

Airway

Management

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www.developinganaesthesia.org

Welcome to www.developinganaesthesia.org. This web site has been created to promote the advancement of anaesthetic practice and to empower anaesthetists in countries with limited resources. The site also hopes to foster the growth of an online community of anaesthetists throughout the world.

A web-based resource has significant advantages. The information provided can remain current and be tailored to the requirements of the community. Hard copy texts may be expensive, difficult to access and inappropriate to the delivering of anaesthesia outside of tertiary institutions. The majority of journals have similar limitations.

DevelopingAnaesthesia.org is a free, up to date resource, specifically designed to address these problems.

The authors envisage the web site will have five principle functions, though the dynamic nature of web publishing will allow the evolution of the site as directed by the anaesthesia community.

- **1. Continuing education**
DevelopingAnaesthesia.org will provide an anaesthetic educational resource for anaesthetists. The site contains a textbook, articles, case studies and links. with time the site will contain power point and video presentations.
- **2. Anaesthetic training**
DevelopingAnaesthesia.org will provide an anaesthetic educational resource for anaesthetic trainees. The site will contain lecture notes for physiology, pharmacology, equipment, monitoring and statistics.
- **3. Teach the teacher**
DevelopingAnaesthesia.org will provide a resource to aid anaesthetists in educational methods.
- **4. Peer-reviewed publication**
DevelopingAnaesthesia.org will provide a venue for peer-reviewed publication online at no cost to authors or readers. All submitted material (case studies, articles, audits etc) is welcomed and encouraged.
- **5. Discussion forums**
DevelopingAnaesthesia.org has an open forum for discussion, exchange of ideas/experience and seeking advice. A panel of anaesthetists with experience in delivering anaesthesia and teaching in developing countries will moderate the forum but colleges in similar countries may provide the most relevant advice.

Success and the growth of www.developinganaesthesia.org will depend on feedback from the anaesthetic community it serves. Please have a look at the site and register as a user, there is no cost. Registration allows you to participate in forum discussions, submit your own articles and comments and in doing so help foster community growth.

RECOGNISING THE DIFFICULT AIRWAY

Why examine the airway?

Before anaesthetising or sedating any patient it is essential to examine the airway. Failure to adequately manage the airway can lead to hypoxia, brain damage and death. Failed airway management accounts for up to 30 % of perioperative deaths due to anaesthesia.

Failure to adequately evaluate the airway and to predict airway difficulty is the most important factor leading to a failed airway.

The challenge for the anaesthetist is to

- Accurately predict all difficult airways,
- Immediately recognise airway failure and
- Reliably secure continuous gas exchange

Airway management techniques.

There are four basic ventilation techniques that may be used alone or in combination for ensuring adequate gas exchange.

1. Bag mask ventilation (BMV).
2. Laryngoscopy/Endotracheal tubes
3. Supraglottic airway devices
4. Surgical airway

Complete airway assessment must not be restricted to assessing only the ease of laryngoscopy and endotracheal intubation. It must also evaluate the ease/difficulty of bag mask ventilation, supraglottic airway ventilation and performing a surgical airway.

Difficult airway ventilation.

Difficult facemask ventilation is defined as the inability of a trained anaesthetist to maintain a patient's oxygen saturation above 90% by using facemask ventilation.

Approximately 5 % of patients may be difficult to bag and mask. The incidence of difficult mask ventilation requiring a two-person technique was found to be 1.4%, and the incidence of impossible mask ventilation was 0.16% (22,660 cases).

Difficult intubation is defined as an inability to place an endotracheal tube within 10 minutes or 3 attempts at direct laryngoscopy.

Grade 3 laryngoscopic views, requiring multiple attempts at intubation, occur in 1-13 % of all patients. Severe Grade 3 to 4 views making intubation extremely difficult, are estimated to occur in 0.05-0.09 %.

Impossible intubation has been estimated in 0.05% - 0.35% and the ultimately dangerous situation of can't intubate, can't ventilate (CICV) to occur in 0.0001% - 0.02% of patients.

What to assess.

1. The patient
2. The case – urgency, is there a need for muscle relaxation, what is the expected duration and complexity of the case, what position will the patient be in, how easy will it be to access the patient's airway?
3. The environmental conditions – including noise, lighting, time of day,
4. Resources- people, layout of environment, location of equipment, your own experience and level of fatigue, assistance, post operative care

Difficult airway assessment.

The anaesthetist's primary responsibility is to oxygenate the unconscious patient. During any assessment of the patient for anaesthesia, ask yourself if mask ventilation is possible, will a supraglottic airway work, if tracheal intubation is possible and whether or not a surgical airway is feasible.

The patient's past medical/anaesthetic history valuable. Of particular note is a history of difficult intubation, mask ventilation or both. Symptoms of airway compromise such as, hoarseness, stridor, wheezing, dysphagia, dyspnoea and positional airway obstruction should be sought.

Ease of bag mask ventilation.

Bag mask ventilation is a basic skill required to maintain oxygenation and ventilation. Airway disasters occur from failure to ventilate, not from failure to intubate. Bag mask ventilation is the first rescue action for failed airways. All anaesthetists must be proficient in bag mask ventilation.

Assessment of bag mask ventilation is essential for every patient. Factors making bag mask ventilation more difficult include a difficult mask seal (beard, facial oedema, facial deformity/trauma/abscess, burns, radiation), obesity (BMI>26), intra-oral masses, lesions,

age >55, no teeth, a history of snoring (obstructive sleep apnoea), severely limited jaw protrusion and the addition of cricoid pressure.

Ease of ventilation with a supraglottic airway.

Supraglottic devices such as the laryngeal mask airway may be used as the primary airway management plan for anaesthesia, a bridging airway or as a rescue device for when intubation equipment or intubation skills are unavailable or in the event of difficult intubation.

Factors that may impede the use of a supraglottic airway include restricted mouth opening, airway obstruction, disrupted or distorted airway, obesity, radiation, burns, intra-oral masses (tumors, abscess, haematoma).

Ease of surgical airway.

The surgical airway (needle cricothyrotomy/open cricothyrotomy) is used mostly as a life saving technique. In some cases, elective tracheostomy may be the best choice of airway management.

A surgical airway may prove difficult if there is a distorted airway, haematoma/infection, obesity, and previous radiation therapy or tumour involvement.

Ease of laryngoscopy/intubation.

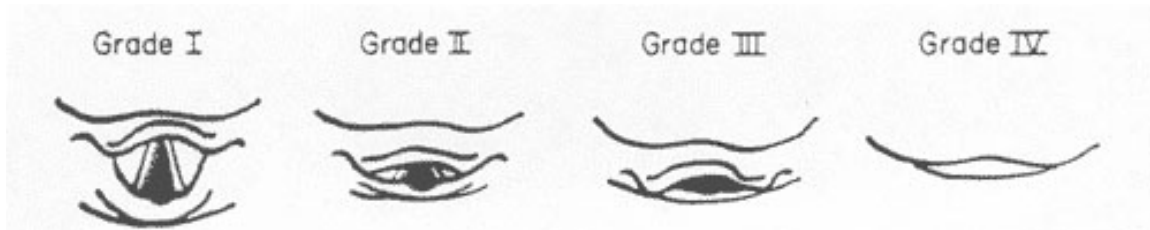
Tracheal intubation by direct laryngoscopy is an essential skill. It may be rendered more difficult or impossible due to co-existing disease or abnormal physical features. When recognized beforehand virtually all the difficult airways can be secured by the selected use of specialized airway techniques and a careful airway plan. When unrecognized, the results can be catastrophic because personnel and equipment may not be immediately available and the patient's spontaneous respiratory efforts may have been eliminated by anaesthetics or muscle relaxants.

Intubation requires mobility of the atlanto-occipital joint and temporomandibular joint. There also needs to be a line of sight from the mouth to the larynx. To achieve this, there must be sufficient space into which to displace the tongue out of the line of sight and it must be possible to move the epiglottis away from the larynx.

There are several bedside examinations to assess anatomical causes of difficult airways. Rarely, non-invasive clinical investigation may also be used. These tests try to predict how much of the larynx can be seen with laryngoscopy.

The view of the larynx is commonly graded using the Cormack and Lehane classification:

- Grade one – all of the vocal cords seen
- Grade two – partial view of the vocal cords (posterior)
- Grade three – epiglottis only
- Grade four – no view.



By themselves these examinations are very poor in prediction of difficult airways. They should be used in combination.

In a study of 10,500 patients who were assessed prospectively prior to anesthesia, and who were then graded according to the difficulty of intubation or ventilation, el Ganzouri et al (Anesth Analg 1996 Jun; 82(6): 1197-204) identified the following seven criteria as independent risk factors for difficulty with laryngoscopy; mouth opening, thyromental distance, oropharyngeal classification (Mallampati), neck movement, ability to prognath, body weight and history of difficult tracheal intubation.

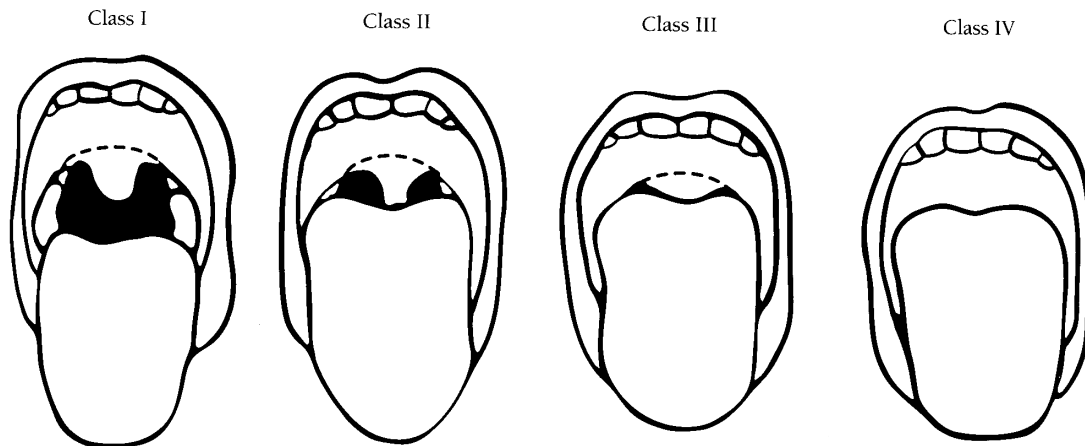
1. *Teeth* (mouth opening)- inter incisor distance (<3.5cm)
2. *Mouth and pharynx – Mallampati classification.*

The Mallampati classification is based on the fact that the base of the tongue is the source of airway obstruction in the anaesthetized patient and is in close proximity to the laryngeal inlet. A massive tongue not only overshadows the larynx but also masks the visibility of the pharyngeal space and other structures. This classification however does not take into account other anatomical factors such as limited neck mobility etc. In addition significant inter observer variability exists.

The size of the tongue in relation to the size of the oral cavity is graded by how much of the pharynx is obscured by the tongue and the visibility of the uvula.

The patient is examined whilst sitting. The head is in a neutral position. The patient opens their mouth as wide as possible and the tongue is protruded as far as possible. The patient does not phonate. The airway is classified according to what oropharyngeal structures can be seen.

Class I	Soft palate, fauces, entire uvula, tonsillar pillars
Class II	Soft palate, fauces, uvula
Class III	Soft palate, base of uvula
Class IV	Soft palate only



A critical factor in achieving a reliable score for the Mallampati classification is ensuring that the patient opens the mouth and protrudes the tongue maximally.

The Mallampati classification versus the Cormack-Lehane view on laryngoscopy linear correlation index is 0.9. A Mallampati Class 4 correlated with a Cormack-Lehane grade 3 (0.85) and Cormack-Lehane grade 4 (0.80).

3. *Neck extension* is assessed by placing one finger on the mentum and one on the occipital spine –if the finger on the occipital spine is higher or at the same level of the mentum with the head fully extended then mobility is regarded as poor. Full extension at the alanto-occipital joint should be at least 35 degrees.

4. *The thyro-mental distance* is measured from the lower border of the mentum to the thyroid notch. In the sniffing position, the critical distance is 6 cm or three finger breadths (6.5cm in some papers)

5. *The sterno-mental distance* is measured from lower border of the mentum to the sternal notch 12.5cm

6. *Anterior protrusion* of the mandibular teeth relative to the maxillary teeth.

7. *The Wilson risk sum* is calculated on the basis of five risk factors. They are, weight, head, neck and jaw movement, mandibular recession and the presence or absence of protruding teeth. Each of these is given a score from 0 to 2 and a score above 2 is considered a predictor of difficult intubation.

Risk factor	Level	score
Weight	<90 kg	0
	90-100kg	1
	>100kg	2
Head and neck movement	Above 90 degrees	0
	About 90 degrees	1
	Below 90 degrees	2
Jaw movement	IIG >5 cm or sLux >0	0
	IIG <5 cm and sLux =0	1
	IIG <5 cm and sLux <0	2
Receding mandible	Normal	0
	Moderate	1
	Severe	2
Buck teeth	Normal	0
	Moderate	1
	Severe	2

IIG = inter incisor gap, sLux = subluxation or maximal forward protrusion of the lower incisors beyond the upper incisors.

Of all of the predictors used in the Wilson risk sum, weight was the least useful of the predictors.

Predicting the difficult laryngoscopy/intubation.

Definitions:

- Sensitivity is the proportion of difficult laryngoscopies that were correctly predicted to be difficult.
- Specificity is the proportion of easy laryngoscopies that were predicted to be easy.
- Positive predictive value is the proportion of patients predicted to be difficult who proved to be difficult.
- Negative predictive value is the proportion of predicted easy intubations that actually proved to be easy.

The predictive value of all tests is poor when used alone. It has been shown in multiple studies that the sensitivity, specificity and positive predictive value are improved by combining the tests. For patients with no abnormal airway characteristics, tracheal intubation was found to be easy in 96.3% in a prospective study of over 18,000 patients. (Rose, Cohen. The airway: problems and predictions in 18,500 patients. Can J Anaesth, 1994 May; 41(5 Pt 1): 372-83.)

The weakness of all prediction studies lies in that their findings only relate to the sample from which they were derived (see appendix of several studies).

There is limited usefulness of predictive tests when the event they are trying to predict is very rare. Unless there is near 100% sensitivity and specificity, the positive and negative

predictive values will be low. Therefore, most patients who are predicted to be difficult are not.

