# 11. Resp Miscellaneous

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>CICO Drills</td>
<td>2</td>
</tr>
<tr>
<td>Pre-Oxygenation</td>
<td>3</td>
</tr>
<tr>
<td>Functional Residual Capacity</td>
<td>3</td>
</tr>
<tr>
<td>Preoxygenation</td>
<td>3</td>
</tr>
<tr>
<td>Co2 in Preoxygenation</td>
<td>3</td>
</tr>
<tr>
<td>Apnoeic Mass-Movement Oxygenation</td>
<td>3</td>
</tr>
<tr>
<td>Gas Laws</td>
<td>5</td>
</tr>
<tr>
<td>Terminology</td>
<td>5</td>
</tr>
<tr>
<td>Oxygen</td>
<td>5</td>
</tr>
<tr>
<td>Pharmacology</td>
<td>5</td>
</tr>
<tr>
<td>Production</td>
<td>5</td>
</tr>
<tr>
<td>Oxygen Storage</td>
<td>6</td>
</tr>
<tr>
<td>Oxygen Measurement</td>
<td>6</td>
</tr>
<tr>
<td>Effects of Oxygen</td>
<td>6</td>
</tr>
<tr>
<td>Toxicity of Oxygen</td>
<td>6</td>
</tr>
<tr>
<td>Oxygen Equipment</td>
<td>7</td>
</tr>
<tr>
<td>Medical Gases</td>
<td>8</td>
</tr>
<tr>
<td>Bulk Flows</td>
<td>8</td>
</tr>
<tr>
<td>Gas Cylinders</td>
<td>8</td>
</tr>
<tr>
<td>Low Pressure Gas Supply</td>
<td>9</td>
</tr>
</tbody>
</table>
Unanticipated difficult tracheal intubation - during routine induction of anaesthesia in an adult patient

Direct laryngoscopy

Plan A: Initial tracheal intubation plan

1. Direct laryngoscopy - check:
   - Neck flexion and head extension
   - Laryngoscope technique and vector
   - External laryngeal manipulation - by laryngoscopist
   - Vocal cords open and immobile
   - If poor view: introducer (bougie) - seek clicks or hold-up and/or Alternative laryngoscope

2. Convert to definitive airway as soon as possible

3. These techniques can have serious complications - use only on life-threatening situations

Notes:
1. Technique can have serious complications - use only in life-threatening situations
2. Convert to definitive airway as soon as possible
3. Postoperative management - see other difficult airway guidelines and flow-charts
4. Mannitol with low-pressure ventilation may be successful in patient breathing spontaneously

Plan B: Secondary tracheal intubation plan

1. Confirm ventilation of lungs, and exhalation
2. Commence cautious ventilation
3. Confirm tracheal position by air aspiration
4. Maintain position of cannula - assistant’s hand
5. Insert cannula through cricothyroid membrane

Plan C: Maintenance of oxygenation, ventilation, postponement of surgery and awakening

1. Failed intubation, increasing hypoxaemia and difficult ventilation (other than laryngoscopy)
2. Failed intubation and difficult ventilation (other than laryngoscopy)
3. Use face mask, oxygenate and ventilate
4. Postpone surgery and awakening

Plan D: Rescue techniques for “can’t intubate, can’t ventilate” situation

1. Cannula cricothyroidotomy
2. Surgical cricothyroidotomy

Notes:
1. Cannula cricothyroidotomy
2. Surgical cricothyroidotomy

Difficult Airway Society Guidelines Flow-chart 2004 (use with DAS guidelines paper)

By Adam Hollingworth
Pre-Oxygenation

Functional Residual Capacity
- FRC = major oxygen store within body
- FRC = balance between tendency of chest wall to spring outwards and tendency of lung to collapse
- Volume changes by many factors:
  - Decreasing factors:
    - Age
    - Posture - supine
    - Anaesthesia - mm relaxants - diaphragm tone will ↓pull away from lungs
    - Pregnancy - ↑abdo pressure
    - Surgery - laprasocpic
    - Pulmon fibrosis
    - Pulmon oedema
    - Obesity
    - Abdo swelling
  - Increasing factors:
    - ↑ing height
    - Erect position
    - Emphysema - less elastic recoil of lungs
    - Asthma - air trapping

