

# 11.Resp Miscellaneous

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# CICO Drills

Unanticipated difficult tracheal intubation - during routine induction of anaesthesia in an adult patient

Direct laryngoscopy → Any problems → Call for help

## Plan A: Initial tracheal intubation plan

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

Not more than 4 attempts, maintaining:  
(1) oxygenation with face mask and  
(2) anaesthesia

→ succeed →

Tracheal intubation

Verify tracheal intubation  
(1) Visual, if possible  
(2) Capnograph  
(3) Oesophageal detector  
"If in doubt, take it out"

failed intubation

## Plan B: Secondary tracheal intubation plan

ILMA™ or LMA™  
Not more than 2 insertions  
Oxygenate and ventilate

→ succeed →

Confirm: ventilation, oxygenation, anaesthesia, CVS stability and muscle relaxation - then fiberoptic tracheal intubation through IMLA™ or LMA™ - 1 attempt  
If LMA™, consider long flexometallic, nasal RAE or microlaryngeal tube  
Verify intubation and proceed with surgery

failed oxygenation (e.g. SpO<sub>2</sub> < 90% with FiO<sub>2</sub> 1.0) via ILMA™ or LMA™

failed intubation via ILMA™ or LMA™

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

Revert to face mask  
Oxygenate and ventilate  
Reverse non-depolarising relaxant  
1 or 2 person mask technique (with oral ± nasal airway)

→ succeed →

Postpone surgery  
Awaken patient

failed ventilation and oxygenation

## Plan D: Rescue techniques for "can't intubate, can't ventilate" situation

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

Failed intubation, increasing hypoxaemia and difficult ventilation in the paralysed anaesthetised patient: Rescue techniques for the "can't intubate, can't ventilate" situation

failed intubation and difficult ventilation (other than laryngospasm)

Face mask  
Oxygenate and ventilate patient  
Maximum head extension  
Maximum jaw thrust  
Assistance with mask seal  
Oral ± 6mm nasal airway  
Reduce cricoid force - if necessary

failed oxygenation with face mask (e.g. SpO<sub>2</sub> < 90% with FiO<sub>2</sub> 1.0)

call for help

→ succeed →

Oxygenation satisfactory and stable: Maintain oxygenation and awaken patient

"can't intubate, can't ventilate" situation with increasing hypoxaemia

## Plan D: Rescue techniques for "can't intubate, can't ventilate" situation

**Cannula cricothyroidotomy**  
Equipment: Kink-resistant cannula, e.g. Palfi (Cook) or Ravussin (VBM)  
High-pressure ventilation system, e.g. Manujet III (VBM)  
Technique:  
1. Insert cannula through cricothyroid membrane  
2. Maintain position of cannula - assistant's hand  
3. Confirm tracheal position by air aspiration - 20ml syringe  
4. Attach ventilation system to cannula  
5. Commence cautious ventilation  
6. Confirm ventilation of lungs, and exhalation through upper airway  
7. If ventilation fails, or surgical emphysema or any other complication develops - convert immediately to surgical cricothyroidotomy

**Surgical cricothyroidotomy**  
Equipment: Scalpel - short and rounded (no. 20 or Minitrach scalpel)  
Small (e.g. 6 or 7 mm) cuffed tracheal or tracheostomy tube  
4-step Technique:  
1. Identify cricothyroid membrane  
2. Stab incision through skin and membrane  
Enlarge incision with blunt dissection (e.g. scalpel handle, forceps or dilator)  
3. Caudal traction on cricoid cartilage with tracheal hook  
4. Insert tube and inflate cuff  
Ventilate with low-pressure source  
Verify tube position and pulmonary ventilation

fail →

Notes:  
1. These techniques 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. 4mm cannula with low-pressure ventilation may be successful in patient breathing spontaneously

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



Unanticipated difficult tracheal intubation - during rapid sequence induction of anaesthesia in non-obstetric adult patient