Summary

Always question:

- Is it necessary to intubate? Does the patient need to be unconscious? Do I have adequate resources and equipment? Do I have the experience and skill to manage the airway? If not, get help before the crises occurs.

- Do I have an airway management plan?

A thorough bedside assessment of the airway will alert the anaesthetist to some cases of difficulties with intubation but not all.

Difficult intubation, especially can't intubate, can't ventilate, occurs rarely and can occur without warning.

Patients don't die of difficult laryngoscopy but they do die from hypoxia. Saturations less than 60-70% lasting longer than 3 minutes will cause harm. Always have an airway management plan. The challenge for the anaesthetist is to rapidly recognise airway failure and to maintain oxygenation by following their airway plan. Oxygenation and time are critical.

Groups at risk for difficult intubation

1. Pregnancy increases the incidence of failed intubation by up to ten fold. Difficult intubation is estimated to occur in 6.4% of patients. (Gupta et al. Comparison of two methods for prediction difficult intubation in obstetric patients. Middle East J Anesthesiol. 2003 Jun; 17(2): 275-85)

Rocke et al (Anesthesiology, 1992 Jul; 77(1): 67-73) found a significant association between difficult intubation in the obstetric patient and short neck, obesity missing maxillary incisors, protruding maxillary incisors and receding mandible.

2. Redundant pharyngeal tissue is present in obesity; sleep apnoea patients, oedema (bleeding after neck surgery), and angioedema.

3. Bony restriction may occur in rheumatoid arthritis, cervical fusion ankylosing spondylitis. Acromegaly can lead to mandibular hypertrophy and tongue or epiglottic overgrowth, as well as airway narrowing if there is enlargement of the vocal cords.

4. There is soft tissue tethering after radiation, burns, surgical scars, and with some tumours.

5. Infections of the floor of the mouth, tonsils, pharynx, and epiglottis and dental abscess will cause pain, oedema and trismus and may lead to upper airway obstruction.

6. Airway trauma can cause oedema, bleeding in to airway, and effacement of the regular anatomy and may limit the options for a surgical airway.

Clinical studies.

(Merah et al. Modified Mallampati test, thyromental distance and interincisor gap are the best predictors of difficult laryngoscopy in West Africans. *Can J Anaesth.* 2005 Mar; 52 (3): 291-6) Study of 380 consecutive patients. Difficult laryngoscopy defined as CL view of III or IV).

Test	Sensitivity	Specificity	Positive predictive value
Mallampati (III or IV)	61.5%	98.4%	57.1%
Thyromental distance (6.5cm)	15.4%	98.1%	22.2%
Sternomental distance (13.5 cm)	0%	100%	0%
Horizontal length of mandible (9cm)	30.8%	76%	4%
Interincisor gap (4 cm)	30.8%	97.3%	28.6%
Combination of Mallampati, TMD, IIG	84.6%	94.6%	35.5%

Savva (*Br J Anaesth* 1994 Aug; 73(2): 149-53) studied 350 patients prospectively and found that sternomental distance was more sensitive and more specific than thyromental distance, Mallampati test and forward protrusion of the mandible.

Test	Sensitivity	Specificity
Mallampati	64.7%	66.1%
Thyromental distance	64.7%	81.4%
Sternomental distance	82.4%	88.6%
Forward protrusion of mandible	29.4%	85%

Bilgin and Ozyurt (Anaesth Intensive Care 1998; 26:382-386) compared the Mallampati test, Wilson risk sum and thyromental distance to predict difficult intubation in 500 Turkish patients and found the incidence of difficult intubation to be 8%. The results are presented below. They concluded that the Wilson risk sum was the most sensitive test and the thyromental distance had the highest positive predictive value for difficult intubation.

Test	Sensitivity	Specificity	Positive predictive value
Mallampati Test	43%	93%	33%
Wilson risk sum	58%	91%	37%
Thyromental distance	35%	95%	39%

Shiga et al (Anesthesiology 2005 Aug; 103(2): 429-37) performed a meta analysis of bedside screening tests as predictors of difficult intubation and found the overall incidence of difficult intubation to be 5.8% with a confidence interval of 4.5-7.5% and that each screening test (Mallampati, thyromental distance, sternomental distance, mouth opening and Wilson risk score) had poor to moderate sensitivity (20-62%) and moderate to fair specificity (82-97%). They found that the most useful test for prediction was a combination of the Mallampati classification and thyromental distance and their conclusion was that combinations of tests add some incremental diagnostic value in comparison to each test alone.

REGIONAL ANAESTHESIA OF THE AIRWAY

Every anaesthetist must be able to provide regional anaesthesia of the airway. This skill is commonly used for an awake fibre-optic intubation in a patient with a predicted difficult airway however this skill is also essential when a fibre optic intubation bronchoscope is not available and the anaesthetist must determine the safest option in a patient with a suspected difficult intubation. In this situation, regional airway anaesthesia is used to allow direct awake laryngoscopy to truly assess if intubation is possible.

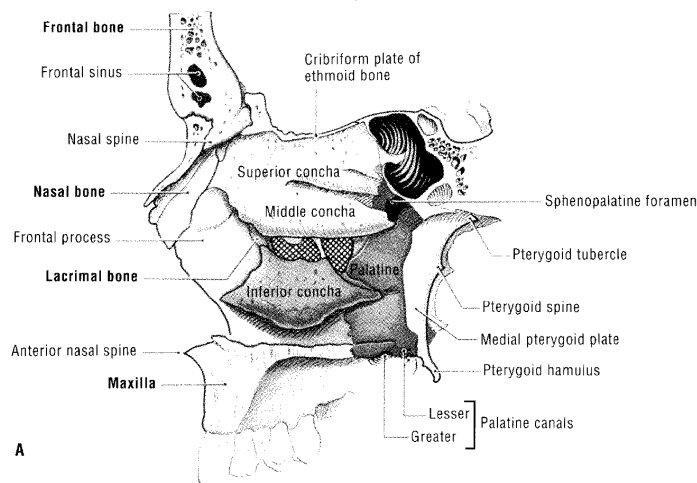
Success is dependent on attention to detail, knowledge of airway anatomy, an understanding of local anesthetic pharmacology (especially the latency of onset and maximum safe dose of local anesthetics) and careful explanation to the patient.

Anatomy.

The airway consists of the oral and nasal cavities, pharynx, larynx and trachea.

Nose.

Each nasal cavity has a floor, roof, and lateral and medial wall (nasal septum). The lateral wall has three horizontal ridges that project medially (turbinates). The major nasal airway is located below the inferior nasal turbinate that declines slightly (20 degrees) from front to back. The floor of the nose extends posteriorly in a transverse plane. Therefore, a nasal endotracheal tube should be directed backwards and slightly inferiorly along the floor of



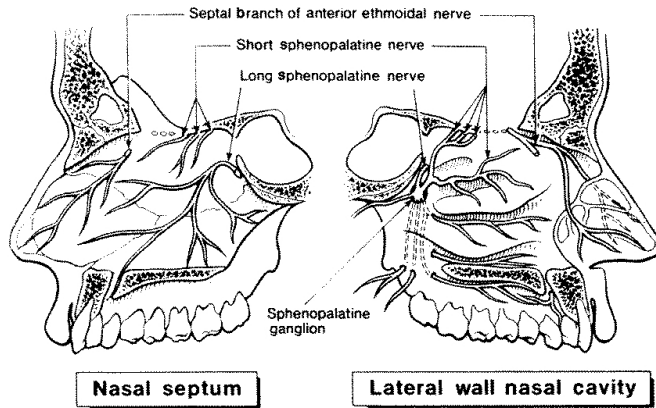
the nose. It must not be directed superiorly along the roof the nose towards the cribriform plate of the ethmoid bone and the base of brain. If the nasal endotracheal tube is difficult to insert, then alternative clockwise and anti-clockwise rotation may help the tube to pass an obstruction but excessive force must be avoided.

Epistaxis occurs in 10% of nasal intubations. Some authors suggest that the

bevel of the endotracheal tube should face the septum, keeping the leading point away from the septum, which is vascular.

The trigeminal cranial nerve (V) is a mixed motor (muscle of mastication) and sensory (principal sensory nerve to the head) nerve. It has three large sensory divisions: ophthalmic, maxillary and mandibular nerves.

Most of the internal surface of the nose receives sensory innervation from the anterior ethmoidal nerve (derived from the ophthalmic division of the trigeminal nerve) and from branches of the sphenopalatine ganglion (derived from the maxillary division of the trigeminal nerve). The anterior alveolar nerve innervates a small area of the anterior floor of the nasal cavity.



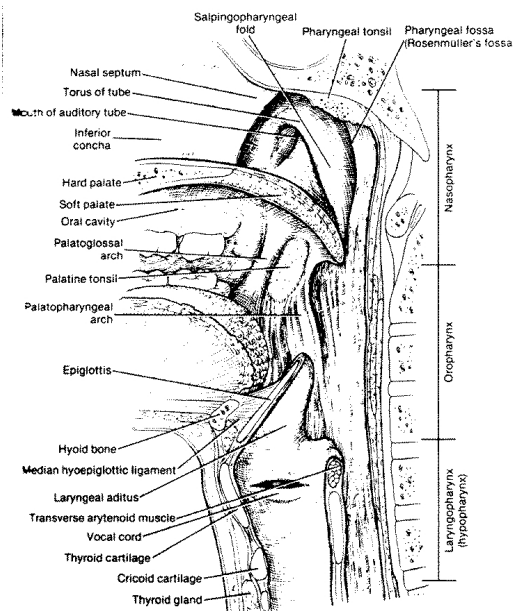
Mouth:

The mouth is made up of the anterior two thirds of the tongue and lateral mucosal reflections, the hard palate and the anterior part of the soft palate. The lingual nerve, a branch of the mandibular division of the trigeminal nerve, innervates the anterior two thirds of the tongue. The lingual nerve runs along beneath the mucosa of the floor of the mouth, lateral to the tongue in the lingual sulcus with the hypoglossal nerve (XII motor nerve to the tongue). It is not necessary to provide anaesthesia to the anterior two thirds of the tongue. (Anesthesia of the posterior third of the tongue and surrounding area is very important in regional anaesthesia of the airway to prevent gagging). Accidental anaesthesia of the hypoglossal nerve will make swallowing difficult.

Pharynx:

The pharynx is a U shaped tube, which extends from the base of the skull to the lower border of the cricoid cartilage where it is continuous with the oesophagus. The junction of the pharynx and the oesophagus is the narrowest portion of the gastrointestinal tract and is therefore a common place for foreign bodies to become stuck.

Posteriorly the pharynx lies against the prevertebral fascia and anteriorly it opens into the nasal cavity (nasopharynx), oral cavity (oropharynx) and larynx (laryngopharynx).



The medial view of the pharyngeal mucosa. [Reproduced with permission from Zorray DO, Baker SR. Basic science: anatomy. In: Otolaryngology Head and Neck Surgery, 3rd ed. Cummings CW, et al., eds. St. Louis: Mosby 1998].

Sensation to the nasopharynx and the oropharynx is primarily from the ninth cranial nerve, the glossopharyngeal nerve, but the maxillary division of the trigeminal nerve also supplies sensation to part of the roof of the nasopharynx.

Sensation to the laryngopharynx is from the internal branch of the superior laryngeal nerve. The internal branch of the superior laryngeal nerve also innervates the laryngeal inlet above the cords and the epiglottis, though the superior surface may receive sensory innervation from the glossopharyngeal nerve.

Trachea:

The recurrent laryngeal nerve supplies sensation below the vocal cords and all the intrinsic muscles of the larynx except the cricothyroid muscles.

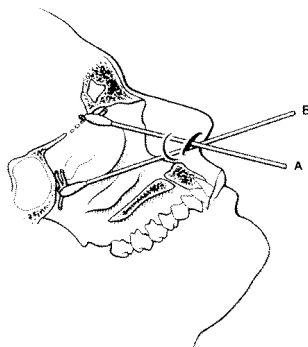
Techniques.

Regional anaesthesia of the airway can be achieved using a wide variety of single or combined techniques including:

- Spraying/ointment/gel/cream/gargle
- Aerosol
- Aspiration
- Nerve blocks.

Nose.

The anaesthetist should first check that the nostril is patent by having the patient occlude one nostril and breathing through the other. The anaesthetist should also check if the septum is deviated and choose the best nostril for intubation.



Regional anaesthesia of the nose is easily achieved by several topical techniques. Lignocaine may be placed on the sphenopalatine ganglion and anterior ethmoidal nerve by spraying through a multi orifice catheter (e.g. epidural catheter), by an atomizer, from a nebuliser with the patient told to breathe through their nose or by direct application from a lignocaine gel covered nasopharyngeal airway or by cotton buds soaked in lignocaine

One cotton bud should be inserted 5cm along the anterior border of the nasal cavity (A) for 10 minutes to block the anterior ethmoidal nerve and one cotton bud should be inserted 6 to 7 cm at 20 to 40 degrees to the floor of the nose (B) to block the sphenopalatine ganglion. The strength and volume of lignocaine required will be discussed latter but in general, 4% is ideal with lower concentrations being less effective and higher concentrations not providing superior anaesthesia but increasing the risk of

toxicity. Also, though the maximum dose of lignocaine is quoted as 4 to 6 mg/kg, determining the maximum safe dose that can be applied topically to the mucous membrane of the airway is difficult and is dependent on the method of topicalisation.

Another alternative is to lay the patient supine with the head tilted back and fill the nasal cavity with lignocaine gel. With time, the gel will melt and run backwards into the nasopharynx. This is repeated a few times until complete anaesthesia is achieved.

The small area of the anterior floor of the nasal cavity innervated by the anterior superior alveolar nerve requires direct application of a local anaesthetic cream or gel.

A vasoconstrictor is recommended but is not mandatory.

Oropharynx (gag reflex/laryngoscopy).

Regional anaesthesia of the airway always requires good anaesthesia of the posterior third of the tongue, soft palate, tonsillar pillars and adjacent pharynx to prevent gagging. The glossopharyngeal nerve is a mixed motor and sensory nerve providing sensation through pharyngeal, tonsillar and lingual branches to the most of the pharynx, tonsils and posterior tongue. However some sensation of the soft palate and adjacent tonsils (as well as the roof of the nasopharynx) is from branches of the maxillary division of the trigeminal nerve and some sensation of the posterior tongue is from the internal branch of the superior laryngeal nerve.

