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Excerpt
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Chapter 1

Airway

Basic Concepts

Airway Assessments

How Is the Airway Assessed Clinically?

Assessment is based on the principle of: *Look*, *Listen* and *Feel*.

- *Look*: for the presence of accessory muscles of respiration (neck, shoulders, chest and abdomen) being used, obstructing foreign bodies in the airway, facial/airway injury and the 'see-saw' pattern of complete airway obstruction (NB: central cyanosis is a late sign)
- *Listen*: for inspiratory stridor which indicates upper airways obstruction (laryngeal level and above). Take note of grunting, gurgling (liquid or semi-solid foreign matter in the upper airways) and snoring sounds (indicating the pharynx is partially occluded by the tongue or palate). Expiratory wheeze suggests lower airways obstruction. Crowing indicates laryngeal spasm
- *Feel*: for chest wall movements and airflow at the nose and mouth (for 10 seconds)

Note that in cases of trauma the assessment must be performed with cervical spine (C-spine) control.

What Techniques of Airway Management Do You Know?

Broadly speaking there are *simple* and *definitive* airway management techniques.

- Simple measures:
  - *Basic airway manoeuvres*: head tilt, chin lift and jaw thrust, which open up the airway and permit the use of rigid suction devices (Yankauer sucker) to clear secretions and forceps (Magill) to remove solid debris
  - *Basic airway adjuncts*: nasopharyngeal and oropharyngeal airways. If the patient does not tolerate an oropharyngeal airway, then it is prudent to request an anaesthetic review as the airway is at risk of imminent collapse
- Complex measures:
  - *Endotracheal intubation*: this requires expertise and can be achieved through the mouth (orotracheal) or the nose (nasotracheal) intubation
  - *Surgical airway*: a cut down through tissues in the neck and can be achieved in three ways (*see* Airway Adjuncts later in this chapter)

How Are the Head Tilt, Chin Lift and Jaw Thrust Manoeuvres Performed?

- *Head tilt*: the hand is placed on the patient's forehead and another under the occipital protuberance to tilt the head back gently

- *Chin lift:* the fingers of one hand are placed under the mandible in the midline and then lifted upwards to bring the chin forward
- *Jaw thrust:* the angles of the mandible are identified on both sides, the index and middle fingers are placed behind it and a steady upwards and forwards pulling pressure is applied to lift the mandible (this is painful and if not tolerated, consider an anaesthetic review). Finally, the thumbs are used to slightly open the mouth by downward displacement of the chin

These simple methods are often unsuccessful when airway obstruction is caused by loss of muscle tone in the pharynx. Always check for intervention success after each manoeuvre using the Look, Listen and Feel sequence.

Oxygen: Basic Physiology

What Is the FiO_2 of Atmospheric Air?

0.21. Since 21% of the atmosphere is made up of oxygen.

What Is Meant by the *Oxygen Cascade*?

This describes the incremental and successive drops in the pO_2 from the atmosphere to the arterial circulation.

What Are the Changes in the Oxygen Cascade?

- *Atmospheric air*: pO_2 = 21.0 kPa
- *Tracheal air*: pO_2 = 19.8 kPa
- *Alveolar gas*: pO_2 = 14.0 kPa
- *Arterial blood gas*: pO_2 = 13.3 kPa

How Is Oxygen Transported in the Body?

Oxygen is transported by binding to haemoglobin (99%) or dissolved in solution (1%).

What Does Henry's Law State, and How Is This Used to Calculate the Amount of Oxygen Dissolved in the Blood?

Henry's law states that the *gas content* of a *solution* is equal to the *product* of the *solubility* and the *partial pressure* of the *gas*. At 37 °C the solubility of oxygen in blood is 0.03 ml/L for every mmHg rise in the partial pressure ($0.03 \times PaO_2$).

What Is Haemoglobin Composed Of?