Direct laryngoscopy → Any problems → Call for help

## Plan A: Initial tracheal intubation plan

Pre-oxygenate  
Cricoid force: 10N awake → 30N anaesthetised  
Direct laryngoscopy - check:  
Neck flexion and head extension  
Laryngoscopy technique and vector  
External laryngeal manipulation - by laryngoscopist  
Vocal cords open and immobile  
If poor view:  
Reduce cricoid force  
Introducer (bougie) - seek clicks or hold-up and/or Alternative laryngoscope

→ succeed →

Tracheal intubation

Not more than 3 attempts, maintaining:  
(1) oxygenation with face mask  
(2) cricoid pressure and  
(3) anaesthesia

Verify tracheal intubation  
(1) Visual, if possible  
(2) Capnograph  
(3) Oesophageal detector  
"If in doubt, take it out"

failed intubation

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

Maintain 30N cricoid force

Plan B not appropriate for this scenario

Use face mask, oxygenate and ventilate  
1 or 2 person mask technique (with oral ± nasal airway)  
Consider reducing cricoid force if ventilation difficult

→ succeed →

Postpone surgery and awaken patient if possible or continue anaesthesia with LMA™ or ProSeal LMA™ - if condition immediately life-threatening

failed oxygenation (e.g. SpO<sub>2</sub> < 90% with FiO<sub>2</sub> 1.0) via face mask

LMA™  
Reduce cricoid force during insertion  
Oxygenate and ventilate

→ succeed →

## Plan D: Rescue techniques for "can't intubate, can't ventilate" situation

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



## Plan A: Initial tracheal intubation plan

Direct laryngoscopy → succeed →

Tracheal intubation

failed intubation

## Plan B: Secondary tracheal intubation plan

ILMA™ or LMA™ → succeed →

Confirm - then fiberoptic tracheal intubation through ILMA™ or LMA™

failed oxygenation

failed intubation

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

Revert to face mask  
Oxygenate & ventilate → succeed →

Postpone surgery  
Awaken patient

failed oxygenation

## Plan D: Rescue techniques for "can't intubate, can't ventilate" situation

LMA™ → improved oxygenation →

Awaken patient

increasing hypoxaemia

or

Cannula cricothyroidotomy

Surgical cricothyroidotomy

fail →



# 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 - laparoscopic
    - 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% O<sub>2</sub> from close fitting mask for 3-5mins (or 4 vital capacity breaths)
- Aim is to denitrogenate lungs ⇒ oxygenation of FRC >1800mls O<sub>2</sub>
- ↑time to desaturation of 7-8mins
- Best way to measure effectiveness of preoxygenation is measure ET O<sub>2</sub> fraction (FEO<sub>2</sub>)
  - FEO<sub>2</sub> ≈ FAO<sub>2</sub> (alveolar o<sub>2</sub> fraction)
- use alveolar gas equation to understand % of O<sub>2</sub> in lung:
  - $149 - 40/0.8 = 100\text{mmHg}$
  - 100mmHg as percentage of 1atmosphere (760mmHg) =  $100/760 \times 100 = 13\%$
- ∴ Typical FRC volume = 2.2 litres which in RA contains 13% O<sub>2</sub> = 270mls O<sub>2</sub>
- In norm adult with complete preoxygenation (FAO<sub>2</sub> >0.9) lungs should contain around 2000ml O<sub>2</sub>
- Total body oxygen consumption ≈ 250mls/min
  - ∴ apnoea with norm store takes ~1min (270/250)
- If FRC preoxygenated with FiO<sub>2</sub> 1:
  - $760 - 47 - (40/0.8) = 663$
  - $663/760 \times 100 = 0.87$
  - $2200 \times 0.87 = 1914\text{mls}$
  - $1914/250 = 7.65\text{mins}$

## Co<sub>2</sub> in Preoxygenation

- Amount Co<sub>2</sub> entering alveoli is considerably less
- Co<sub>2</sub> more water soluble than O<sub>2</sub>
  - ∴ 10% of CO<sub>2</sub> produced every minute reaches alveolar space
    - ↳  $200\text{mls} \times 0.1 = 20\text{mls}$
    - ↳ remaining 90% remains dissolved in tissues