In the majority of patients, topical anaesthesia of the oropharynx/nasopharynx is sufficient to block the gag reflex and there are several topical techniques. The best topical results are achieved from a combination of topical techniques or a topical technique to minimize the gag reflex plus gentle direct laryngoscopy with direct topical application of lignocaine to areas not adequately anaesthetized.

The anaesthetist must be patient, allowing sufficient time for the local anaesthetic to work, before attempting direct laryngoscopy. Spraying lignocaine directly on the laryngeal inlet during direct laryngoscopy may cause trauma, as the patient will cough.

There are several methods for topical anaesthesia of the oropharynx/nasopharynx. The simplest technique is by aspiration however though the results are described as satisfactory; the patient will still have some gagging and coughing. With aspiration, the patient is positioned supine and the tongue is gently retracted. 20 mls of 1.5% lignocaine is simply dripped slowly onto the dorsum of the tongue. The swallowing reflex is initially activated but this is eventually anaesthetized and then the lignocaine pools in the posterior pharynx and is aspirated. Gargling a couple of times with lignocaine (5 mls of 2 – 4%) beforehand decreases the intensity of the swallowing reflex.

Lignocaine may be applied with sequential administration by the direct application with sprays, commercial mucosal atomizers (or home made atomizer), and gels or creams.

Patient comfort and the success of topical anaesthesia by direct application is improved if the patient first gargles with lignocaine to provide some anaesthesia of the base of the tongue and adjacent oropharynx. Success is then dependent on patience, and gentle exposure of the structures that require topicalisation with preferably a tongue depressor, which is less traumatic if the patient coughs or gags.

Combined topical application should be able to provide adequate anesthesia for a gentle look and see to determine if successful intubation is possible. (Inadequate anaesthesia can be improved by direct nerve blocks, which are discussed later). Complete laryngoscopy will require anaesthesia of the laryngopharynx. Awake intubation will also require anaesthesia of the laryngopharynx, larynx and trachea.

Aerosol application of lignocaine can provide excellent airway anaesthesia including partial or complete anaesthesia of the laryngopharynx, larynx and trachea. The effectiveness is very dependent on the method of administration. Administration through the nose (10-20 ml 4%) is more efficient than through the mouth as the local anesthetic is directed to the pharynx, larynx and trachea. Aerosol administration through the mouth can be improved by using an oral airway device.

The size of the droplet is also very important for efficiency and safety. Nebulisers are made to deliver small droplets of respiratory drugs (2 μm) to their site of action in the bronchioles and the alveoli. (Also in this portion of the lung, drug absorption is equal to intravenous administration). For maximum efficiency and safety, lignocaine aerosol needs to produce large droplets (ideally > 60 μm), which will rain out in the proximal airway. To achieve this nebulisers must be used with low flow rates. Many studies have demonstrated the efficiency and safety of using 10 mg/kg (and more) with nebulisers at a flow rate of 6 – 8 ml/min (e.g. 20 ml 4% lignocaine at 6 l/min flow rate for 10 minutes plus 3 ml 4% lignocaine transtracheal injection).

Direct nerve blocks can be use alone to achieve regional airway anaesthesia or can be used to supplement topical anesthesia.

The glossopharyngeal nerve can be blocked with three techniques.

The external approach is unacceptably dangerous. (With the external approach the glossopharyngeal nerve is blocked as it leaves the base of the skull through the jugular foramen along with the vagus nerve, accessory nerve, internal jugular vein and internal carotid artery).

Though the intra-oral posterior approach will block the pharyngeal, tonsillar and lingual branches of the glossopharyngeal nerve is not widely used, as it requires adequate mouth opening, anaesthesia of the tongue and adjacent pharyngeal mucosa to allow exposure of the posterior tonsillar pillar with a tongue depressor and it also has an overall complication rate of 2%. For the posterior approach a needle is inserted 0.5 cm behind the mid point of the palatopharyngeal fold and directed 1 cm laterally and posteriorly to block the glossopharyngeal nerve where it is located 1 cm deep to the mid point of the posterior tonsillar pillar. 2 ml of 2% lignocaine will provide anaesthesia within 1 minute for 45 to 60 minutes.

The intra-oral anterior approach blocks the lingual branch (posterior third of the tongue) of the glossopharyngeal nerve but there may also be some retrograde spread to block the tonsillar and pharyngeal branches. For this approach a needle is inserted to a depth of 0.5 cm at the palatoglossal fold (anterior tonsillar pillar) 0.5 cm lateral to the base of the tongue. A tongue depressor is required to provide adequate exposure. After negative aspiration, 2 ml of 2 % lignocaine will provide 20 minutes of anaesthesia. If blood is aspirated the needle should be directed medially and if air is aspirated the needle is in the oropharynx and needs to be withdrawn slightly. Local anaesthetic injected into the floor of the mouth anterior to the anterior tonsillar pillar may block the hypoglossal nerve.

Studies have shown that gargling with viscous 2 % lignocaine plus direct application of 10% lignocaine is equally efficient as gargling plus anterior glossopharyngeal nerve blocks.

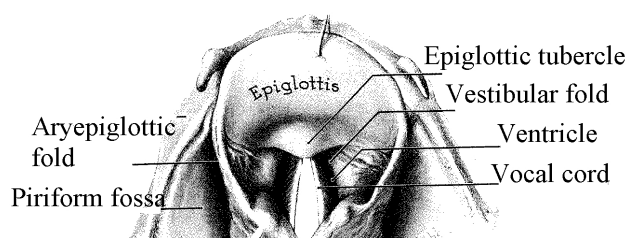
Laryngopharynx, larynx and trachea.

Aerosol application of lignocaine at low flow rates for an adequate time (see above) can provide good anaesthesia of the airway though usually requires some supplementation.

Direct application of local anesthesia to the laryngopharynx and larynx is effective but will cause coughing, which may cause trauma to the patient or anaesthetist's finger.

The laryngopharynx can be anaesthetized by direct nerve blocks. The superior laryngeal nerve has an external laryngeal branch, which innervates the cricothyroid muscle of the larynx (stretches and tenses the vocal cord i.e. changes voice pitch) and an internal laryngeal branch. The internal laryngeal branch pierces the thyrohyoid membrane to provide sensation of the larynx and laryngopharynx above the vocal cords. It may provide sensation to all or just the inferior surface of the epiglottis.

Damage to one superior laryngeal nerve will cause temporary hoarseness. Damage to one recurrent laryngeal nerve will cause permanent hoarseness. Damage to both recurrent laryngeal nerves can cause airway obstruction.



The superior laryngeal nerve can be blocked by direct topical application of lignocaine soaked cotton in the pyriform fossa or by an external superior laryngeal nerve block.

To block the superior laryngeal nerve the patient is placed supine with the neck extended. The hyoid is palpated as a freely mobile bony structure above the thyroid and is held between the anaesthetist's index finger and thumb.

The hyoid bone is displaced towards the side to be blocked and a needle is inserted medially in the frontal plane onto the greater cornu of the hyoid bone. This needle is then "walked off" the greater cornu in a caudal direction until it slips off and pierces the thyrohyoid membrane. The needle needs to only be inserted 2 to 3 mm to lie between the

thyrohyoid membrane and the mucosa of the piriform fossa. After negative aspiration, 2 to mls of lignocaine is injected. If blood is aspirated, the needle is in the superior laryngeal artery or the internal carotid artery and needs to be redirected anteriorly. If air is aspirated, then the needle is in the pharyngeal lumen and needs to be withdrawn.

The recurrent laryngeal nerve supplies all the intrinsic muscles of the larynx except the cricothyroid muscles and provides sensation below the vocal cords. It is easily anaesthetized by a transtracheal injection through the cricothyroid membrane with 4ml of 2 % lignocaine. Correct position of the needle is confirmed by the aspiration of air. The patient will cough vigorously spreading the local anaesthetic. Maximal spread will occur if the injection is given at the end of inspiration.

Complications are rare but include infection, bleeding, subcutaneous emphysema, pneumomediastinum, and vocal cord damage and oesophageal perforation. Transtracheal injection should not be performed if the patient has a coagulopathy, infection at the site of injection or if the landmarks for injection cannot be identified.

Local anaesthetics.

Lignocaine is the most commonly used local anesthetic for airway anaesthesia. It has a high safety margin, quick onset and good duration of action. Lignocaine is not effective for at least 2 minutes or longer.

2% lignocaine is effective for nerve blocks but for topical anaesthesia the maximal effective concentration appears to be 4%. Lesser concentrations are often ineffective and increasing the concentration above 4% does not appear to increase the duration or speed of onset.

The therapeutic antiarrhythmic serum concentration of lignocaine is 1.5 – 4 µg/ml. Increasing serum concentration cause increasing severity of side effects. Initially the patient experiences lightheadedness, tinnitus, circumoral and tongue numbness, visual changes. At serum concentrations of 10 µg/ml patients are unconscious and suffer seizures. Cardiac arrest occurs at concentrations of 20 – 25 µg/ml.

Systemic absorption of lignocaine from the airway depends the site and technique of application, tissue vascularity, total dose administered, total mucosal area covered, rate and depth of respiration, and the state of the circulation and if a drying agent has been used. Absorption is low from the more proximal airway but approximates intravenous administration from the alveoli.

The total dose of local anesthetic used will not be the same as the total dose that is actually administered. Up to 50% of nebulised drug is loss to the atmosphere. Local anesthetic will also be swallowed and may be spat out.

It would seem that the traditional dosage guideline of 4 – 6 mg/kg for lignocaine is generally excessively conservative and this has been confirmed by many large studies using at least 10m/kg of lignocaine with serum concentrations less than therapeutic however there are also case reports of lignocaine toxicity occurring when lignocaine dosage has exceeded traditional guidelines. The anaesthetist must be aware of the signs of toxicity and be prepared to treat them. Regional airway anaesthesia must never be attempted without intravenous access or resuscitation medications. The patient should be assessed constantly, lignocaine dosages (volumes) calculated beforehand and lignocaine should be administered in fractions of the total calculated dose.

Antisialgogues.

Drying agents will improve vision and reduce the mechanical barrier between the local anaesthetic and the mucosa. These agents work by reducing secretions so therefore must be given in advance to be effective. Intramuscular atropine (0.2 – 0.4 mg) or glycopyrolate (0.4 mg) needs to be given 30 minutes in advance. Intravenous atropine and glycopyrolate is effective in 10 minutes. Scopolamine is a sedative and may be contraindicated in the patient with a difficult airway.

Sedation.

All sedatives are respiratory depressants and sedation is contraindicated (and not necessary if the regional anaesthesia is adequate) in patients with a compromised airway. However when used with care sedatives can further minimize discomfort, reduce anxiety and provide amnesia. The goal is to have patients calm and cooperative. They must always be fully conscious i.e. able to obey commands.

Midazolam, fentanyl, remifentanyl and ketamine have all been used for improved patient cooperation. They must all be administered in very small doses.

Questions.

Can topical anaesthesia of the airway cause airway obstruction?

There is extensive experience with lignocaine topical airway management and it is very safe but anaesthetists must be aware that in patients with pre-existing airway compromise, regional airway anaesthesia and airway instrumentation has been associated with complete airway obstruction. However these are the patients that may most urgently need an awake airway management. If the patient needs awake airway management then the anaesthetist must also be skilled and prepared to perform an awake surgical airway.

Is regional anaesthesia of the airway contraindicated in a patient with a full stomach?

Local anaesthesia of the oropharynx, laryngopharynx, larynx and trachea reduces the protective airway reflexes and may allow aspiration. Though there are many case series of airway anaesthesia in patients with a full stomach with no aspiration complications there is always a risk. This apparently very small risk of aspiration (which can be treated) must be balanced against the risk of failed intubation and failed ventilation.

Which technique is best?

The best technique depends on the patient, the resources available and the urgency of the situation and the experience of the anaesthetist.

In an uncooperative patient, nebulised lignocaine may provide the best initial analgesia to assess the difficulty of intubation.

When a nebuliser is not available, a cooperative non-urgent patient with good mouth opening can be easily managed with an antisialagogue, gargling lignocaine and direct application.

AIRWAY MANAGEMENT CHOICES.

Fundamental to airway management is the maintenance of adequate oxygenation and ventilation, and protection of the airway from aspiration therefore it is essential that the airway (ease of ventilation) of every patient is assessed, and the anaesthetist develops a plan for the airway management of the patient before providing sedation, general and regional anaesthesia.

Every anaesthetist must be skilled in techniques of bag mask ventilation, general anaesthesia direct laryngoscopy and performing an emergency surgical airway. The use of a supraglottic airway is a standard technique for airway management during anaesthesia and as an airway rescue device.

These are basic anaesthetic and life saving skills, which must be meticulously taught to anaesthetic trainees and regularly assessed.

Flexible fiberoptic bronchoscopy/laryngoscopy is an extremely versatile airway management technique, which has many benefits. Its primary indication is in the non-emergency (time permitting) management of the anticipated difficult airway.

Advantages of flexible fiberoptic laryngoscopy and intubation include:

- Minimal regional anaesthesia and minimal or no sedation
- Ability to see around corners,
- Minimal cervical spine movement
- Minimal mouth opening

However limitations include:

- Extreme urgency
- Uncooperative patient
- Fixed laryngeal obstruction with stridor at rest (implies a reduction in airway to 4.0 mm or less)
- Blood, secretions or vomit obscuring vision
- The requirement for special training
- Expensive equipment.

There have been many other advances in airway management. An anaesthetist may not be proficient in all airway techniques or have access to all the available airway devices however they should be confident with some of the alternatives.

ALTERNATIVE AIRWAY MANAGEMENT WITHOUT ADVANCED/EXPENSIVE EQUIPMENT.

The choice of alternative airway management is highly dependent on the patient's clinical state, available resources and anaesthetic experience.

1. **Ketamine anaesthesia.**

Avoids airway manipulation and generally preserves respiratory function but cannot guarantee adequate oxygenation and ventilation.

2. **Assisted or spontaneous mask ventilation** (+/- nasopharyngeal oropharyngeal airways).

These patients must be assessed preoperatively as easy to mask ventilate and must have no history of airway obstruction when awake or during normal sleep.

3. **Awake supraglottic airway.**

There are many simple techniques to provide regional anaesthesia of the airway. In patients that the anaesthetist believes that a supraglottic airway will be suitable, but has some doubts, the supraglottic airway can be tried with the patient awake.