Preoxygenation
- = breathing 100% O2 from close fitting mask for 3-5mins (or 4 vital capacity breaths)
- Aim is to denitrogenate lungs ➞ oxygenation of FRC >1800mls O2
- ↑time to desaturation of 7-8mins
- Best way to measure effectiveness of preoxygenation is measure ET O2 fraction (FEO2)
  - FEO2 ≈ FAO2 (alveolar o2 fraction)
  - use alveolar gas equation to understand % of O2 in lung:
    - 149 - 40/0.8 = 100mmHg
    - 100mHg as percentage of 1atmosphere (760mmHg) = 100/760 x 100 = 13%
  - ⊴. Typical FRC volume = 2.2 litres which in RA contains 13% O2 = 270mls O2
- In norm adult with complete preoxygenation (FAO2 >0.9) lungs should contain around 2000ml O2
- Total body oxygen consumption ≈ 250mls/min
  - ⊴. apnoea with norm store takes ~1min (270/250)
- If FRC preoxygenated with FiO2 1:
  - 760 -47 - (40/0.8) = 663
  - 663/760 x 100 = 0.87
  - 2200*0.87 = 1914mls
  - 1914/250 = 7.65mins

Co2 in Preoxygenation
- Amount Co2 entering alveoli is considerably less
- Co2 more water soluble than O2
  - ⊴. 10% of CO2 produced every minute reaches alveolar space
    - 200mls * 0.1 = 20mls
    - remaining 90% remains dissolved in tissues

Apnoeic Mass-Movement Oxygenation
- apnoic patient breathing RA:
  - alveolar gas composition reaches equilibirum with mixed venous blood within minutes
  - @equilibrium point:
    - ignoring changes to composition of reciculating mixed venous blood:
      - PAO2 fall to ~40mmHg
• PACO2 rise to ~ 46mmHg
  ○ Changes correspond to content changes of:
    ▪ ~230-250mlO2/min uptake
    ▪ ~21ml CO2/min output
    ⇣ difference is because 90% CO2 diverted to body stores
  ○ post equilibirum:
    ▪ As CO2 body stores fill will see a slow rise in PACO2 of ~3-6mmHg/min
    ⇣ in mixed venous, PaCO2, PACO2 values all remain v similar
    ▪ PAO2 will steadily fall towards mixed venous values as recirculating mixed venous uptakes O2
    ▪ Lung volume will fall by difference of:
      * O2 uptake (230ml/min) MINUS
      * CO2 output ~21ml/min
      ⇣ = ~209ml/min
• What happens next depends on patency of airway and FiO2

Room Air & Obstructed Airway
• Assuming tidal breathing (around FRC)
• Gross hypoxia occur @ 90seconds:
  ○ PAO2 rapid equilibriates with mixed venous value within a minut
  ○ FRC is being used at 230ml/min (norm FRC O2 content @RA = 0.21x (30ml/kg)

Room Air & Patent Airway
• Same as with an obstructed airway but instead of lung volume falling at 209ml/min air is entrained down trachea due to mass movement down pressure gradient
• O2 entrained in the air (21%) is rapidly removed leaving N2 to accumulate & rise above norm 79%
• Resultant hypoxia ~ 2mins

FiO2 100% & patent Airway
• Same as above but 100% O2 is entrained
  ∴ no N2 is added and the PAO2 will only fall as fast as the PACO2 rises ie 3-6mmHg/min
• if preoxygenated prior to apnoea – starting PAO2 = 660mmHg
• ∴ theoretically take up to 100min before pt become hypoxic
  ⇣ as long as airwya open and connected to 100% O2

By Adam Hollingworth
Gas Laws

- Daltons Gas Law = total pressure exerted by the mixture of non reactive gases is equal to the sum of partial pressures of individual gases

Terminology

- Mixed venous blood = mixture of all systemic venous blood draining from all tissue capillary beds of body (including myocardium)
- Venous admixture = the amount of mixed venous blood that would have to be added to pulmonary end-capillary blood to produce the observed drop in arterial PO2 (PaO2) from the PO2 in the end-capillary blood (Pc'O2)
- Shunt = refers to blood entering arterial system without passing through ventilated lung
  → can be:
    - Anatomical shunt
    - Physiological
    - Pathological shunt
- Hypoxaemia = presence of abnormally low PO2 levels in arterial blood (<90mmHg)
- Hypoxia:
  - = presence of tissue levels of PO2 low enough to interfere with normal tissue function ie oxidative phosphorylation stops
  - Causes:
    - Hypoxic hypoxia = low blood PO2 ie hypoxaemia from lung disease
    - Anaemic hypoxia = inadequate DO2 by Hb due to anaemia/C0 poisoning
    - Circulatory hypoxia = inadequate DO2 due to cardiovascular causes
    - Histotoxic hypoxia = eg poisoning of cytochromes in electrotransfer chains by cyanide