## Apnoeic Mass-Movement Oxygenation

- apnoeic patient breathing RA:
  - alveolar gas composition reaches equilibrium with mixed venous blood within minutes
  - @equilibrium point:
    - ignoring changes to composition of recirculating mixed venous blood:
      - PAO<sub>2</sub> fall to ~40mmHg

- PACO<sub>2</sub> rise to ~ 46mmHg
- Changes correspond to content changes of:
  - ~230-250mlO<sub>2</sub>/min uptake
  - ~21ml CO<sub>2</sub>/min output
  - ↳ difference is because 90% CO<sub>2</sub> diverted to body stores
- post equilibrium:
  - As CO<sub>2</sub> body stores fill will see a slow rise in PACO<sub>2</sub> of ~3-6mmHg/min
    - ↳ in mixed venous, PaCO<sub>2</sub>, PACO<sub>2</sub> values all remain v similar
  - PAO<sub>2</sub> will steadily fall towards mixed venous values as recirculating mixed venous uptakes O<sub>2</sub>
  - Lung volume will fall by difference of:
    - O<sub>2</sub> uptake (230ml/min) MINUS
    - CO<sub>2</sub> output ~21ml/min
    - ↳ = ~209ml/min
- What happens next depends on patency of airway and FiO<sub>2</sub>

### **Room Air & Obstructed Airway**

- Assuming tidal breathing (around FRC)
- Gross hypoxia occur @ 90seconds:
  - PAO<sub>2</sub> rapid equilibrates with mixed venous value within a minut
  - FRC is being used at 230ml/min (norm FRC O<sub>2</sub> 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
- O<sub>2</sub> entrained in the air (21%) is rapidly removed leaving N<sub>2</sub> to accumulate & rise above norm 79%
- Resultant hypoxia ~ 2mins

### **FiO<sub>2</sub> 100% & patent Airway**

- Same as above but 100% O<sub>2</sub> is entrained
- ∴ no N<sub>2</sub> is added and the PAO<sub>2</sub> will only fall as fast as the PACO<sub>2</sub> rises ie 3-6mmHg/min
- if preoxygenated prior to apnoea – starting PAO<sub>2</sub> = 660mmHg
- ∴ theoretically take up to 100min before pt become hypoxic
  - ↳ as long as airway open and connected to 100% O<sub>2</sub>

# 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 PO<sub>2</sub> (PaO<sub>2</sub>) from the PO<sub>2</sub> in the end-capillary blood (Pc'O<sub>2</sub>)
- Shunt = refers to blood entering arterial system without passing through ventilated lung
  - ↳ can be:
    - Anatomical shunt
    - Physiological
    - Pathological shunt
- Hypoxaemia = presence of abnormally low PO<sub>2</sub> levels in arterial blood (<90mmHg)
- Hypoxia:
  - = presence of tissue levels of PO<sub>2</sub> low enough to interfere with normal tissue function ie oxidative phosphorylation stops
  - Causes:
    - Hypoxic hypoxia = low blood PO<sub>2</sub> ie hypoxaemia from lung disease
    - Anaemic hypoxia = inadequate DO<sub>2</sub> by Hb due to anaemia/CO poisoning
    - Circulatory hypoxia = inadequate DO<sub>2</sub> due to cardiovascular causes
    - Histotoxic hypoxia = eg poisoning of cytochromes in electrotransfer chains by cyanide

## Oxygen

### Pharmacology

- Molecular weight of oxygen = 15.9 ∴ O<sub>2</sub> = 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<sub>ATM</sub>))

[Gas]

- Critical temp = - 118 C

↳ cannot be liquified above this temp no matter how much pressure (P)

- Specific gravity=

- Liquid O<sub>2</sub> = 1.1
- Gaseous O<sub>2</sub> = 1.4

- O<sub>2</sub> under high pressure will cause ignition ie it supports combustion