4. **General anaesthesia supraglottic airway.**

The supraglottic airway may be the primary airway choice, a temporary airway choice or a rescue airway.

5. **Awake laryngoscopy.**

Awake laryngoscopy can be used to fully assess a suspected difficult airway or for endotracheal intubation without risking loss of the airway with paralysis/general anaesthesia.

6. **General anaesthesia laryngoscopy.**

Laryngoscopy and intubation under general anaesthesia can be performed with muscle relaxants or with ultra short acting narcotics.

7. **Digital intubation.**

Digital intubation is an acceptable alternative to direct laryngoscopy for tracheal intubation when the standard technique is contraindicated, has failed, or is not possible because of an equipment problem. It may be performed on any patient but is easier in small adults and paediatric patients.

Standing at the side of the patient (face to face), the left index and middle fingers are inserted into his mouth and along the tongue to digitally identify the epiglottis. If an

assistant is available, they can grasp and pull the tongue forward. This helps to lift the epiglottis anteriorly and makes palpation of the structures of the upper airway easier. With the fingers pressing the epiglottis against the pharyngeal wall, a bougie is passed along the axis of the middle finger (stabilizing it between the index and middle finger) and inserted through the glottis, where it may elicit tracheal clicking. The endotracheal tube is then passed over the bougie into the trachea, and its correct position is confirmed by capnography/auscultation.



Digital intubation can be performed in 1 minute.

Originally digital intubation was described without the use of a bougie (and can be performed with the fingers alone). However, because of the bougie's smaller diameter and malleability, it is easier to digitally insert through the glottis than an endotracheal tube. Even when the supraglottic structures are digitally identified, it can be difficult to direct the unassisted tracheal tube through the glottic opening. The use of the bougie makes digital intubation rapid and simple.

If a bougie is not available, placing a stylet within the endotracheal tube and bending it to form a “hockey stick” shape may make placement of the endotracheal tube easier.

8. Light Wand.

Light-guided intubation using the principle of transillumination has proven to be an effective and simple technique. When the tip of the lightwand is placed inside the glottis, a bright light glow can be seen easily in the soft tissue of the anterior neck. In contrast, if the lightwand is placed in the esophagus, no transillumination can be observed

With the patient lying supine, the jaw is lifted upward to elevate the epiglottis. The light wand can be inserted from the midline position or if this is a problem, the light wand can be introduced from the lateral corner of the mouth and repositioned in the midline following its entry into the oropharynx. The midline position is maintained while the device is gently advanced in a rocking motion along an imaginary arc.

A faint glow seen above the



thyroid prominence indicates that the tip of the light wand is located in the glosso-epiglottic or epiglottic fold. If the light wand enters the esophagus, no glow can be detected. A bright glow observed in the lateral aspect of the larynx indicates that the tip of the light wand is placed in the piriform fossa and a redirection of the light wand to the midline is then required.

When the tip of the light wand enters the glottic opening, a well-defined circumscribed glow can be seen in the anterior neck slightly below the thyroid prominence

The light wand may be a useful option in the case of a difficult or impossible laryngoscopic intubation for both anticipated and unanticipated situations

The light wand can also be used together with other devices, such as the laryngeal mask airway, the intubating LMA and direct laryngoscopy.

Lightwand intubation is not without potential hazards. Since light wand intubation does not permit direct visualization of the anatomical structures, it should be avoided in patients with known abnormalities of the upper airway, such as tumors, polyps, infections (e.g., epiglottitis and retropharyngeal abscess), and trauma or presence of a foreign body in the upper airway.

A light-guided technique should not be attempted in an uncooperative awake patient and caution should be used in patients when transillumination of the anterior neck may not be adequate (e.g., grossly obese patients or patients with limited neck extension)

9 Blind nasal intubation.

Blind nasal intubation is an option whenever oral access is difficult or even impossible. It is usually performed with the patient awake and the airway anaesthetized by regional anaesthesia though it can be performed under general anaesthesia.

The best results are obtained by a combination of regional block and sedation, which aims at decreasing patient anxiety but allows patient cooperation and always maintains a patent airway.

Absolute contraindications to elective awake intubation include allergy to the local anesthetic and refusal or incapacity of the patient to cooperate with the procedure. It must be used with care in patients with a bleeding diathesis. Base of skull fractures, severe maxillofacial fractures and known or suspected nasal obstruction are other contraindications.

Blind nasal intubation is usually performed with the patient supine and the head in the sniffing position though it can be successfully performed with the patient sitting up. It is usually easier for the right-handed anaesthetist to use the right nostril though the most patent nostril should be chosen.

It is important to know how the endotracheal tube connector is orientated with respect to the curvature of the endotracheal tube.

The airway from the nares to the trachea requires regional anaesthesia.

Slowly and gently the endotracheal tube is advanced along the floor of the nose until it enters the nasopharynx. The tube is orientated towards the larynx. This would be slightly to the left for a tube entering the right nares. The endotracheal tube is slowly advanced forward listening for maximal breath sounds. Elevating the tip of the endotracheal tube may facilitate intubation. This can be achieved by inflating the endotracheal cuff. The cuff will need to be deflated before passing through the laryngeal inlet.

A light wand or gum elastic bougie can be used to assist blind nasal intubation.

The endotracheal tube will be in one of four positions:

Trachea: breath sounds continue through the tube, the tube continues to advance, and patient coughs

Anterior: breath sounds continue through the tube, it cannot be advanced, cough heard mainly through the tube. The tube should be withdrawn and re-advanced with the patient's head and neck slightly flexed.

Oesophageal: breaths sounds stop, the tube continues to advance, and there is no coughing. The tube should be withdrawn and re-advanced with the neck extended or apply posterior pressure to the larynx or largely inflate the cuff and advance until resistance is felt and while maintaining some advancing pressure on the tube, slowly deflate the cuff. If the endotracheal tube continues to enter the oesophagus, it can be left there and a second tube is inserted through the other nostril.

Pyriiform sinus: breath sounds through the tube stop, the tube cannot be advanced, and there is no coughing. The tube should be slightly withdrawn to a point where the breath sounds can be heard again and rotated towards the midline and advanced.

Awake blind nasal intubation is a safe, simple and efficient technique. It requires a calm and tolerant patient and excellent regional airway anaesthesia or can be performed with the patient asleep.

10. Intubation through a laryngeal mask/intubating laryngeal mask

The standard laryngeal mask is an excellent primary airway and can also be used as a temporary airway in cases of suspected difficult intubation or as a rescue airway in failed intubation.

In cases of suspected difficult intubation a laryngeal mask may be inserted awake or under spontaneously breathing general anaesthesia. If the laryngeal mask provides a safe

airway the anaesthetist can then use it to pass an endotracheal tube. The standard laryngeal mask may tend to direct the endotracheal tube anteriorly. This can be corrected by inserting the endotracheal tube with the curve backwards. Using a light wand, gum elastic bougie or fiber optic bronchoscope may facilitate the passage of the endotracheal tube. The application of cricoid pressure may decrease the success rate.

The intubating laryngeal mask has been modified to improve the intubation success rate.

11. **Retrograde intubation**

Retrograde intubation has been used in awake, sedated and anaesthetized patients. It has been used successfully in adult and paediatric patients.

Retrograde intubation is contraindicated in the presence of unfavourable anatomy, laryngotracheal pathological conditions, significant coagulopathy and infection.

It can be performed with a commercial kit or from locally available equipment.

Saline is drawn up into a syringe and an initial percutaneous puncture through the cricothyroid membrane is made with a size 16g or 14g introducer needle and catheter at 30 to 40 degrees to the skin in a cephalad direction. Aspiration of air (bubbles) confirms correct placement. The needle and syringe are removed and a wire is passed up the trachea until it appears in the mouth or nose.

The catheter is removed and the wire is clamped at the skin.

The wire is pulled taught and ideally a guiding catheter is advanced anterograde over the wire, into the trachea until tenting is noted at the cricothyroid puncture site. The endotracheal tube is then passed over the wire (and guiding catheter) into the trachea until resistance is felt at the level of the cricothyroid puncture site.

The wire is unclamped and the wire and guiding catheter is removed from above the endotracheal tube. As the last portion of the wire is removed, the endotracheal tube is further advanced into the trachea. Alternatively the wire is held taught until resistance is felt at the level of the cricothyroid puncture site and then the wire is gradually released as the tube and the wire is advanced into the trachea. An epidural catheter may be superior to a guide wire as it bends more easily and is less traumatic.

The two main problems are

(1) The endotracheal tube is larger than the wire and may catch on the epiglottis or laryngeal inlet. Using a guiding catheter (or a small endotracheal tube) reduces the difference in size between wire and endotracheal tube. Placing the endotracheal tube over the wire with the bevel facing posteriorly (backwards curve) may also help.

It is essential that resistance at the epiglottis be not mistaken for the endotracheal tube being in the trachea at the end of the wire.

(2). The endotracheal tube may inadvertently slip into the oesophagus after withdrawal of the guide wire, due to the short distance between the cricothyroid puncture site and the vocal cords. This is a serious possible hazard of the retrograde method.

If the guide wire is passed through the side hole (Murphy's eye) of the endotracheal tube rather than the distal end, an extra 1 cm of endotracheal tube can be placed below the level of the vocal cords before the guide wire is removed.

Another technique is to pass another wire or catheter or a gum elastic bougie down the endotracheal tube when it is in its final position before the guide wire is removed. This helps direct the tube further down the trachea and prevent oesophageal displacement. (If the catheter has the capacity to monitor expired carbon dioxide then its correct placement can be confirmed before advancing the endotracheal tube).

If the tracheal puncture is made more distal (at the level of the first or second tracheal ring) then the distance between the puncture site and the cords is increased however this technique may lead to a higher bleeding and complication rate.

The most common complication of retrograde intubation is a sore throat. More significant complications are rare and include failure to intubate the trachea, infections, bleeding, subcutaneous emphysema and injury to vocal cords and the upper airway.

12. **Rigid bronchoscopy**

13. **Needle cricothyrotomy/surgical cricothyrotomy**

Needle cricothyrotomy and surgical cricothyrotomy are essential airway skills. Though rarely used, every anaesthetist must be confident that they are capable of performing these procedures.

There are three absolute contraindications to surgical cricothyrotomy: (1) endotracheal intubation can be achieved easily and rapidly and no contraindications to endotracheal intubation are present, (2) tracheal transection with retraction of the distal end into the mediastinum and (3) a fractured larynx or significant damage to the cricoid cartilage or larynx.

Relative contraindications are acute laryngeal diseases, coagulopathy, age less than 5 to 12 years and significant neck oedema, haematoma, infection.

14. **Tracheostomy**

In some cases (severe airway) and some situations (minimal resources) an elective awake tracheostomy is the safest airway choice.

ALTERNATIVE AIRWAY DEVICES.

A fundamental skill of an anaesthetist is the maintenance of adequate oxygenation and ventilation, and the protection of the airway from aspiration.

Tracheal intubation remains the “gold standard” for providing effective ventilation, while at the same time providing protection from aspiration of gastric contents. It is, however difficult to learn and requires regular practice to maintain the skill. Bag mask ventilation is also a difficult skill to learn and maintain.

There are increasing numbers of alternative airway devices including variants of laryngoscopic blades, supraglottic devices, stylets and video laryngoscopy. These various airway adjuncts have certain advantages and disadvantages. Factors to be considered include ease of use, cost and maintenance.

An anaesthetist may not be proficient in all airway techniques or have access to all the available airway devices however they should be confident with some of the alternatives.

Unfortunately the increased use of alternative airway devices has had a predictable negative effect on mastering and maintaining the skills of bag mask ventilation and endotracheal intubation.

A. SUPRAGLOTTIC AIRWAYS.

Before to the 1980s, there were two main choices for airway management in patients undergoing general anesthesia. Either endotracheal intubation or facemask ventilation.

Since the 1980s many supraglottic airways have been introduced. Supraglottic airways (SGAs) are usually inserted blindly and ventilate patients by delivering gases above the level of the vocal cords. They provide a more secure airway than mask ventilation and free the anaesthetist’s hands, are less invasive for the respiratory tract, better tolerated by patients, and easier to place while avoiding disadvantages of endotracheal intubation (soft tissue, tooth, vocal cords, laryngeal and tracheal damage, exaggerated haemodynamic response, failed intubation, increased incidence of laryngospasm, increased training). Disadvantages of SGAs include misplacement and the risk of dislodgement. Some supraglottic airways may not be the ideal airway because the seal may be inadequate for positive pressure ventilation.

There are three main airway-sealing mechanisms for SGAs: a cuffed perilaryngeal seal (e.g. laryngeal mask), a cuffed pharyngeal seal (e.g. laryngeal tube) and cuffless anatomical pre-shaped seal (e.g. SLIPA).

Laryngeal mask, proseal, intubating laryngeal mask and CTrach.

Since the introduction of the laryngeal mask airway (LMA) in the late 1980s, they have been used in millions of patients, for the management of both normal and difficult airways of patients under general anesthesia, with an excellent record of efficacy and safety. Accordingly, the LMA has become both a primary airway and a rescue device in difficult and failed intubation algorithms.

The Proseal laryngeal mask has a modified cuff design to improve its seal and a drainage tube for gastric tube placement. This modification broadens the range of cases that it can be used for.

While it is possible to intubate the trachea through a laryngeal mask, success rates are variable. The intubating laryngeal mask (FastrachTM) has a rigid curved airway tube, an epiglottic elevating bar, a deeper bowl and a ramp that directs the endotracheal tube up and into the larynx, therefore increasing the intubating success rate.

The CTrach is a variant of the intubating laryngeal mask containing an integrated fibreoptic system that allows visualisation of the larynx. The CTrach has two built in fibreoptic channels. One to provide light and one to transmit the image

I Gel

There have been several variants of the laryngeal mask developed, which are very similar (e.g. Ambu laryngeal mask, soft seal laryngeal mask).



The i-gel differs in that it is made from a medical grade thermoplastic elastomer. The i-gel has been designed to create a non-inflatable, anatomical seal of the pharyngeal, laryngeal and perilaryngeal structures. Like the Proseal it has a gastric channel and an integral bite block. The solid design of the i-gel may reduce the risk of rotation.

