By Adam Hollingworth

11.Resp Miscellaneous

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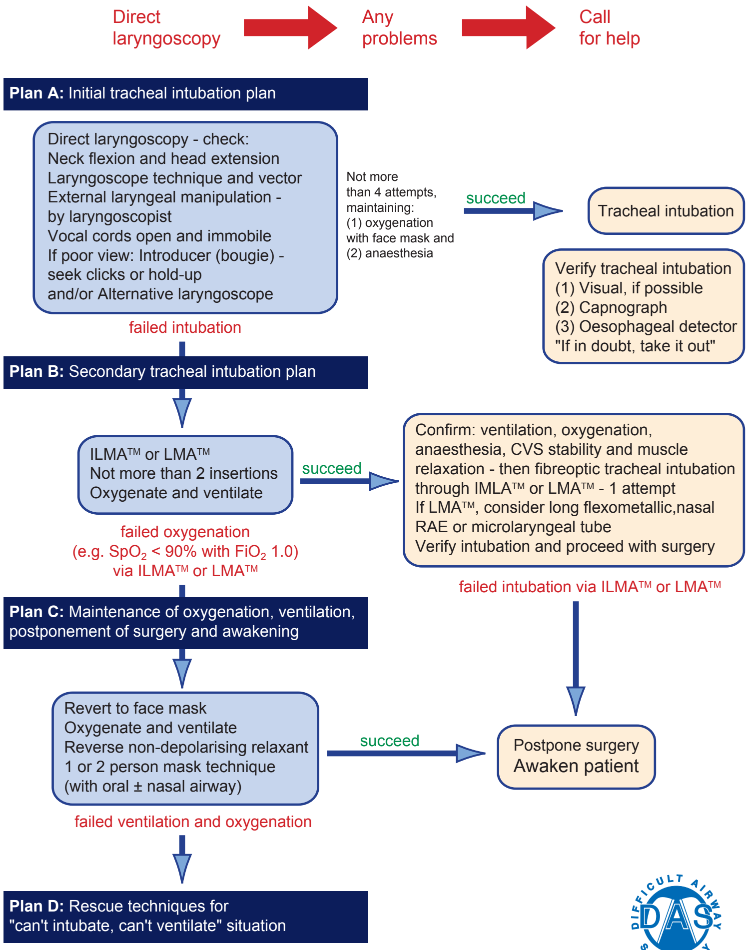
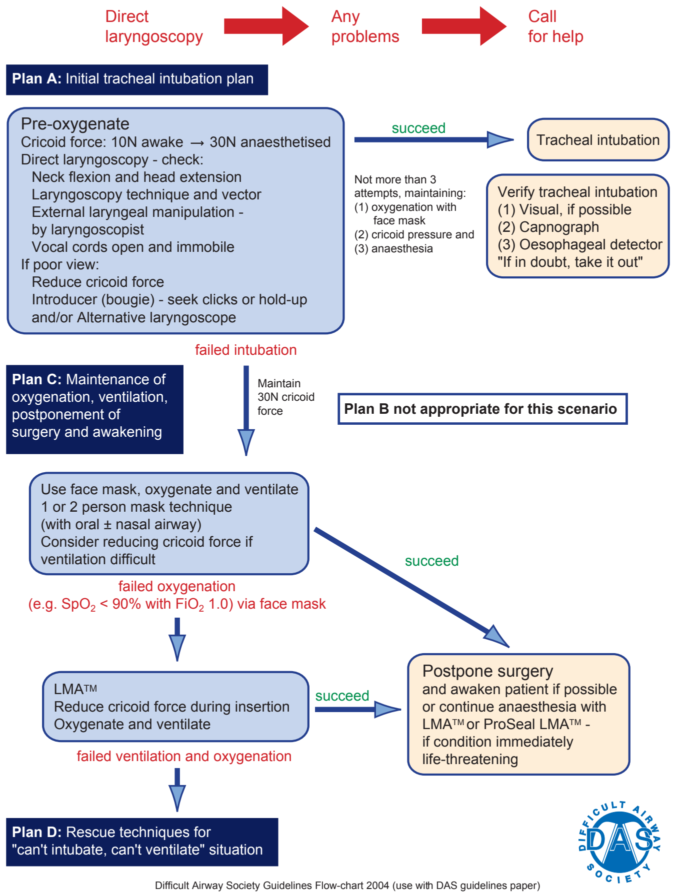
CICO Drills