↳ critical pressure = 50 bar

### Production

- Fractional distillation of liquid air
  - N<sub>2</sub> comes off first
  - Most common method for hospital use
  - O<sub>2</sub> supplied as liquid

- O<sub>2</sub> concentrator:
  - Extracts O<sub>2</sub> from air
  - Passed under pressure through column of zeolite
  - Zeolite acts molecular sieve which traps N<sub>2</sub> & water vapour ⇒ leaving O<sub>2</sub> & trace gases
  - Produces continuous supply O<sub>2</sub> >90% O<sub>2</sub>
- Electrolysis of water
- Brin Process:
  - Heat Barium oxide (BaO) to 500 deg C ⇒ barium peroxide (BaO<sub>2</sub>)
  - 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% O<sub>2</sub>:
    - 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

- O<sub>2</sub> can be administered as
  - partial supplement to V<sub>t</sub> or MV
  - Entire source of inspired volume

### Variable Performance (or Low Flow)

- O<sub>2</sub> 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
  - V<sub>t</sub> <800mls
  - Norm insp flow rate 10-30L/min

Examples:

|                                      | O <sub>2</sub> flow rate(l/min) | FiO <sub>2</sub> range (%O <sub>2</sub> ) |
|--------------------------------------|---------------------------------|---|
| 1) Nasal prongs: ⇒                   | 1                               | 21 - 24                                   |
|                                      | 2                               | 23 - 28                                   |
|                                      | 3                               | 27 - 34                                   |
|                                      | 4                               | 31 - 38                                   |
|                                      | -6                              | 32 - <b>44</b>                            |
| 2. Simple mask (eg <b>Hudson</b> ) ⇒ | 5-6                             | 30 - 45                                   |
|                                      | -8                              | 40 - <b>60</b>                            |
| 3) Masks with reservoirs ⇒           | 5                               | 35 - <b>50</b>                            |
| 4) Partial rebreathing mask-bag ⇒    | 7                               | 35 - <b>75</b>                            |
|                                      | 15                              | 65 - <b>100</b>                           |
| 5) Non-rebreathing mask-bag ⇒        | 7 - 15                          | 40 - <b>100</b>                           |
| 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

- O<sub>2</sub> form whole of inspired gas
- Delivered O<sub>2</sub> is not effected by change in ventilatory demands
- Eg anaesthetic breathnign circuits, O<sub>2</sub> tents
- Profound dyspnoeic/hypoxic pts need:
  - 100% O<sub>2</sub>
  - flows >100L/min

# Medical Gases

## Bulk Flows

- = **low pressure system ie 4bar (50Psi, 400kPa)**
- Oxygen: as above
  - stored outside hospital
  - O<sub>2</sub> in VIE as above
- N<sub>2</sub>O:
  - 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:
    - O<sub>2</sub> = 680 litres
    - N<sub>2</sub>O = 1800 litres
  - J:
    - O<sub>2</sub> = 6800 litres
    - N<sub>2</sub>O 18000 litres
- O<sub>2</sub> stored entirely as a gas at 137 bar or 13,700kPa
- N<sub>2</sub>O 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:
  - O<sub>2</sub> gauge is accurate as is stored completely as a gas ie amount in cylinder proportional to pressure
  - N<sub>2</sub>O:
    - 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

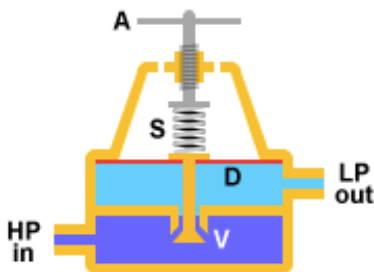


## Hazards

- 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 O<sub>2</sub> or N<sub>2</sub>O - 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



- 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
    - $\hookrightarrow$  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
    - $\hookrightarrow$  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 O<sub>2</sub> & N<sub>2</sub>O  $\therefore$  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 N<sub>2</sub>O if O<sub>2</sub> supply fails
  - audible & visual alarm for O<sub>2</sub> pressure failure