Haemoglobin is a globular protein consisting of a haem component and a globin chain. The haem moiety consists of Fe^{2+} and a protoporphyrin ring. The globin chain consists of 2-α and 2-β chains together and a 2,3-bisphosphoglycerate (2,3-BPG) molecule in an adult. A total of four oxygen molecules are able to bind to each globin molecule.

What Other Molecules May Bind to Haemoglobin Under Normal Circumstances?

- *Carbon dioxide*: this binds to the globin chain forming a carbamino compound
- *Protons (H^+)*: these specifically bind to amino, carboxyl and imidazole groups in the globin chain
- *2,3-BPG*: this is a by-product of red cell metabolism. It is able to form covalent bonds with the β-subunits, wedging them apart in the de-oxygenated state

Where Are the Main Sites of Haemopoesis?

- *Yolk sac*: in the first few weeks of gestation
- *Bone marrow*: from the first few weeks after birth
- *Liver and spleen*: most important sites up until the first 7 months of gestation. The adult can revert to these sites in pathological states – so-called 'extramedullary haemopoesis'

What Is the Life Span of a Red Blood Cell?

The average life span is 120 days, after which it is broken down in the reticuloendothelial system.

Draw the Oxygen Dissociation Curve and Label the Axis

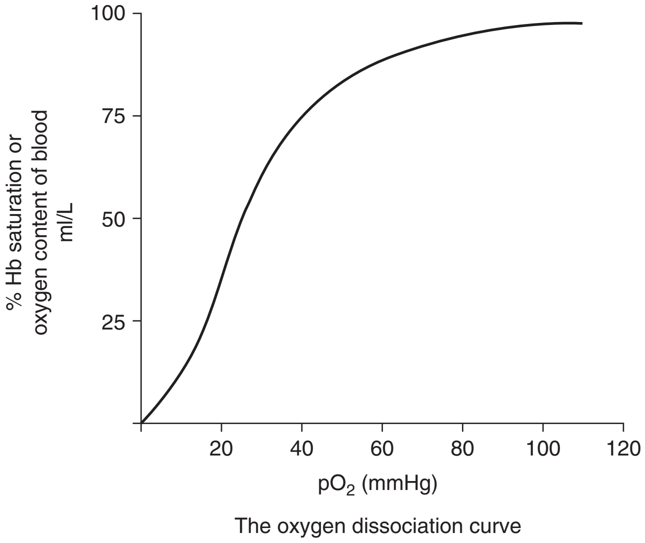

Figure 1.1

What Accounts for the Shape of the Curve?

The sigmoidal curve reflects the progressive nature with which each oxygen molecule binds to haemoglobin. This binding is termed *cooperative* – the binding of one oxygen molecule facilitates the bind of the next.

What Is the Bohr Effect and What Causes It?

The Bohr Effect is a *shift* of the dissociation curve to the *right*, signifying a reduction of the oxygen affinity of the molecule and, therefore, a greater tendency to offload oxygen into the tissues. This *right shift* can be caused by:

- Increased temperature
- Increased acidity
- Increased 2,3-BPG (e.g. due to chronic hypoxia)
- Hypercarbia

What Physiological Effect Does It Have?

It ensures greater and more ready tissue oxygenation during states of acute or chronic reduction in tissue perfusion.

How Does the Oxygen Dissociation Curve in the Foetus Compare to That of the Adult and What Accounts for This Difference?

The foetal oxygen dissociation curve is shifted to the *left*. This reflects the increased oxygen affinity of foetal haemoglobin caused by the presence of the γ-subunit (instead of the β) that cannot form covalent bonds with 2,3-BPG. This ensures that it is readily able to take up oxygen from the maternal haemoglobin molecule.

How Much Oxygen Is Bound to Haemoglobin When Fully Saturated?

When fully saturated each gram of haemoglobin can bind to 1.34 ml of oxygen. It follows that the oxygen carrying capacity of the blood is 1.34 × [Hb] at full (100%) saturation.

Therefore on What Factors Does the Total Amount of Oxygen in the Blood Depend? How Is This Calculated?

