BLOOD GAS MONITORING

Terms you will become familiar with in this module

pulse oximeter	diffusion
metabolism	arterial saturation of oxygen
acidity [pH]	hypoxaemia
buffer	partial pressure
physiological status	saturation curve
therapy	spectrophotometer
haemoglobin	pulsatile blood flow
oxyhaemoglobin	sensor
deoxyhaemoglobin	blood gas analyzer
arterial blood	dyshaemoglobin
venous blood	

INTRODUCTION

The analysis of blood gas in medicine is a measurement of the amount of Oxygen [O_2] and Carbon Dioxide [CO_2] present in the blood. Oxygen is used in normal processes in the body which produce Carbon Dioxide as a by-product. Oxygenated [arterial] blood contains certain normal levels of Oxygen and Carbon Dioxide. In order for the body to function at its best, the normal levels of these gases must be held fairly constant.

One part of blood gas analysis involves measuring how acidic the blood is. For normal body processes [**metabolism**] to occur, the **acidity [pH]** must be held within a narrow range by the combined action of the respiratory system [lungs] and the renal system [kidneys] (amongst other systems). These systems, together with some dissolved chemicals [called **buffers**] work together to maintain balance [homeostasis] in terms of the oxygen and carbon dioxide levels and the acidity [or pH] of the blood.

The purpose of blood gas analysis is to determine the present health [**physiological status**] of the client, to measure the effect of treatment procedures [**therapy**] and to assess or monitor the results or on-going effects of treatment.

ANATOMY AND PHYSIOLOGY

Oxygen can be carried through the body dissolved in the blood as microscopically small bubbles [about 3 per cent] or attached to **Haemoglobin** (Heem - a-glow-bin) molecules [97 per cent] in the red blood cells. Oxygen can join chemically with heamoglobin [abbreviated Hb] in the lungs. Bright red arterial blood contains Hb loaded with O_2 [called **oxyhaemoglobin**]. This oxygen-rich blood is then pumped

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through the arteries to the tissues where the oxygen unloads from the Hb molecule and is transferred [**diffused**] into the tissues. The dark red [**venous**] blood in the veins has unloaded its oxygen into the tissues and joined with carbon dioxide instead [it is now called **de-oxy-haemoglobin**]. Deoxyhaemoglobin-rich blood flows back to the lungs where the CO_2 is replaced with oxygen again.

Because of their difference in redness, oxyhaemoglobin and deoxyhaemoglobin have differing light reflecting and absorbing abilities. Infrared light is more easily reflected from the bright red oxygen carrying blood and more easily absorbed by the darker, carbon dixide carrying venous blood.

Activity

We wear dark clothing in winter to absorb the warmth of infrared light. In summer we wear bright coloured clothing to reflect the same infrared light so that we remain cooler.

Find a light cloth and a dark cloth. Wrap one around each hand and then place both hands in the sunlight or near a heater. The hand which feels warm first is absorbing more infrared light. The hand which stays cooler is reflecting much of the same infrared light. Try covering one hand with a single layer of aluminium foil. This will cause even greater reflection.

The levels of oxygen and carbon dioxide which can be carried by haemoglobin are affected by the acidity [pH] of the blood and by several other factors including outside air pressure, body temperature and blood pressure,. Certain diseases and medical conditions also have a big effect on the ability of the blood to hold oxygen and carbon dioxide.

The total amount of oxygen held in the blood as oxyhaemoglobin [HbO_2] compared with the amount it could hold is called the **Arterial Saturation of Oxygen** [SaO_2]. It is described as a percentage. Arterial saturation (SaO_2) is important because it helps to describe the amount of O_2 available to the body for its normal operation [metabolism]. If the body carries too little oxygen, we suffer from oxygen starvation [**hypoxaemia**].

The measured saturation of oxygenattached to Hb is related to the pressure of oxygen carried in the blood. The normal **partial pressure** of oxygen for arterial blood [PaO2] is 80 - 100 mmHg.

The relationship between PaO_2 and SaO_2 is described by the Oxygen/Haemoglobin Saturation Curve. This curve describes the ability of Hb to combine with O_2 under various conditions. It is the base point for the measurements displayed by the Pulse Oximeter.

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[for Oxygen/Haemoglobin Saturation Curve, see for example Anatomy and Physiology by Guyton (1995) publisher Butterworth]

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PULSE OXIMETRY

Oximetry: a method of using light to measure oxygen levels in the blood. A **spectrophotometer** is used to measure differences in the way light is absorbed by deoxygenated and oxygenated haemoglobin in the red blood cells.

CASE STUDY

Equipment which is ***emphasised,*** **referred to or used** in this case study includes:

- ***Pulse Oximeter***
- **Spectrophotometer**
- Blood Gas Analyser
- end tidal CO_2 monitor

Following a motor vehicle accident, a 23 year old woman, Mae Cheong, is admitted to the Accident and Emergency department of the hospital where you work. By the time you arrive, she is very pale and sweaty, her pulse is rapid [138 per minute] and weak. She is breathing rapidly but only taking shallow breaths. There are obvious wounds to her legs and head. She seems to be awake but she is not being very cooperative.

The nursing staff have decided to monitor her breathing (oxygen saturation) using a pulse oximeter placed over an uninjured finger on her left hand. After a few tries to get a reading from the Oximeter they decide that it is faulty and call you to assist with troubleshooting the problem.

