Arterial Blood Gas (ABG) interpretation for medical students, OSCEs and MRCP

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Arterial Blood Gas (ABG) interpretation for medical students, OSCEs and MRCP PACES

This section presents how to interpret arterial blood gases. It explains each component in turn followed by clinical examples to work through.

The most important points when assessing a patient are the history, examination and basic observations. Investigations such as arterial blood gases add to the information you have already gained to guide your management.

Before starting…

- Arterial blood gas analysis can be used to assess gas exchange and acid base status as well as to provide immediate information about electrolytes.
- It is also useful to have access to any previous gases. This is particularly important if your patient is known to have chronic respiratory disease with existing chronic ABG changes.

Normal values for arterial blood gas (ABG)

- Normal values are given below. Note that these may vary slightly between analysers. Be sure to know the normal ranges and units for the analyser you will be using.
- pH: 7.35 – 7.45
- pO2: 10 – 14kPa*
- pCO2: 4.5 – 6kPa*
- Base excess (BE): -2 – 2 mmol/l

- HCO_3: 22 – 26 mmol/l

*1kPa = 7.5mmHg. p stands for the ‘partial pressure of…’

Components of the ABG

pH

- pH is a logarithmic scale of the concentration of hydrogen ions in a solution. It is inversely proportional to the concentration of hydrogen ions.
- When a solution becomes more acidic the concentration of hydrogen ions increases and the pH falls.
- Normally the body’s pH is closely controlled at between 7.35 – 7.45. This is achieved through buffering and excretion of acids. Buffers include plasma proteins and bicarbonate (extracellular) and proteins, phosphate and haemoglobin (intracellularly).
- Hydrogen ions are excreted via the kidney and carbon dioxide is excreted via the lungs.
- Changes in ventilation are the primary way in which the concentration of H+ ions is regulated. Ventilation is controlled of the concentration of CO_2 in the blood.
- If the buffers and excretion mechanisms are overwhelmed and acid is continually produced, the he pH falls. This creates a metabolic acidosis.
- If the ability to excrete CO_2 is compromised this creates a respiratory acidosis.
- Note that a normal pH doesn’t rule out respiratory or metabolic pathology. This why you must always look at all the values other than pH as there may be a compensated or mixed disorder.

Partial pressure (PP)

- Partial pressure is a way of assessing the number of molecules of a particular gas in a mixture of gases. It is the amount of pressure a particular gas contributes to the total pressure. For example, we normally breathe air which at sea level has a pressure of 100kPa, oxygen contributes 21% of 100kPa, which corresponds to a partial pressure of 21kPa.
- When used in blood gases, Henry’s law is used to ascertain the partial pressures of gases in the blood. This law states that when a gas is dissolved in a liquid the partial pressure (i.e. concentration of gas) within the liquid is the same as in the gas in contact with the liquid. Therefore you can measure the partial pressure of gases in the blood.
- **PaO_2** is the partial pressure of oxygen in arterial blood
- **$PaCO_2$** is the partial pressure of carbon dioxide in arterial blood.

Base excess (BE)

- This is the amount of strong base which would need to be added or subtracted from a substance in order to return the pH to normal (7.40).

- A value outside of the normal range (-2 to +2 mEq/L) suggests a metabolic cause for the acidosis or alkalosis.
- In terms of basic interpretation
- A base excess more than +2 mEq/L indicates a metabolic alkalosis.
- A base excess less than -2 mEq/L indicates a metabolic acidosis.

Bicarbonate (HCO_3)

- Bicarbonate is produced by the kidneys and acts as a buffer to maintain a normal pH. The normal range for bicarbonate is 22 – 26mmol/l.
- If there are additional acids in the blood the level of bicarbonate will fall as ions are used to buffer these acids. If there is a chronic acidosis additional bicarbonate is produced by the kidneys to keep the pH in range.
- It is for this reason that a raised bicarbonate may be seen in chronic type 2 respiratory failure where the pH remains normal despite a raised CO_2.

Electrolytes

- A venous or arterial blood gas is a good way to quickly check potassium and sodium values. This is particularly important in the immediate management of cardiac arrhythmias as it gives an immediate result.

Lactate

- Lactate is produced as a by-product of anaerobic respiration. A raised lactate can be caused by any process which causes tissue to use anaerobic respiration. It is a good indicator of poor tissue perfusion.

Haemoglobin (Hb)

- Haemoglobin acts as a guide but is notoriously inaccurate in an ABG. Lab samples should be used to verify results.

Glucose

- Don't forget to check this. Glucose is especially pertinent in the management of the patient who has decreased consciousness or seizures. It is also important in patients with known or suspected diabetes.
- Glucose may also be raised in patients with severe sepsis or other metabolic stress.

