depending on severity of individual disorder.

DISORDER	pH	$PaCO_2$	HCO_3-
METABOLIC ACIDOSIS	↓	↓	↓
METABOLIC ALKALOSIS	↑	↑	↑
RESPIRATORY ACIDOSIS	↓	↑	↑
RESPIRATORY ALKALOSIS	↑	↓	↓

RESPIRATORY ACID BASE DISTURBANCES

Primary respiratory disturbances (primary changes in $PaCO_2$) invokes compensatory metabolic response (secondary changes in HCO_3-).

Compensation in Simple Respiratory Disturbances:-

A) Respiratory acidosis

Acute: HCO_3- increases by 1mEq/L for every 10 mmHg increase in $PaCO_2$.

Chronic : HCO_3- increases by 4mEq/L for for every 10 mmHg decreases in $PaCO_2$

B) Respiratory alkalosis

Acute: HCO_3- decreases by 2mEq/L for every 10 mmHg increase in $PaCO_2$.

Chronic: HCO_3- decreases by 4mEq/L for every 10 mmHg increase in $PaCO_2$.

HOW TO KNOW IF RESPIRATORY ACIDOSIS IS ACUTE OR CHRONIC?

Calculate Δ H+ & Δ $PaCO_2$

If $\Delta H+ / \Delta PaCO_2$ < 0.3 - chronic

If $\Delta H+ / \Delta PaCO_2$ 0.3 to 0.8 - acute or chronic

If $\Delta H+ / \Delta PaCO_2$ >0.8 - acute

METABOLIC ACIDOSIS

The primary change is in HCO_3-, lungs compensate by exhaling CO_2.

Expected $PaCO_2 = (1.5 \times HCO_3\text{-}) + (8 \pm 2)$

- if actual $PaCO_2$ is less than expected, additional respiratory alkalosis

- If actual $PaCO_2$ is more than expected, additional respiratory acidosis
- $PaCO_2$ is rarely <10mm Hg
- If actual $PaCO_2$ is <10, consider additional respiratory alkalosis.

Types of metabolic acidosis

- High anion gap metabolic acidosis
- Normal anion gap metabolic acidosis

Anion Gap (AG)

It is difference between actual & calculated anion gap. It is because of few unmeasured anions.

The AG quantifies [unmeasured anions]-[unmeasured cations]

$$AG = Na+ - [HCO_3- + Cl-]$$

Normal AG = 8-12 (average 10 mEq/L)

Albumin Corrected Anion Gap :

For every 1 gm increase or decrease of serum albumin beyond normal(4 gm/dl),

AG increases or decreases by 1.

Causes of increased AG metabolic acidosis

K – ketoacidosis – diabetic, starvation,alcoholic
L - lactic acidosis
U – uremia
M – methanol
P – paraldehayde
E – ethanol ,ethylene glycol
S – salicylates

Determine whether other metabolic disturbences co-exist with high AG metabolic acidosis –

Determine ΔAG & ΔHCO_3- & $\Delta AG/\Delta HCO_3-$

1) High AG metabolic acidosis , ratio is one.
2) High AG metabolic acidosis + metabolic alkalosis -> 1
3) High AG metabolic acidosis + normal AG metabolic acidosis - <1

The different types of normal anion gap metabolic acidosis, clinical features & management of metabolic acidosis is out of the scope of this review article.

Metabolic alkalosis

The relationship of $PaCO_2$ & HCO_3 is is difficult to predict & its nonlinear.

Expected $PaCO_2 = PaCO_2 + [0.6 \times \Delta HCO_3^-]$

ΔHCO_3^- is change in HCO_3^-

A patient will increase $PaCO_2$ above 40 but not greater than 50-55.

If the $PaCO_2$ is > 55, consider additional respiratory acidosis.

In metabolic alkalosis, if pH is less than expected, consider additional metabolic acidosis.

T**o summarize,**

Cleck validity of report before interpreting the ABG values.
Check FiO2 before interpreting oxygenation status.
Check anion gap always.
Interpret ABG in context with clinical condition only.

Treat the patient and not the ABG.