Several SGAs exist, which are quite different in design compared to the LMA. These airway devices include: the Combitube, the Laryngeal Tube (LT), the Cobra Perilaryngeal Airway (CobraPLA), Streamlined Liner of Pharyngeal Airway (SLIPA), the Elisha and the cuffed oropharyngeal airway (COPA).

Oesophageal Tracheal Combitube.

The Combitube (CBT) is a twin lumen device designed for use in emergency situations and difficult airways. It can be inserted without direct visualization into the oropharynx, and usually enters the esophagus (95%). It has a low volume inflatable distal cuff and a much larger proximal cuff designed to occlude the oro- and nasopharynx.



The CBT is usually inserted blindly along the surface of the tongue with the patient's head placed in a neutral position and their jaw lifted. It requires only minimal mouth opening. After insertion the oropharyngeal is inflated first (85/100ml), then the distal balloon (10ml).

If the tube has entered the trachea, ventilation is achieved through the distal lumen as with a standard endotracheal tube. More commonly the device enters the esophagus and ventilation is achieved through multiple proximal apertures situated above the distal cuff. In the latter case the proximal and distal cuffs have to be inflated to prevent air from escaping through the esophagus or back out of the oro- and nasopharynx.

If ventilation is impossible through both lumens, the CBT is likely to have been placed too deeply with proximal lumen positioned in the oesophagus and the oropharyngeal balloon obstructing the larynx.

The Combitube has been used effectively in cardiopulmonary resuscitation. It has been used successfully in patients with difficult airways secondary to severe facial burns, trauma, upper airway bleeding and vomiting where there was an inability to visualize the vocal cords. It can be used in patients whose cervical spine has been immobilized with a rigid cervical collar, though placement may be more difficult. Ventilation does not seem to be affected by the rigid cervical collar if the Combitube can be placed.

The main advantages of the CBT are that it requires little training in use, has a high success rates, and needs minimal mouth opening and no movement of the cervical spine. While protection against aspiration is not guaranteed, it can be used with positive pressure ventilation up to 50 cm H₂O.

Potential disadvantages include aspiration, oral, tracheal or oesophageal trauma, subcutaneous emphysema and inadequate oxygenation. The trachea cannot be suctioned when the CBT is in the oesophageal position.

The Combitube can only be used in the adult population (small adult 37F 4-6ft and 41F for patients taller than 6 ft), as no pediatric sizes are available. Two circumferential rings printed on the proximal end of the tube indicate the correct depth of insertion.

Laryngeal Tube LT

The laryngeal tube is a single lumen tube with an approximate angulation of 130 degrees with two low-pressure cuffs (proximal and distal) and two oval holes between them to allow ventilation. The proximal hole is “protected” by a “V” shaped deflection in the pharyngeal cuff such that when the cuff is inflated soft tissue is deflected from the opening. The distal balloon seals the airway distally and protects against regurgitation. The proximal balloon seals both the oral and nasal cavity. Both balloons are inflated by a single pilot balloon.

The laryngeal tube is also available with an additional gastric drain, which allows decompression of the stomach.

The laryngeal tube requires at least 23 mm of mouth opening and is inserted blindly with the tip pressed against the hard palate and the patient’s head in the neutral or sniffing position.

(The *Laryvent*TM and *Airway Management Device AMD*TM are very similar to the laryngeal tube).

Cobra PeriLaryngeal Airway

The CobraPLA[®] is a cuffed, disposable, sterile, and latex free SGA. It is made of polyvinyl chloride and has three main parts: a breathing tube, a circumferential pharyngeal cuff, and a head. The head broadens distally into the shape of the head of a Cobra snake. Slotted openings of the Cobra head hold both the soft tissue and the epiglottis away and permit air exchange through the openings. An internal ramp directs ventilation towards the larynx. The bars of the head are sufficiently flexible to allow an endotracheal tube to pass easily.



It is designed to be positioned in the hypopharynx opposite the laryngeal inlet.

The CobraPLA[®] is easily inserted, straight back through the mouth between the tongue and hard palate, with the aid of a jaw lift and the patient’s head in the sniffing position.

This SGA is available in eight sizes, and can be used for neonates as well as for infants

The main disadvantage of the CobraPLA[®] is that it does not protect against aspiration.

Streamlined Liner of Pharyngeal Airway. SLIPA



The SLIPA comprises a hollow chamber, shaped like a boot, with a toe bridge that seals at the base of the tongue and a heel that anchors the device in position between the esophagus and the nasopharynx.

No cuff is necessary for the device to seal in the pharynx because the shape of the SLIPA is similar to that of a pressurized pharynx.

A unique feature of the SLIPA is the hollow chamber, which provides a large capacity chamber for storing regurgitated liquids from the stomach. This may prevent the contents from overflowing into the trachea, thus significantly reducing the risk of aspiration pneumonia. Unlike drainage tube methods, the SLIPA may accommodate particulate matter without the risk of obstruction.

Even though the SLIP has a chamber with a capacity of approximately 50 ml, which most often exceeds the volume of gastric contents in fasted patients, its efficacy in prevention of aspiration has yet to be proven.

Cuffed oropharyngeal airway. COPA

The COPA is a modified Guedel's airway with a cuff at its distal end and a standard 15 mm connector at its proximal end. It was intended for use during anaesthesia in spontaneously breathing patients.



The COPA offers no protection against aspiration.

Elisha airway, Pharyngeal Airway Express (PAXPRESSTM), Gasa Glottic Aperture Seal Airway.

There are many other supralottic airways. The Elisha airway device allows three functions: ventilation, blind and/or fiberoptic-aided intubation without interruption of ventilation, and gastric tube insertion. The PAXPRESS is similar to laryngeal tube but with a no inflatable gilled conical tip at the distal end.

B. INTUBATION DEVICES.

An ideal intubating device should be easy to use, quickly learnt, portable and allow rapid intubation without the risk of aspiration and minimal haemodynamic disturbance or

airway trauma and cervical manipulation. It should be suitable for awake and general anaesthesia, nasal and oral intubation in both adults and paediatrics. The device should allow for ventilation during intubation, be 100% successful and cost effective.

No such device exists.

Intubation techniques can be classified as:

Direct laryngoscopy

Indirect laryngoscopy

- Flexible fiberoptic bronchoscope
- Rigid fiberoptic laryngoscopes (e.g. Bullard)
- Video laryngoscopes (e.g. Glidescope)
- Optical laryngoscopes (e.g. airtraq)
- Optical Stylets (e.g. Bonfils)
- C trach

Inferred intubation

- Light guided stylet (eg. Light wand)
- Hearing feeling air movement
- Digital intubation

Blind techniques

- Via airway device
- Truly blind

LARYNGOSCOPE BLADES.

The first direct laryngoscopy, described by Kirsten in 1895, used a straight blade with the tip passing posterior to the epiglottis, which was then lifted to expose the vocal cords.

Jackson and Magill described the insertion of the blade as lateral as possible in the mouth, along the paraglossal gutter away from the tongue. The straight blades were semi-tubular in cross section and once the vocal cords were visualized, the endotracheal tube was passed down the semi-tubular blade. The passage of the endotracheal tube hid the view of the vocal cords. The introduction of a bulky balloon onto the red rubber endotracheal made it very difficult to pass the tube.

A variety of straight blades have been introduced over the years. The Miller laryngoscope is the most popular straight laryngoscope blade. It has a lower cross-sectional dimension, which makes it easier to insert and position but its small size is also its major disadvantage, as an endotracheal tube cannot easily be passed through its channel and the passage of the endotracheal tube hides the view of the larynx.

The tip of the Miller blade may also be traumatic and the light source can become obscured by tissues and secretions.

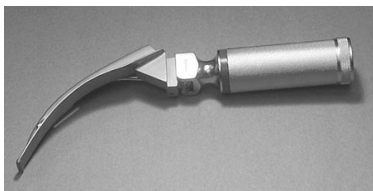
Modifications of the Miller blade (e.g. Phillips, Henderson, Flagg, Guedel, Wisconsin) have tried to correct one or more of the disadvantages of the Miller blade.

In 1943 Macintosh described a curved blade with a “z” shaped cross section. The blade was designed to sweep the tongue to the left side of the mouth, creating sufficient space to pass the bulky endotracheal tubes and allowed the anaesthetist to see the tube pass through the vocal cords. The curved blade also had the improvements of an atraumatic tip and a light that did not become blocked by airway tissue.

The Macintosh blade is easy to insert as the curve follows the natural curve of the mouth and as it is advanced along the mid line, rather than the lateral approach of a straight blade, this helps to locate the epiglottis.

Equally important, Macintosh described the technique of indirect elevation of the epiglottis by stretching the hyoepiglottic ligament. This can only be achieved when the tip of the blade is deep in the vallecula and the vector of force applied to the laryngoscope is in the optimal direction. The force required by a straight blade is 30% less than that required by a Macintosh blade.

However by the late 1940s Macintosh had changed back to using a straight blade. He had designed the gum elastic bougie, which he inserted down the lumen of a straight blade into the trachea, then moved the blade to the center of the mouth and guided the endotracheal tube over the gum elastic bougie.



The Polio version of the Macintosh laryngoscope has the blade at an obtuse angle to the handle. It was introduced for the use in patients in iron lung respirators. Other modifications include the addition of a prism. These prisms refract light approximately 30 degrees so that larynx can be viewed without a direct line of sight.

The McCoy and similar blades have a hinged tip, which flexes when a lever on the handle is depressed. These blades may help improve grade 3 Cormack/Lehane view to grade 2 or 1.



LIGHT STYLET GUIDED INTUBATION

Light-guided intubation using the principle of transillumination has proven to be an effective and simple technique. When the tip of the light guided stylet is placed inside the glottis, a bright light glow can be seen easily in the soft tissue of the anterior neck. In

contrast, if the light guided stylet is placed in the esophagus, no transillumination can be observed.

With the patient lying supine, the jaw is lifted upward to elevate the epiglottis. Neck movements can be kept minimal. The light guided stylet can be inserted from the midline position or if this is a problem, the light guided stylet can be introduced from the lateral corner of the mouth and repositioned in the midline following its entry into the oropharynx. The midline position is maintained while the device is gently advanced in a rocking motion along an imaginary arc.



A faint glow seen above the thyroid prominence indicates that the tip of the light guided stylet is located in the glosso-epiglottic or epiglottic fold. If the light guided stylet enters the esophagus, no glow can be detected. A bright glow observed in the lateral aspect of the larynx indicates that the tip of the light guided stylet is placed in the piriform fossa and a redirection of the light guided stylet to the midline is then required.

When the tip of the light guided stylet enters the glottic opening, a well-defined circumscribed glow can be seen in the anterior neck slightly below the thyroid prominence

The light guided stylet may be a useful option in the case of a difficult or impossible laryngoscopic intubation for both anticipated and unanticipated situations.

The light guided stylet can also be used together with other devices, such as the laryngeal mask airway, the intubating LMA and direct laryngoscopy.

Light guided stylet intubation is not without potential hazards. Since light guided stylet intubation does not permit direct visualization of the anatomical structures, it should be avoided in patients with known abnormalities of the upper airway, such as tumors, polyps, infections (e.g. epiglottitis and retropharyngeal abscess), and trauma or presence of a foreign body in the upper airway.

A light-guided technique should not be attempted in an uncooperative awake patient and caution should be used in patients when transillumination of the anterior neck may not be adequate (e.g., grossly obese patients or patients with limited neck extension)

OPTICAL STYLETS.

Optical stylets have an optical viewing system (fibreoptic in most modern systems) within a stylet that may be malleable or preshaped. The stylet is inserted within the endotracheal tube and, through an eyepiece or on a video monitor; the anaesthetist watches the advancement of the endotracheal tube. These devices require less mouth opening and though they do not require the neck movements of conventional laryngoscope, intubation may be aided with jaw lift, neck extension or even conventional laryngoscopy to lift the tongue and epiglottis off the posterior pharyngeal wall.

Light is supplied to the distal end from a remote light source or from an attached battery handle. The distal viewing angle varies from 50 to 90 degrees. Unlike fibreoptic scopes, few of these devices have a hollow working channel for suction or oxygenation. The inability to suction material (blood, secretions) may obscure the view of the larynx.

These devices should be warmed by immersion in warm water before use to prevent fogging. The patient's upper airway should be well suctioned to prevent blood and secretions obscuring the view.

Examples include the Bonfils Intubating Fiberscope (non malleable, 90 degrees, working channel), the Shikani Optical Stylet (malleable, 70 degrees), the Video Optical Intubating Stylet (semi-rigid, 50 degrees), and the Levitan FPS (malleable).

Optical stylets are more portable, durable and less expensive than flexible fibreoptic scopes. Being rigid they may be easier than a flexible fibreoptic bronchoscope to keep in the midline. With training and especially in combination with conventional laryngoscopy they have a high rate of success in difficult intubations though one major draw back is that they provide a restricted visual field.



VIDEO AND OPTIC LARYNGOSCOPES.

Successful conventional laryngoscopy requires a line of sight (LOS) from the anaesthetist's eye to the laryngeal inlet. To achieve this the anaesthetist must manipulate the head and neck and upper airway structures, which can cause significant haemodynamic disturbances, airway injury and dental damage.

Both video laryngoscopes (via a distal camera) and optical laryngoscopes (via fiberoptic bundles and a lens) transmit the image from the tip of the laryngoscope so successful intubation is not dependent on achieving a line of sight. The risks of conventional laryngoscopy are reduced and successful laryngoscopy is increased.

These devices vary from a single or limited use designs that use traditional optics (e.g. Airtraq) to devices that incorporate a fiberoptic scope into a metal holder or guide (rigid fiberoptic laryngoscope) such as the Bullard laryngoscope, Wu laryngoscope and Upsher scopes, or systems that incorporate miniaturized video cameras into a more traditional laryngoscope design (rigid video laryngoscope), such as the GlideScope, Pentax Airway Scope and McGrath Video Laryngoscope.

Optical laryngoscope: Airtraq

The Airtraq is a single use, battery powered (90 minutes) optical laryngoscope. It is an anatomically shaped laryngoscope with two channels. One channel transmits the glottic view through a series of lenses and prisms. The other channel holds and guides the endotracheal tube through the vocal cords. Turning on the LED light for at least 30 seconds before use activates an anti-fogging system for the lenses.

The Airtraq works with any style of endotracheal tube. It is inserted over the tongue with minimal distortion to the anatomy to place its tip into the vallecula. A vertical lifting force elevates the epiglottis and the endotracheal tube is advanced down the channel and can be seen passing through the vocal cords.