Other components of the ABG

- These are rarely deranged and often overlooked. However, it is important to notice them if they are abnormal. This is especially true in the case of carbon monoxide as there may be other people at risk.

Carbon monoxide (CO)

- Normally CO is <10%. In city dwellers or smokers levels can be raised up to 10% but a level >10% indicates poisoning, commonly from poorly ventilated boilers or old heating systems.
- At levels of 10 -20% symptoms such as nausea, headache vomiting and dizziness will be predominant. At higher levels patients may experience arrhythmias, cardiac ischaemia, respiratory failure and seizures.

Methaemoglobin (metHb)

- MetHb is an oxidized form of haemoglobin. Levels of >2% are abnormal.
- Methaemoglobinaemia is a rare condition but again it is important not to miss. It may be caused by errors of metabolism or by exposure to toxins such as nitrates.

Compensation

pH is closely controlled in the human body and there are various mechanisms to maintain it at a constant value. It is important to note that the body will never overcompensate as the drivers for compensation cease as the pH returns to normal. In essence compensation for an acidosis will not cause an alkalosis or visa versa.

Respiratory Compensation

- If a metabolic acidosis develops the change is sensed by chemoreceptors centrally in the medulla oblongata and peripherally in the carotid bodies.
- The body responds by increasing depth and rate of respiration therefore increasing the excretion of CO_2 to try to keep the pH constant.
    - The classic example of this is ‘Kussmaul breathing’ the deep sighing pattern of respiration seen in severe acidosis including diabetic ketoacidosis. Here you will see a low pH and a low pCO_2 which would be described as a metabolic acidosis with partial respiratory compensation (partial as a normal pH has not been reached).

Metabolic Compensation

- In response to a respiratory acidosis, for example in CO_2 retention secondary to COPD, the kidneys will start to retain more HCO_3 in order to correct the pH.
- Here you would see a low normal pH with a high CO_2 and high bicarbonate.

- This process takes place over days.
- It is important to ensure that the compensation that you see is appropriate, i.e. as you would expect. If not then you should start to think about mixed acid base disorders.

How to interpret an ABG

A systematic approach to ABG interpretation leads to easy interpretation. Here is one such system:

1. Look at the patient! Review history and examination findings.
2. What is the pO2 – how much oxygen was your patient on when the gas was taken?
3. What is the pH? Is the patient acidaemic or alkalaemic.
4. What is the pCO2?
5. What is the HCO3 and base excess?
6. Is the patient compensating?
7. What are the other values? Ensure that you look at all other figures on the gas.

How to present an ABG

1. State that this is an arterial blood gas sample (rather than venous).
2. State the patients name and outline history/pertinent examination findings.
3. State the time the sample was taken and how much oxygen the patient was on at the time.
4. Present your findings: e.g. this showed type one respiratory failure with a p02 of 7
5. Present any abnormal findings or important negatives from the rest of the values.
6. A one line summary of your findings.

For example:

- “This is an arterial blood gas sample taken from Mrs Smith, a 70 year old lady who presented this morning with shortness of breath. She has a back ground of heart failure and diabetes and on auscultation of her chest she has bibasal crackles.
- This gas was taken at 10 a.m. today when Mrs Smith was on 15l per minute of oxygen via a non rebreathe mask.
- It showed type one respiratory failure with a p02 of 10.0 and a pCO2 of 4.1.
- There is no acid base disturbance although her glucose was noted to be 15.

- In summary this lady has type 1 respiratory failure."
    - N.B. the pO_2 of 10 whilst on 15l/min of oxygen is indicative of severe respiratory disease. This is why including all the information in the presentation is incredibly important as a pO_2 of 10 on air would be far less worrying.
    - In patients with chronic respiratory disease it is very useful to see an old ABG as this may give useful clues as to a patient's normal respiratory status.

Respiratory failure

Respiratory failure can be split into Type one or Type 2 respiratory failure. These are differentiated by the pCO_2.

Type 1 Respiratory failure (T1RF)

- Type one respiratory failure is defined as a PaO_2 less than 8 and a $PaCO_2$ which is low or normal.
- T1RF is caused by pathological processes which reduce the ability of the lungs to exchange oxygen, without changing the ability to excrete CO_2.
- Examples of T1RF are pulmonary embolus, pneumonia, asthma and pulmonary oedema.

Type 2 respiratory failure (T2RF)

- This is defined as a PaO_2 of less than 8 and a raised $PaCO_2$.
- You can think of it as being caused by a problem with the lungs or by a problem with the mechanics or control of respiration.

Pulmonary problems	Mechanical problems	Central problems
COPD	Chest wall trauma	Opiate overdose
Pulmonary oedema	Muscular dystrophies	Acute CNS disease
Pneumonia	Motor neurone disease	
	Myasthenia Gravis	

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