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



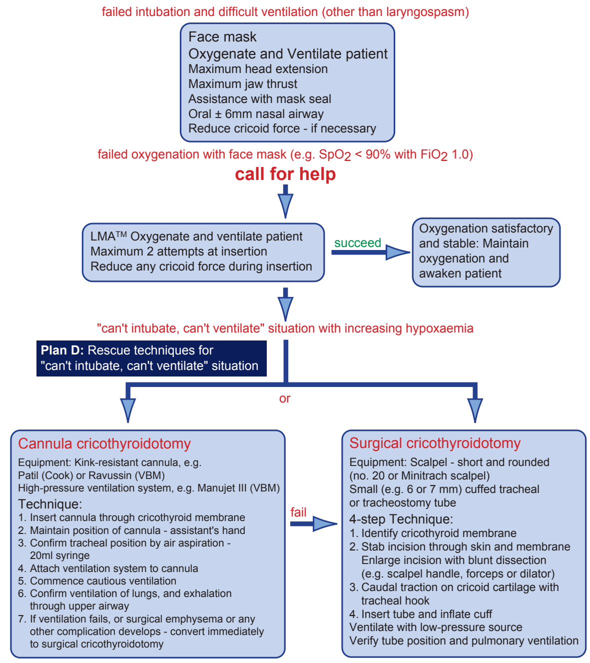
Difficult Airway Society Guidelines Flow-chart 2004 (use with DAS guidelines paper)

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



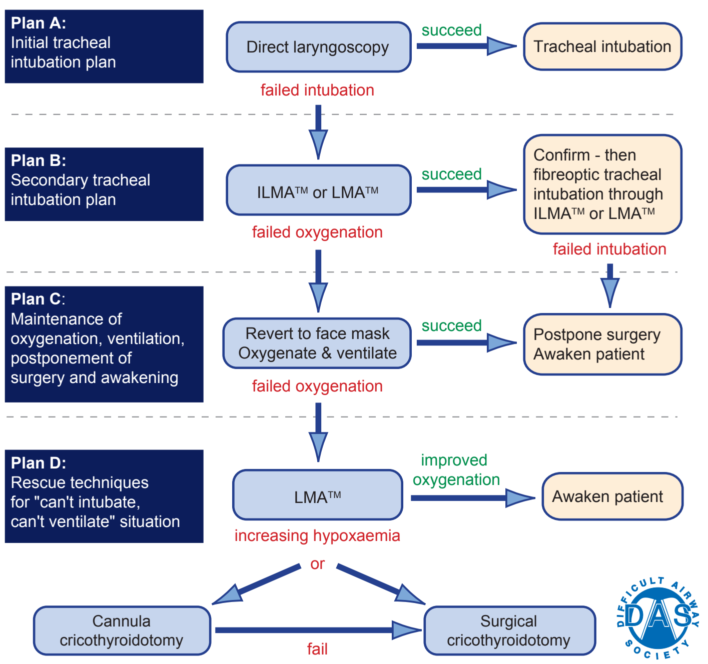
Difficult Airway Society Guidelines Flow-chart 2004 (use with DAS guidelines paper)

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



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)



Pre-Oxygenation

Functional Residual Capacity

- FRC = major oxygen store within body
- FRC = balance between tendeancy 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