Oxygen

Pharmacology

- Molecular weight of oxygen = 15.9 .. O2 = 32
  [Solid < -213 C]
- Melting point = -213 C
  [Liquid]
- Boiling point = -183 degC
  (boiling point = temp at which Saturated vapour pressure (SVP) = Atmospheric pressure (P_P ATM))
  [Gas]
- Critical temp = -118 C
  → cannot be liquified above this temp no matter how much pressure (P)
- Specific gravity=
  - Liquid O2 = 1.1
  - Gaseous O2 = 1.4
- O2 under high pressure will cause ignition ie it supports combustion
  → critical pressure = 50 bar

Production

- Fractional distillation of liquid air
  - N2 comes off first
  - Most common method for hospital use
  - O2 supplied as liquid
O2 concentrator:
- Extracts O2 from air
- Passed under pressure through column of zeolite
- Zeolite acts molecular sieve which traps N2 & water vapour ⇒ leaving O2 & trace gases
- Produces continuous supply O2 >90% O2

Electrolysis of water

Brin Process:
- Heat Barium oxide (BaO) to 500 deg C ⇒ barium peroxide (BaO2)
- Further heating to 800 C ⇒ BaO and O
  → not used commercially anymore

Oxygen Storage
- can be stored as a:
  - gas:
    - stored as gas in black cylinders with white shoulders
    - stored at 137 bar
  - liquid:
    - in a vacuum insulated evaporator (VIE):
      - rests on 3 legs - 2 are hinged while 3rd acts as a weighing device enabling contents to be displayed on dial
      - 10bar & -180C
      - this must be located outside

Oxygen Measurement
- depends on sample type:
  - mixture of gases = various methods:
    - mass spectrometer
    - paramagnetic analyser
    - fuel cell
  - dissolved in blood:
    - Clarke electrode
    - transcutaneous electrode
    - pulse oximetry
  - in vitro blood sample:
    - bench
    - co-oximetry

Effects of Oxygen
- CVS:
  - used to correct hypoxia ⇒ improvement of all CVS parameters
  - hyperoxaemia or prolonged 100% O2:
    - directly slight ↓ CO
    - coronary artery vasoC
    - ↓ pulmon vasc resistance ⇒ ↓ pulmon artery pressure
- resp:
  - in healthy: high conc ⇒ mild resp depression
  - pts with hypoxic drive - modest amount may remove vent drive

Toxicity of Oxygen
- caused by free radicals
- if pp >200KPa free radicals can cause:
  - CNS: anxiety, nausea, seizures
  - lung: alveolar capillary membrane lipid peroxidation ⇒ regional atelectasis
• neonates: retrolental fibroplasia - due to vasoC of retinal vessels during development

Oxygen Equipment
• O2 can be administered as
  • partial supplement to Vt or MV
  • Entire source of inspired volume

Variable Performance (or Low Flow)
• O2 form portion of inspired gas
• Intended for pts with stable breathing patterns
• Variable amounts of room air will be entrained as ventilatory demands change
• These systems adequate for:
  • MV <8-10L/min
  • RR <20/min
  • Vt <800mls
  • Norm insp flow rate 10-30L/min

Examples:

<table>
<thead>
<tr>
<th>O2 flow rate(l/min)</th>
<th>FiO2 range (%O2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21 - 24</td>
</tr>
<tr>
<td>2</td>
<td>23 - 28</td>
</tr>
<tr>
<td>3</td>
<td>27 - 34</td>
</tr>
<tr>
<td>4</td>
<td>31 - 38</td>
</tr>
<tr>
<td>-6</td>
<td>32 - 44</td>
</tr>
</tbody>
</table>

2. Simple mask (eg Hudson) ⇒ 5-6 30 – 45
-8 40 - 60
3) Masks with reservoirs ⇒ 5 35 – 50
-8 40 - 60
4) Partial rebreathing mask-bag ⇒ 7 35 – 75
15 65 - 100
5) Non-rebreathing mask-bag ⇒ 7 – 15 40 – 100
6) Venturi masks/Jet nebulizers ⇒ 4-6(total=15) 24
4-6(tot=45) 28
8-10(tot=45) 35
8-10(tot=33) 40
8-12(tot=33) 50

Fixed Performance or High Flow
• O2 form whole of inspired gas
• Delivered O2 is not effected by change in ventilatory demands
• Eg anaesthetic breathnign circuits, O2 tents
• Profound dyspnocic/hypoxic pts need:
  • 100% O2
  • flows >100L/min
Medical Gases