The Airtraq requires minimal mouth opening (18 mm), causes less haemodynamic response than conventional laryngoscopy and is easily learnt. The simplistic (and cheap) nature of the optics means that the image is not as good as other video and optical laryngoscopes.



Rigid Fibreoptic laryngoscope

These devices have in common a fibreoptic viewing channel, light source and blade.

To facilitate intubation the airway should be cleared of secretions and the device prepared with an anti-fogging spray or warm water immersion. The head and neck are usually positioned in a neutral position and the blade is inserted by rotation behind and around the tongue until the blade is vertical. Then it is allowed to drop against the posterior pharyngeal wall. The blade is then advanced in a caudad direction before lifting it vertically so that the viewing channel is directly pointing at the glottic opening. A jaw lift can help elevate the epiglottis.

Unlike optical stylets, the width and depth of the visual field allows the anaesthetist to easily recognize anatomical landmarks.



The *Bullard laryngoscope* has three channels: a light, fibreoptic and working channel. The blade has a spatula shape and is only 6 mm thick so can be used with minimal mouth opening. The endotracheal tube can be passed freehand or loaded onto an intubating stylet that is attached to the Bullard laryngoscope.

The *Upsher scope* consists of a J-shaped blade with an incorporated C-shaped channel through which the endotracheal tube is advanced. This narrower and more rounded blade makes it more difficult to control the tongue and epiglottis.

The *WuScope* has a tubular blade, through which the endotracheal tube is passed, and needs 20-25 mm of mouth opening.

Rigid Video laryngoscope



The current video laryngoscopes: *GlideScope*, *McGrath Video Laryngoscope* and *Pentax Airway Scope* have a modified Macintosh style curved blade with a camera and light source towards the tip. This allows comparable or superior laryngeal visualization in both routine and difficult airways without the need for direct line of sight. Cervical spine movement and the intubating force are significantly reduced and

these devices may be easier to learn to use and are easier to teach.

The scopes are inserted in the midline or slightly to the left of the tongue to avoid distortion of the pharyngeal or laryngeal anatomy. Special patient positioning is not

required. The uvula, base of tongue and epiglottis should be seen in succession to ensure proper midline orientation. The blade is preferentially placed in the vallecula but if the epiglottis obscures the laryngeal view, the blade can be used like a straight blade and pick up the epiglottis.

Despite the excellent laryngeal view, the main problem with rigid video laryngoscopes is passing and advancing the endotracheal tube past the larynx and, unlike direct laryngoscopy, optimizing the laryngeal view may make passing the tube more difficult.

With direct laryngoscopy aligning oral, pharyngeal and laryngeal axes creates a straight line of sight. With video laryngoscopy these axes are not aligned, so the tip of the endotracheal tube must pass around a relatively acute angle to enter the larynx. (Successful placement of the endotracheal tube usually requires a stylet).

Because of the acute angle at which the endotracheal tube is entering the larynx, the endotracheal tube may be difficult to advance, hitting the anterior tracheal wall.

Rotating the handle of the laryngoscope more caudad may worsen the view but allow advancement of the endotracheal tube, as this will reduce the angle. (Rotation of the wrist producing a more vertical orientation of the handle tilts the laryngeal axis upwards, improving the view but increasing the angle of the advancing endotracheal tube). Alternatively clockwise and anticlockwise rotation of the tube may be useful.

If the endotracheal tube cannot be advanced, a gum elastic bougie can be used as a guide.

Although video laryngoscopes require less force and movement of the head and airway, (in particular using the maxillary teeth as a fulcrum), they can actually result in increased airway trauma because when performing video laryngoscopy, the anaesthetist's visual attention is diverted from the mouth and videoscope to the video screen and the view at the tip of the laryngoscope. The anaesthetist may fail to look at what is happening at the level of the teeth and lips.

LARYNGOSCOPY AND INTUBATION

Failure to properly evaluate the airway and to predict difficulty is the most important factor leading to a failed airway. The challenge for the anaesthetist is to accurately predict all difficult intubations, immediately recognize intubation failure and to reliably secure continuous gas exchange.

Airway evaluation encompasses more than just “ease of intubation”. There are four primary techniques for ensuring gas exchange.

- Mask bag ventilation (BMV)
- Laryngoscopy and intubation
- Supraglottic airway devices (SGD)
- Surgical airway (SA)

Complete airway assessment includes the assessment of ease/difficulty of each of the above.

It is not possible to predict every difficult intubation. The anaesthetist must be prepared for unanticipated difficulty. Always have back up plans. **The maintenance of oxygenation always takes priority over all other issues.**

Laryngoscopy.

Laryngoscopic oral intubation is an essential but difficult skill to master. It has been estimated that a trainee requires about 50 intubations to ensure a 90% probability that laryngoscopic intubation will be successful.

Laryngoscopy simply tries to obtain a direct line of sight from the anaesthetist to the larynx. The maxillary teeth, tongue and epiglottis are the three structures that must be controlled to obtain the line of sight.

The anaesthetist’s best attempt at laryngoscopy should be their first attempt. It should not be necessary for the anaesthetist to make major adjustments to the patient’s position during laryngoscopy.

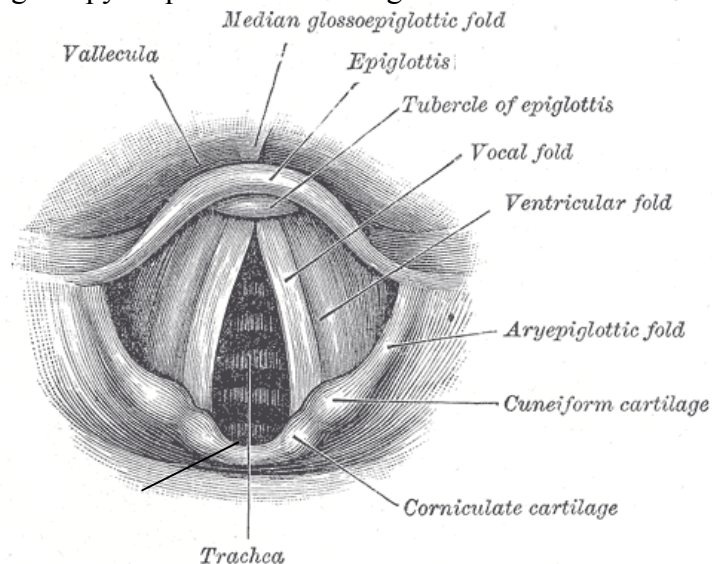
Benumof describes a best attempt as having six components.

- (1) Performance by an experienced anaesthetist,
- (2) No significant muscle tone (paralysis),
- (3) Optimal positioning of the airway,
- (4) The use of external laryngeal manipulation,
- (5) Appropriate length of blade and
- (6) Appropriate type of blade.

The anaesthetist must maintain oxygenation, avoid trauma and always have a back up plan.

Anatomy.

Successful laryngoscopy requires a knowledge of the relevant anatomy, dexterity and planning.



The anaesthetist must be able to recognize the anatomy of the laryngeal inlet. With a perfect view the anaesthetist can see the white vocal cords in their triangular orientation beneath the epiglottis. Below the vocal cords are the rounded corniculate cartilages. Between and slightly beneath the corniculate cartilages is the interarytenoid notch. With a very poor view, this may be the only landmark identified (Cormack and Lehane grade 3)

Position.

The anaesthetist should position the patient at a height that is comfortable for them.

The generally accepted position of the patient's head and neck for laryngoscopy and intubation is in the sniffing position, recommended by Magill, whereby the neck is flexed and the head slightly extended. (Jackson recommended full head extension without neck flexion).

Head extension is very important. It facilitates the insertion of the laryngoscope, reduces contact between the laryngoscope and maxillary teeth (by rotating the maxillary teeth out of the way), moves the maxillary teeth out of the line of sight and is essential for full mouth opening. The sniff position is particularly useful in patients who are obese or have limited neck mobility.

Laryngoscopy.

The purpose of laryngoscopy is to facilitate tracheal intubation under direct vision.

Laryngoscopy and endotracheal intubation has four components.

1. Insertion,
2. Optimizing position of laryngoscopy,
3. Place the tube between the vocal cords,
4. Confirmation of correct placement.

Laryngoscopy should be a two handed procedure. The laryngoscope is held in the left hand. The right hand extends the neck, which causes the mouth to open a moderate amount. With a curved laryngoscope blade, the blade is inserted to the right of the midline. (The assistant or the little finger of the left hand can retract the lower lip from between the mandibular teeth and the blade if it has become trapped).

The curved blade is moved to the left, displacing the tongue horizontally away from the line of sight. The blade is gradually advanced. Sighting the uvula confirms that the blade is in the midline. The tip of the curved blade is slowly advanced until it is placed deep in the vallecula, contacting softly with the hyoepiglottic ligament. The epiglottis is elevated indirectly by stretching the hyoepiglottic ligament.

To stretch the hyoepiglottic ligament (elevate the epiglottis), the anaesthetist applies a significant lifting force along the axis of the laryngoscope handle. The amount of force required varies. Heavier patients require a greater lifting force. The force required with a curved blade is greater than with a McCoy or straight blade. Applying sufficient lifting force is very important in achieving successful intubation. Recognising the appropriate force, which achieves an optimum view with a minimal risk of trauma is gained with experience.

The lifting force must be along the axis of the handle. The anaesthetist must never lever the laryngoscope blade on the maxillary teeth.

The curved blade is good in most cases, quickly learnt, follows the natural curve of the airway and as it is advanced in the midline it is easy to identify structures. However the anaesthetist should be skilled with both the curved and straight blade laryngoscope. A straight may work when curved has failed!

The straight blade may be more efficient than a curved blade at obtaining a line of sight. The straight blade is inserted to the right side of the mouth and advanced along the paraglottic gutter. With this approach both the maxillary teeth and tongue are unlikely to obscure the line of sight and the distance to the larynx is reduced. Lifting the epiglottis directly by placing the tip of the blade beneath the epiglottis may be easier than by stretching the hyoepiglottic ligament.

Though seeing the laryngeal inlet may be easier with a straight blade, placing the endotracheal tube may be more difficult because the paraglottic approach has less room to insert the endotracheal tube (because the tongue is not displaced) and the endotracheal tube may obscure the anaesthetist's line of sight before it passes through the laryngeal inlet. (Magill use a straight blade with a gum elastic bougie).



The flex-tip (McCoy 1993) laryngoscope has a hinged tip, which flexes when a lever on the handle is depressed. The flexi-tip may be very good at improving the view at laryngoscopy from grade 3 to grade 1 or 2.

If view of the larynx is poor, first check that maximum head extension and mouth opening has been used and that, with a curved blade, the entire tongue is displaced to the left. Frequently the tip of the laryngoscope has not been inserted deeply enough into the vallecula. The lifting force (along the axis of the handle) may need to be increased.

External laryngeal manipulation (Backwards, Upwards, Right Pressure – BURP) is an extremely important part of laryngoscopy if the view is inadequate. This is best done with the right hand of the anaesthetist. When the anaesthetist finds optimal position of the larynx, the assistant maintains the larynx in that position.

The anaesthetist should not accept a partial view unless they have checked that the patient's position, the placement of the laryngoscope, the lifting force and the application of external laryngeal positioning are all optimal.

Once the optimal view is achieved the anaesthetist takes the endotracheal tube in the right hand. The assistant can help by pulling the right side of the mouth open. The endotracheal tube is passed from the right side of the mouth so that its passage toward and between the vocal cords can be seen.

Stylets and introducers (Eschmann or Gum elastic bougie).

Most modern PVC (not the older red rubber) endotracheal tubes are preformed to a good shape and are rigid. A malleable stylet (usually a metal rod, coated in plastic) can be inserted into the lumen of an endotracheal tube and bent into a shape (usually a J or hockey stick) that may facilitate intubation. The stylet should not protrude beyond the tip of the tracheal tube.

When the tip of the endotracheal tube has passed 2 cm beyond the vocal cords the assistant should remove the stylet. The stylet should be well lubricated; otherwise when the assistant pulls the stylet out of the endotracheal tube they may also pull the endotracheal tube out of the patient.

The tracheal tube introducer or gum elastic bougie is an extremely important piece of intubation equipment and should be immediately available for every patient requiring laryngoscopy.

It is cheap, easy to learn to use and has a high success rate with relatively few complications (trauma to the airway and oesophagus have been reported).

The gum elastic bougie is usually 60 cm in length, with a J tip (35 degrees) and though semi-rigid it is flexible enough to follow a tortuous route. Markings along its length indicate the distance from the tip.

The gum elastic bougie is invaluable for grade 3 and difficult grade 2 laryngoscopic views. The bougie is advanced in the midline and the tip of the bougie is hooked under the epiglottis. The 35-degree angle of the tip helps to direct the bougie through the cords.

As the gum elastic bougie is advanced the anaesthetist can often feel “clicks” as the tip of the bougie slides over the tracheal rings. Also when correctly placed, the bougie cannot be gently advanced further than 30-35 cm (as it reaches a distal airway). If incorrectly placed in the oesophagus the bougie will be easily advanced its entire length.

When the gum elastic bougie correctly placed, an endotracheal tube can be advanced over it into the trachea. To make the advancement easier and to avoid trauma, the epiglottis should be elevated as much as possible, preferably by direct laryngoscopy.

The tip of the endotracheal tube may catch on the epiglottis or other laryngeal structures. Rotating the endotracheal 90 degrees counterclockwise, then clockwise can help with advancement.

Confirmation of placement.

Confirmation of the position of the endotracheal tube (endotracheal, endobronchial or oesophageal) is mandatory.

There are several techniques to help confirm that the endotracheal is in the airway and not in the oesophagus. The most reliable are seeing the tracheal tube between the vocal cords, end-tidal carbon dioxide monitoring and the use of a flexible fiberoptic bronchoscope within the endotracheal tube to visualize the cartilaginous rings of the trachea and the tracheal carina.

All techniques can fail. Unrecognised oesophageal intubation is fatal. If the anaesthetist has any suspicion that the endotracheal tube might be in the oesophagus, it must be removed and oxygenation maintained by bag mask ventilation.