O_2 content of blood
= amount bound to Hb + amount dissolved in blood

or

$= (1.34 \times [\mathrm{Hb}] \times \%\ \text{saturation}) + (0.03 \times P\mathrm{aO_2})$

The factors determining the total oxygen content of the blood are:

- [Hb]
- (%) saturation of the molecule
- $P\mathrm{aO_2}$
- Temperature as this determines the oxygen solubility (although in practice this is of little significance)

The total is in the order of 200 ml/L for arterial blood at 97% saturation.

Carbon Dioxide: Basic Physiology

What Is the $FiCO_2$ of Atmospheric Air?

0.00035. Since 0.035% of the atmosphere is made up of carbon dioxide.

What Are the Changes in the Carbon Dioxide Cascade?

- *Atmospheric air*: pCO_2 = 0.03 kPa
- *Alveolar air*: pCO_2 = 5.30 kPa
- *Arterial blood gas*: pCO_2 = 5.30 kPa
- *Venous blood gas*: pCO_2 = 6.10 kPa
- *Exhaled air*: pCO_2 = 4.00 kPa

Why Is There Virtually No Alveolar-Arterial pCO_2 Difference, Unlike Oxygen?

Carbon dioxide has a very high water-solubility compared to oxygen and rapidly diffuses across the respiratory epithelium.

Under What Conditions Does This Difference Increase?

Under the pathological conditions of a ventilation/perfusion mismatch and when there is an increase in CO_2 production.

How Is Carbon Dioxide Transported in the Body?

- *Bicarbonate ions (HCO_3^-)*: accounts for 85–90% of carriage
- *Carbamino compounds*: formed when CO_2 binds with the terminal amino group of plasma proteins. 5–10% of CO_2 is transported in this way
- *Physically dissolved in solution*: this accounts for 5%

How Does the Mode of CO_2 Transport Differ between Arterial and Venous Blood?

In arterial blood there is *less* carbamino compound carriage and *more* bicarbonate carriage. The amount physically dissolved varies little between the two circulations. This variation is due to the difference in pH affecting the binding and dissociation properties of the molecule.

How Does the Amount of CO_2 Physically Dissolved in Plasma Compare to the Amount of Dissolved Oxygen?

Only ~1% of oxygen in blood is dissolved in plasma and 5% for CO_2 because oxygen is 24 times less water soluble.

You Mentioned That CO_2 Combines with Plasma Proteins to Form Carbamino Compounds. What Is the Most Significant of These Plasma Proteins?

Haemoglobin, as CO_2 binds to its globin chain.

How Does CO_2 Come to Be Carried as the Bicarbonate Ion?

$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3^-$

This interchangeable reaction is catalysed by the enzyme *carbonic anhydrase*.

What Happens to All of the H^+ Generated by This Process?

This is 'mopped up' by other buffer systems. The H^+ binds with the haemoglobin molecule, mainly the imidazole groups of the polypeptide chain, and is therefore buffered.

What Effect Does This Buffering Have on the Transport of Oxygen by Haemoglobin?

The addition of the H^+ and CO_2 to the haemoglobin chain leads to a reduced oxygen affinity. This is seen as a *right* shift in the oxygen dissociation curve.

What Happens to the Bicarbonate Generated in the Red Cell When It Carries CO_2?

It diffuses out of the red cell and into the plasma (unlike H^+, it is able to penetrate the red cell membrane). The electrochemical neutrality is maintained by a Cl^- ion entering as an HCO_3^- ion leaves. This is known as the *chloride shift*.

How Does the Transport of CO_2 Affect the Osmotic Balance of a Red Cell?

The bicarbonate and chloride generated following CO_2 carriage by the red cell increases the intracellular osmotic pressure. This causes the cell to swell as extra H_2O diffuses through the cell membrane, which is why the haematocrit (Hct) of venous blood is 3% higher than arterial blood.

How Does the Shape of the Oxygen Dissociation Curve Differ from the CO_2 Dissociation Curve?

- The CO_2 dissociation curve is *curvilinear*
- The O_2 dissociation curve is *sigmoidal*