When you arrive the oximeter is still connected to the client and turned on. The first things you notice are:

- the displayed pulse rate is erratic
- the saturation display is blinking a number of values
- the woman's hands and feet look quite pale.

You **check the actual carotid pulse rate against the displayed pulse rate** before you proceed any further.

Questions

What could be the cause of the erratic pulse rate and saturation displays? How could you overcome this problem? [think about the placement of the sensor]

One strong clue to the possibilities would be the pale, even bluish, appearance of the skin.

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When there is a lack of **pulsatile blood flow**, the Pulse Oximeter cannot detect the difference between arterial oxygen absorbtion and venous and tissue saturations so it cannot measure the SaO_2. This can happen if

the **sensor** is not placed correctly or

the sensor is placed where there is a reduced arterial blood flow or

the blood flow is absent where the sensor is placed - which can happen in situations of low blood pressure if blood flow to the hands and feet is reduced so that more blood is pumped to the essential organs like heart, brain and kidney [as occurs in shock - *Would you expect this client to be in a state of shock?*].

Compression of the extremity has a similar effect as it reduces arterial blood flow to the limb [*Why would there be a tight bandage or other restriction to blood flow between the heart and the finger where the pulse oximeter is placed?* Think young woman, think left hand.]

Question

What else could cause an erratic display on the oximeter?

As you are thinking, you observe the client and the area. You notice that

- the emergency area is lit by a number of fluorescent lights. It is particularly bright.
- Mae Cheong is restless and moving around on the trolley.

Question

What effect could these have on the readings you are seeing? Suggest how you could reduce or prevent these problems.

Pulse Oximeters are normally quite reliable and accurate within reasonable ranges and conditions. Generally they are accurate within 2% in SaO2 range of 80 - 100%. They do have some limitations and these are based on the ability of the sensor to sense light at a constant level (therefore absorption of infrared light) and to detect pulsatile blood flow. The most vulnerable part of the system is the sensor and the cable attaching it. Broken or failing cables often produce erratic readings before they fail completely.

You have explained the problems to the nursing staff and you are about to leave when you notice that one of the nursing staff is removing the nail polish from the Mae's fingernails.

Question

Would red nail polish on the woman's fingernails affect the Oximeter readings?

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Pulse Oximetry works by shining red and infrared light through the tissues of body extremities. When the red and infrared light is absorbed by the HbO_2 in arterial blood, the absorption increases and decreases with the ebb and flow of the blood. The difference between the peak of absorbtion and the trough is the saturation. Because the nail polish is not changing its colour, it should not affect the oximeter readings. Recent research, however suggests that blue, black and green nail polish do affect the readings though the mechanism has not been explained. [See Ralston, Webb & Runciman]

When light is emitted through the tissues the pulsatile nature of arterial blood flow (therefore HbO_2) means that light absorption is pulsatile

see diagram – graphical – to be scanned – plethysmograph

Shortly after you leave, blood is taken from Mae Cheong for **Arterial Blood Gas analysis**. After the results have been interpreted you are again called to 'fix' the pulse oximeter because the measured saturation on the oximeter does not match up with the Blood Gas Analyser. In fact the pulse oximeter reading displays a SaO_2 of 98% whilst the measured PaO_2 was 60 mmHg.

Use the O_2/Hb Saturation Curve to see why this is a problem.
You will see that a partial pressure of oxygen [PaO_2] of 60 mmHg should aproximately relate to an SaO_2 of 90%.

Question

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What could be the reason for the difference between the readings from the two instruments?

The pulse oximeter measures saturation of Hb in arterial blood by O_2. If the Hb level is low, high or normal it makes no difference to the Oximeter because it simply measures the amount of Hb bound to O_2 as a percentage of the amount that can bind. If the client had a low Hb [maybe because of severe bleeding caused in a motor car accident] the Hb may still be well saturated but there just isn't enough Hb to carry enough O_2 to meet the client's needs. Therefore the PaO_2 will be low in the presence of a normal SaO_2. In other words the client is starving for oxygen [hypoxaemic] with a normal saturation of oxygen.

Question

What other explanations could there be for a difference in readings between the Blood Gas Analyser and the Pulse Oximeter? Clue: Consider functional and fractional saturation.

Refer again to the Oxygen/Haemoglobin Dissociation Curve and the conditions affecting the affinity of oxygen for Hb. e.g. Temperature and pH, etc.

Challenge questions

Haemoglobin combines with carbon monoxide in preference to oxygen.
Use your reference books to describe the effect of carbon monoxide poisoning on pulse oximeter readings. What symptoms might have been used by clinical staff to recognise the possibility of carbon monoxide poisoning. Using your knowledge of the case, why might these signs have been reduced or masked.
The presence of **dyshaemoglobins** provide false readings which can lead to incorrect interpretation of pulse oximeter readings. What are dyshaemoglobins and how do they act to affect pulse oximetry results?

Nursing staff begin taking blood pressure on ms Cheong's uninjured left arm. Why does the oximeter alarm indicate poor signal?

REFERENCES

Ralston, A.C., Webb, R.K. and Runciman, W.B. (1991) *Potential errors in Pulse oximetry*, **Anaesthesia.** (46) 202-212

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