1. Visualise the endotracheal tube passing between the vocal cords. – Error: unable to visualise or inadvertent tube movement during patient position change.
2. Observation of chest wall movement- Error: obesity, large breast, chest wall movement can occur with oesophageal intubation
3. Auscultation of chest wall breath sounds- Error: can occur with oesophageal intubation.
4. Epigastric auscultation- Error: breath sounds can be transmitted to the epigastric area and vice versa.
5. Assessment reservoir bag compliance and inflation/deflation- Error: the reservoir bag can inflate and deflate with ventilation of the stomach.
6. Condensation of endotracheal tube- Error: can occur with oesophageal intubation.
7. ETCO₂- Error with cardiac arrest 30% false negative
ETCO₂ monitoring may be by infrared or colormetric techniques. Colormetric devices are single use, lasting up to 2 hours, with usually 3 ranges of colour.

<0.5% (Oesophagus if adequate blood flow. Possible trachea if cardiac arrest with no compressions),

0.5 to 2 % (decreased blood flow to lungs, decreased CO₂ production or with first 6 breaths of oesophageal intubation if some CO₂ present in stomach) and

2 to 5% (tracheal)
8. Oesophageal detector. These are a bulb or large syringe, which are attached to the endotracheal tube. If the tube is in the oesophagus, the bulb usually does not re-inflate and aspiration of a full syringe is not possible. Error: false positive and false negative possible.

EMERGENCY ALGORITHMS

Emergency airway management in the unprepared and unfamiliar patient is often challenging. Although many predictors of a difficult laryngoscopic intubation have been developed, they all have low positive predictive values, and thus the unanticipated difficult laryngoscopic intubation will continue to occur.

Securing and monitoring the airway are among the key requirements of anaesthesia. Failures to secure the airways will drastically increase morbidity and mortality of patients within a very short time.

Endotracheal intubation is often called the ‘gold standard’ for airway management in an emergency, but multiple failed intubation attempts do not result in maintaining oxygenation; instead, they endanger the patient by prolonging hypoxia and causing additional trauma to the upper airways.

Proficiency in alternative techniques for establishing airway access is of crucial importance when routine measures fail. Intensive training in these situations, as well as protocols based on standardized guidelines and algorithms, allow recognition of common problems and institution of appropriate therapeutic measures without delay.

Thus, knowledge and availability of alternative procedures are essential in every anaesthetic. Given the great variety of techniques available, it is important to establish a well-planned, methodical protocol within the framework of an algorithm. This not only facilitates the preparation of equipment and the training of personnel, it also ensures efficient decision-making under time pressure.

The algorithm for emergency airway management describing the sequence of various procedures has to be adapted to internal standards and to techniques that are available.

Techniques of airway management.

Oxygen delivery and clearing the airway

In all patients who are still spontaneously breathing, sufficient oxygenation should be maintained by oxygen delivery in an adequate concentration. Additionally, in cases of partial or complete airway obstruction with fluids or solid foreign bodies in unconscious patients, the airway has to be cleared by suctioning, sweeping the fingers in the mouth or foreign body extraction with Magill forceps under visual control during laryngoscopy.

Bag Mask Ventilation

Bag-valve-mask (BVM) ventilation is a fundamental skill of routine and emergency airway management and must receive a high priority in training. Trainees and

anaesthetists must maintain the skill of bag mask ventilation.

A ventilation bag with attached mask can be used to provide both assisted and controlled ventilation of the patient. Generally, a high-flow oxygen source (10 L/minutes) allows better compensation of facemask leaks and generation of sufficient positive pressure to overcome respiratory system resistance to gas flow. Jaw thrust and neck extension is usually necessary to provide a patent airway.

The mask should be sized to cover the nose at the level of the nose bridge and the mouth just above the chin.

In obese patients, the combination of redundant oropharyngeal soft tissue, a bulky tongue, and a thick chin and neck pad may interfere with the ability to ventilate. Several methods may be used to overcome this resistance. Lifting the chin pad while applying a jaw thrust can straighten the soft tissues of the anterior wall in the hypopharynx and facilitate ventilation. Early insertion of an oral airway or tilting the head laterally while ventilating may reduce the risk of the tongue falling backward against the soft palate.

Finally, two-person mask ventilation may be more effective and should be attempted. The anaesthetist maintains the mask seal with two hands while the assistant squeezes the bag.

Endotracheal intubation

Endotracheal intubation is considered the gold standard of airway management however this skill is difficult to learn and requires practice to maintain the skills to intubate.

Endotracheal tube intubation protects against aspiration, allows ventilation with peak pressures of 50 cm H₂O and the administration of endobronchial drugs.

There are no contraindications for tracheal intubation in an emergency. In trauma patients with suspected cervical spine injury, however, all measures should be carried out with an assistant stabilizing the neck in neutral position.

Performing tracheal intubation, especially in an emergency, requires excellent skills and experience with this relatively complex technology and, additionally, it is necessary to monitor and reliably confirm the placement of the tube tip in the trachea. Undetected oesophageal intubation and inadvertent, unnoticed extubation of the trachea are the most serious incidents in airway management, as they can result in severe hypoxic injury or even death. This underscores the importance of confirming correct endotracheal tube placement.

Fibreoptic intubation

Flexible intubation laryngoscopes (bronchoscope) are the most effective solution in all

cases of *anticipated* difficult intubation in a spontaneously breathing patient. They are much less useful in an emergency intubation.

Of course, the use of flexible intubation laryngoscopes requires extended skills with continuous training and appropriate logistics, especially with regard to cleaning and disinfecting the scopes after each use.

The rigid intubation fibrescope allows indirect laryngoscopy and simplifies orotracheal intubation of patients with various problems that may prohibit successful direct laryngoscopy, such as restricted mouth opening, an immobilized cervical spine, a large tongue, or mandibular retrognathia. However this intubation technique by indirect laryngoscopy is not only more complex than standard laryngoscopy but also requires clinical experience and continuous practice.

Supraglottic devices

Supraglottic devices allow for the blind establishment of an airway that allows oxygenation and ventilation, gives some protection against aspiration and may provide another route for intubation.

Combitube.

The oesophageal/tracheal Combitube (ETC) is primarily used as an emergency tube for ventilating patients during resuscitation. It provides a complete seal of the upper airway and can therefore be used in patients with a risk of regurgitation and aspiration of gastric contents. It has two tubes, one of which resembles a conventional endotracheal tube while the other seals off the oesophagus with an oropharyngeal balloon. The ETC can be inserted blindly through the mouth and is more likely to pass into the oesophagus (95%) than into the trachea (5%). It can safely be inserted in patients with cervical spine injuries because flexion of the neck is not required.

Laryngeal mask.

The cuff around the elliptical body of the laryngeal mask (LMA) seals the larynx posteriorly and enables ventilation of the patient without intubating the trachea. The LMA is available in all sizes from infant to adult and allows, with some experience, rapid manual positioning without additional aids in anaesthetized or unconscious patients.

Numerous reports document the successful use of the LMA in emergencies under difficult conditions, during cardio-pulmonary resuscitation CPR, and in trauma patients even by non-physicians.

Intubating laryngeal mask.

The intubating laryngeal mask airway (ILMA) is an advanced version of the LMA allowing a special endotracheal tube to be passed through the ILMA into the trachea. Its use is recommended especially in cases of difficult intubation, after failed intubation attempts, and for rescuers inexperienced in tracheal intubation.

This device follows a two-step concept: (1) it may be used as a rescue airway when tracheal intubation has failed and in ‘cannot intubate, cannot ventilate’ situations, allowing rapid oxygenation and ventilation; and (2) it serves for securing the airway as a conduit for tracheal intubation through the ILMA (blind or under vision).

In the 2000 ILCOR guidelines, endotracheal intubation is cited as the optimum technique for airway management, but supraglottic devices are explicitly mentioned as alternatives. These alternative devices are described as suitable for use by providers with only limited experience in endotracheal intubation, but also for use in case of failed initial attempts.

According to evidence-based criteria the ETC and LMA are evaluated and classified as follows:

- ETC and LMA are easier to place compared to endotracheal intubation;
- Ventilation with both devices is comparable to that obtained with an endotracheal tube and is definitely superior to BVM ventilation;
- Complication rates are comparable to those of endotracheal intubation;
- ETC and LMA are effective in cases of failed endotracheal intubation.

Both the ETC and the LMA are therefore recommended as acceptable, safe, and helpful alternatives.

There is no question that at least one of the supraglottic airway devices described above should be immediately available in an emergency when laryngoscopic endotracheal intubation fails.

Surgical airway

The ‘surgical airway’ is strictly a means of last resort. It is indicated when the airway cannot be secured by endotracheal intubation or by an alternative techniques and BVM ventilation is not possible.

ALGORITHM

An algorithm provides stepwise procedures or decision trees to guide the anaesthetist through the management of a particular problem.

The management of the difficult airway is the most important patient safety issue in the practice of anaesthesia. Many national societies have developed algorithms and guidelines for management of the difficult airway. These algorithms differ.

There are two opposite approaches to producing algorithms: one may choose to include a wide choice of techniques at each stage within the algorithm, allowing individual choice of the best technique for each situation, or alternatively one may produce simple and

definite flow charts with few items of equipment.

Use of a simple and definitive algorithm with few items of equipment and yes or no responses facilitates familiarity and practice in its use especially as a failed airway algorithm will be used at times of high anxiety.

All algorithms stress the absolute importance of having a series of back-up plans for airway management. Generally, plan B is a secondary airway, plan C emphasises oxygenation and ventilation while plan D describes rescue techniques for the cannot intubate and cannot ventilate disaster.

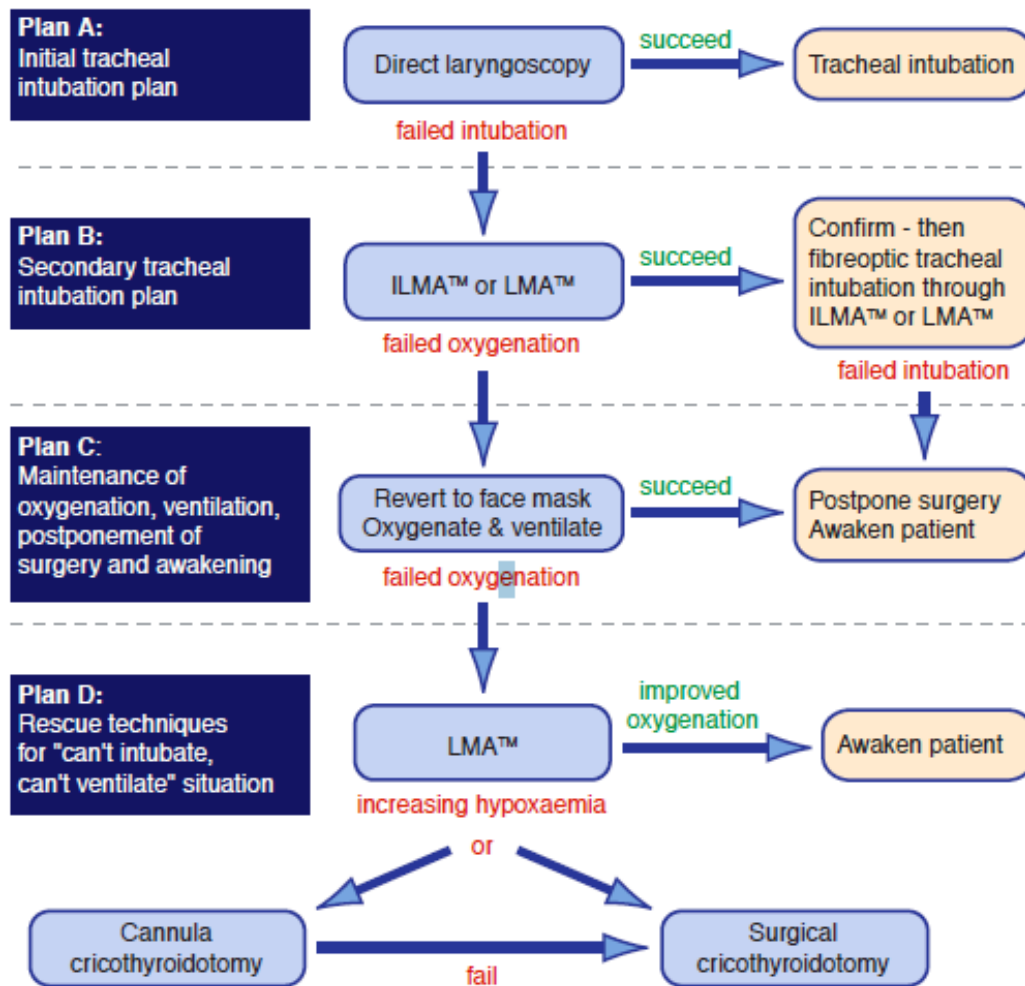
The essential features of back up plans are that they must be decided on before performing the primary plan and the anaesthetist must adhere to the plans.

It is not possible to cover all clinical scenarios with a single flow-chart that remains simple and clear. Flow-charts should be developed and practiced for at least the three scenarios of:

- Unanticipated difficult intubation in routine induction;
- Unanticipated difficult intubation in rapid sequence induction;
- And failed intubation, increasing hypoxaemia and difficult ventilation in the paralysed, anaesthetized patient.

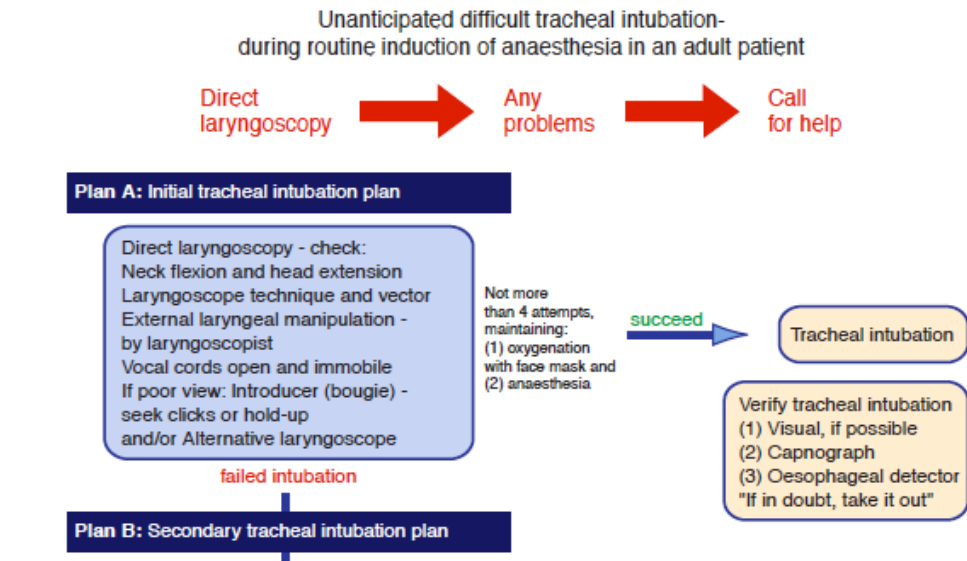
Anaesthetists also need a plan for anticipated difficult airways. This plan should emphasise awake intubation techniques or at least anaesthetic techniques that maintain spontaneous ventilation.