- apnoeic 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

            - $PACO_2$ rise to ~ 46mmHg
    - Changes correspond to content changes of:
        - ~230-250mlO_2/min uptake
        - ~21ml CO_2/min output
        ↳ difference is because 90% CO_2 diverted to body stores
    - post equilibirum:
        - As CO_2 body stores fill will see a slow rise in $PACO_2$ of ~3-6mmHg/min
            ↳ in mixed venous, $PaCO_2$, $PACO_2$ values all remain v similar
        - PAO_2 will steadily fall towards mixed venous values as recirculating mixed venous uptakes O_2
        - Lung volume will fall by difference of:
            - O_2 uptake (230ml/min) MINUS
            - CO_2 output ~21ml/min
            ↳ = ~209ml/min
- What happens next depends on patency of airway and FiO_2

Room Air & Obstructed Airway

- Assuming tidal breathing (around FRC)
- Gross hypoxia occur @ 90seconds:
    - PAO_2 rapid equilibriates with mixed venous value within a minut
    - FRC is being used at 230ml/min (norm FRC O_2 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_2 entrained in the air (21%) is rapidly removed leaving N_2 to accumulate & rise above norm 79%
- Resultant hypoxia ~ 2mins

FiO_2 100% & patent Airway

- Same as above but 100% O_2 is entrained
- ∴ no N_2 is added and the PAO_2 will only fall as fast as the $PACO_2$ rises ie 3-6mmHg/min
- if preoxygenated prior to apnoea – starting PAO_2 = 660mmHg
- ∴ theoretically take up to 100min before pt become hypoxic
    ↳ as long as airwya open and connected to 100% O_2

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 capilary 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 = indequate DO2 by Hb due to anaemia/CO 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_{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

- O_2 concentrator:
  - Extracts O_2 from air
  - Passed under pressure through column of zeolite
  - Zeolite acts molecular sieve which traps N_2 & water vapour ⟹ leaving O_2 & trace gases
  - Produces continuous supply O_2 >90% O_2
- Electrolysis of water
- Brin Process:
  - Heat Barium oxide (BaO) to 500 deg C ⟹ barium peroxide (BaO_2)
  - 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_2:
    - 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 perioxidation ⟹ 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:

	O2 flow rate(l/min)	FiO2 range (%O2)
1) Nasal prongs: ⇒	1	21 - 24
	2	23 - 28
	3	27 - 34
	4	31 - 38
	-6	32 - **44**
2. Simple mask (eg **Hudson**) ⇒	5-6	30 – 45
	-8	40 - **60**
3) Masks with reservoirs ⇒	5	35 – **50**
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 dyspnoeic/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

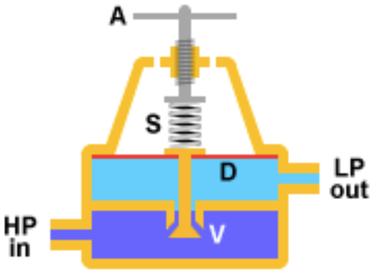
- = **high pressure system**
- cylinders made from molybdenum steel
- types:
  - H type
    - = free standing, attached to anaesthetic machine by flexible hose
    - hose should be regulated at 50psi by regulator at cylinder end
    - big & ↓mobility of anaesthetic machine
  - E type:
    - attached 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

Hazards

- high pressure cylinders ⟹ hazards:
  - unsecured cylinders:
    - direct injury to person
    - explosive decompression if valve breaks off ⟹ cylinder becomes a lethal projectile
    - all cylinders must be secured to something
  - fire/explosion risk due to oxidising ability of O_2 or N_2O - 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 ∴ less prone to inaccuracy



- gas flows out of low pressure chamber LP
- ↓pressure in LP ⟹ ↓pressure of diaphragm on spring
- ⟹ spring pushes valve (V) down ⟹ valve opening
- ⟹ gas from high pressure chamber ⟹ 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 ⟹ sudden very high pressure output ⟹ risk of barotraume
- 2 stage regulators:
  - use 2 regulators in series ⟹ allows finer control of output pressure
    - ↳ 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
    - ↳ 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 cyclinders downstream of regulator
- hazards:
  - leaks are common - should be repaired asap
  - fires & explosions can be caused by oxidising ability of O_2 & N_2O ∴ 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_2O is O_2 supply fails
  - audible & visual alarm for O_2 pressure failure