Bulk Flows
- = low pressure system ie 4bar (50Psi, 400kPa)
  - Oxygen: as above
    - stored outside hospital
    - O2 in VIE as above
  - N2O:
    - delivered in standard tanks & supplied through medical gas system
  - Carbon dioxide:
  - Medical air:
    - supplied via special air compressor using clean outside air
    - pressure up to 7bar/55psi
  - Medical vacuum:
    - powered by various vacuum pump systems exhausting to the atmosphere
    - generally vacuum system in hospital
    - continuous vacuum maintained at 22inches of mercury

Gas Cylinders
- = high pressure system
  - cylinders made from molybdenum steel
  - Types:
    - H type
      - = free standing, attached to anaesthetic machine by flexible hose
      - hose should be regulated at 50psi by regulator at cylinder end
      - big & ↓mobility of anaesthetic machine
    - E type:
      - attached directly to anaesthetic machine via a yoke
  - Sizes:
    - E:
      - O2 = 680 litres
      - N2O = 1800 litres
    - J:
      - O2 = 6800 litres
      - N2O 18000 litres
  - O2 stored entirely as a gas at 137 bar or 13,700kPa
  - N2O stored as part liquid & vapour
    - vapour max pressure = 4400kPa
  - gas specific pin index system means cylinders cannot be connected to incorrect valves on anaesthetic machine
    - same with regulators fitting directly to cylinder
  - Cylinder contents:
    - O2 gauge is accurate as is stored completely as a gas ie amount in cylinder proportional to pressure
    - N2O:
      - as is mixture of liquid & vapour pressure will remain relatively high until all liquid used up
      - then see sudden drop in pressure dial
      - only way to accurately measure content is by weighing

By Adam Hollingworth
Hazards
• high pressure cylinders \(\Rightarrow\) hazards:
  ‣ unsecured cylinders:
    - direct injury to person
    - explosive decompression if valve breaks off \(\Rightarrow\) cylinder becomes a lethal projectile
    - all cylinders must be secured to something
  ‣ fire/explosion risk due to oxidising ability of O2 or N2O - no grease in connectors
  ‣ incorrect identification of cylinder contents

Regulators
• regulator function =
  ‣ reducing valve
  ‣ convert variable high pressure gas supply into constant low pressure supply around 400kPa (4bar)
• advs of low pressure system in anaesthetic machine:
  ‣ easier & safer to manufacture pipe work in machine
  ‣ eliminates need to constantly adjust flowmeter as cylinder pressure falls
  ‣ better control of flow: flowmeters for larger for given flow rate \(\therefore\) less prone to inaccuracy

![](image)

• gas flows out of low pressure chamber LP
• \(\downarrow\) pressure in LP \(\Rightarrow\) \(\downarrow\) pressure of diaphragm on spring
• \(\Rightarrow\) spring pushes valve (V) down \(\Rightarrow\) valve opening
• \(\Rightarrow\) gas from high pressure chamber \(\Rightarrow\) LP
• output pressure adjusted by screw which alters force placed on spring

• limitations:
  ‣ regulated low pressure will only remain to a min pressure in cylinder
  ‣ problems if operator compensates by opening flow control then replaces to full cylinder \(\Rightarrow\) sudden very high pressure output \(\Rightarrow\) risk of barotraume

• 2 stage regulators:
  ‣ use 2 regulators in series \(\Rightarrow\) allows finer control of output pressure
    \(\Leftarrow\) expensive, not generally used to connect to anaesthetic machine
  ‣ essentially used clinically with oxygen flow meters (max flow 15L/min) for connection directly to pt
    \(\Leftarrow\) should not be used with anaesthetic machine as inadequate flow for vent/quick flush

Low Pressure Gas Supply
• carries gas from the regulator to the
  ‣ flowmeter
  ‣ quick flush valve
  ‣ ventilator
• under pressure of 400kPa or 4bar
• may take form of:
  ‣ bulk gas flow: hard plumbing - copper or compression connectors
  ‣ flexible hose - from cylinders downstream of regulator
• hazards:
  ‣ leaks are common - should be repaired asap
  ‣ fires & explosions can be caused by oxidising ability of O2 & N2O \(\therefore\) no grease should be used in connections
• cross connections - should be prevented by specific fitting gas connectors
• hypoxic gas mixtures:
  - most machines have fail safe which switches off N2O is O2 supply fails
  - audible & visual alarm for O2 pressure failure