Unanticipated difficult intubation in routine induction, no risk of aspiration (non-obstetric).



Difficult Airway Society

Plan A.



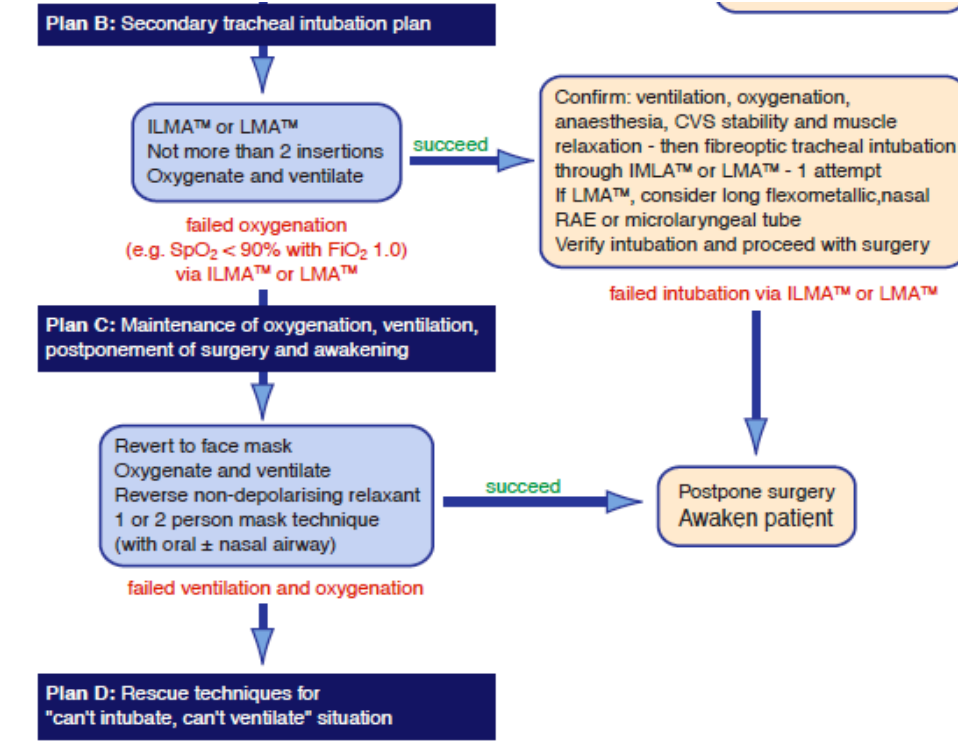
Intubation is attempted by optimal direct laryngoscopy and this has 5 components:

- Optimal head and neck positioning
- Optimal muscle relaxation
- Optimal laryngoscope blade
- Optimal external laryngeal manipulation and
- Optimal use of the bougie.

A number of intubation attempts (3-4) may be undertaken (to change the blade, use a bougie, apply external laryngeal manipulation) but after 3-4 attempts it is likely that the anaesthetist is repeating fruitless attempts and no further attempts should be made.

The anaesthetist must recognise that intubation has failed and proceed with plan B. Start facemask ventilation, ask for a LMA. Ensure oxygenation.

Plan B.



Plan B is initiated by ventilation of the patient initially by facemask and then by laryngeal mask. The priority is oxygenation and stabilizing the patient – not intubation.

If ventilation is not possible by facemask or laryngeal mask go to plan C

The importance of the laryngeal mask is that it usually allows:

- Good ventilation/oxygenation.
- Attachment of a breathing system
- Provides a route for intubation

Both the classic and intubating laryngeal masks are suitable.

Once the patient has been stabilized and oxygenated, the secondary intubation attempt is made through the LMA or intubating LMA. Though blind intubation through the intubating LMA has a high success rate, success can be improved with the use of a fiberoptic scope.

If intubation is successful, the position of the tube in the trachea is confirmed and surgery continues.

If intubation fails or ventilation by LMA is not possible – go to plan C.

Plan C.

If the LMA or intubating LMA has been tried unsuccessfully for intubation but is

successful for ventilation, leave it in, and allow the patient to wake up. Surgery should be postponed. Awake intubation should be considered.

If at the initiation of plan B, ventilation by LMA has not been successful then plan B is bypassed to plan C.

Remove the LMA if there is unsatisfactory ventilation through it and return to facemask ventilation with a large oral airway. Consider using two-hand bag mask ventilation. If this fails try 4-hand bag mask ventilation with one person applying the face mask, another applying jaw thrust and neck extension and another squeezing the bag.

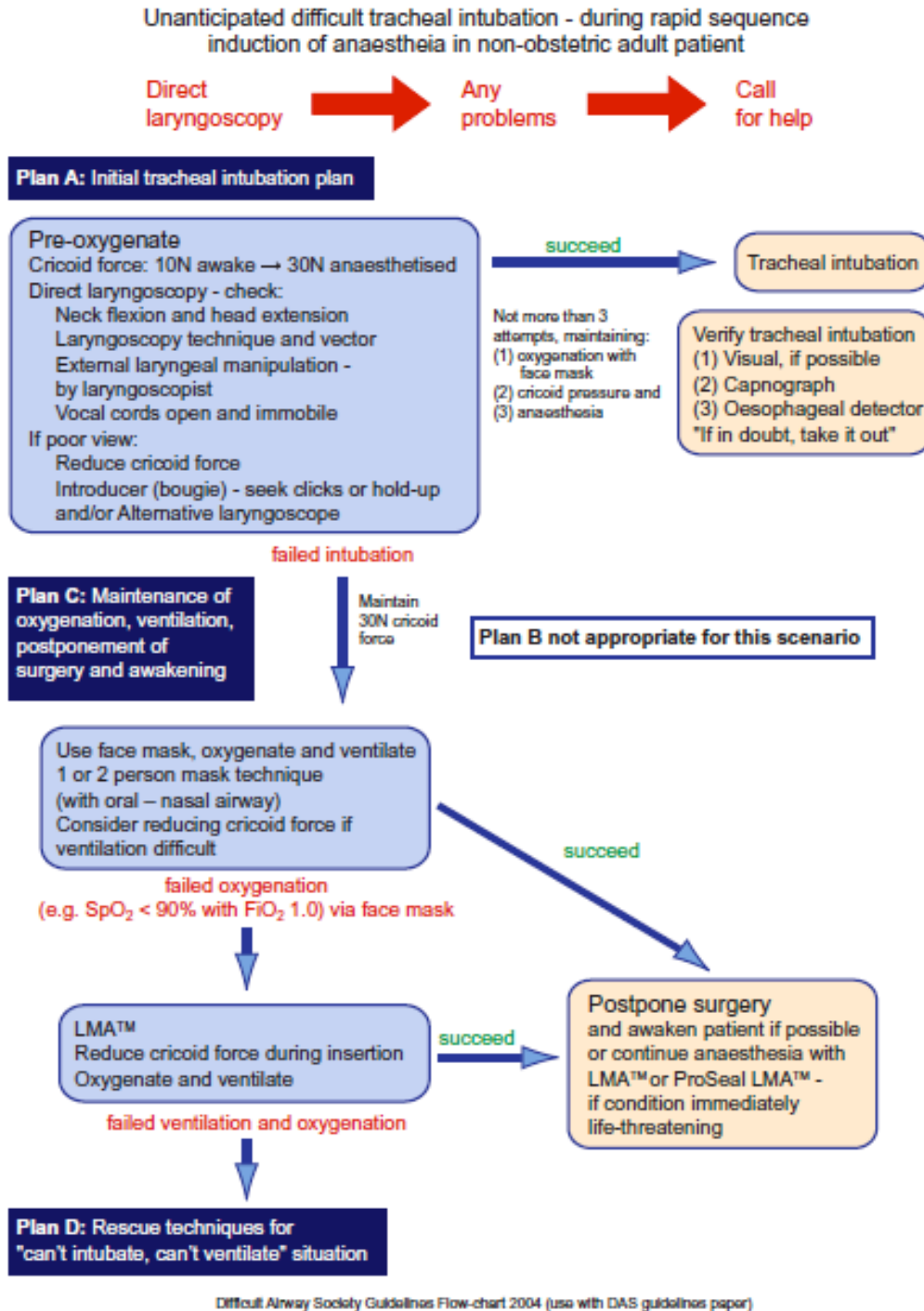
If it is not possible to maintain oxygen saturations above 90% with 100% oxygen, this is a situation of failed ventilation and failed intubation. Immediately proceed to plan D.

Plan D.

Can't intubate, can't ventilate situation with increasing hypoxaemia!

Don't waste time trying to intubate. Recognise the crisis. Oxygenation is the priority. Proceed to an emergency surgical airway.

Unanticipated difficult intubation in rapid sequence induction



The anaesthetic technique includes optimal preoxygenation, the use of an induction agent and suxamethonium, with the application of 30 Newton of cricoid pressure at the onset of unconsciousness.

There is no intubation plan B because the patient is going to be woken up without any

other attempts at intubation. The only task is to move to plan C – the maintenance of oxygenation whilst the induction agent and suxamethonium wears off and the patient awakens.

Call for assistance and keep first responder.

Continue cricoid force at 30 N.

Insert oral airway and attempt facemask ventilation with 100% oxygen.

If necessary use two hands to hold facemask and ask responder to squeeze bag.

If facemask inflation not possible, maintain 30 N cricoid force and insert laryngeal mask. Release cricoid force as laryngeal mask is inserted and reapply when inserted.

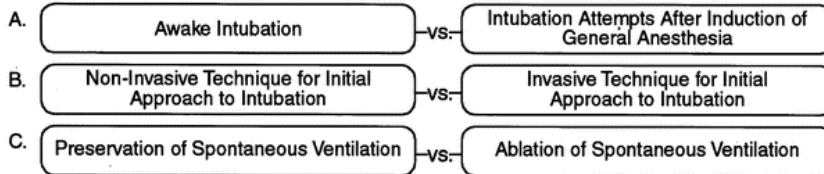
Attempt to ventilate with 100% oxygen via laryngeal mask with cricoid force.

If that fails release cricoid force and try ventilation again through the laryngeal mask.

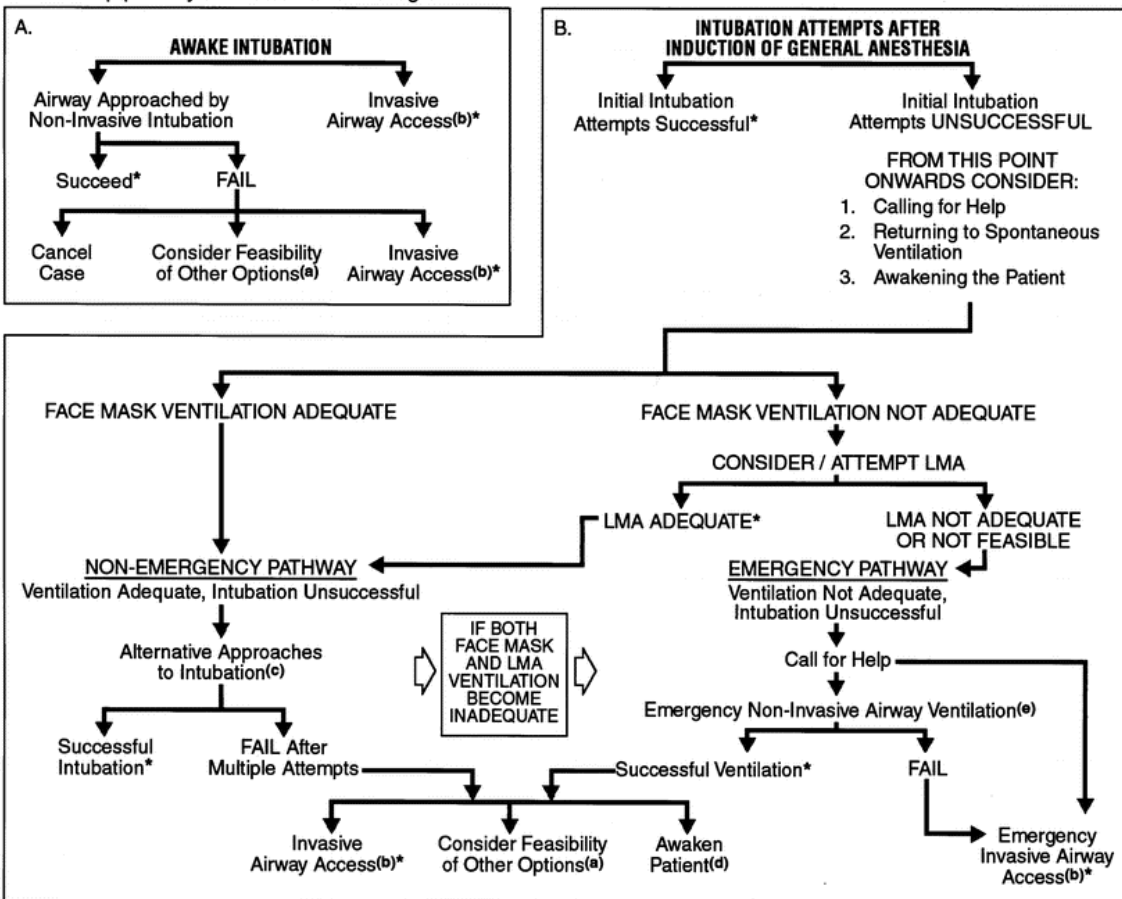
If ventilation is still not possible, and the patient is not awakening/struggling to breathe and the saturations have fallen below 85% go on to Plan D (failed intubation and failed ventilation).

DIFFICULT AIRWAY ALGORITHM

1. Assess the likelihood and clinical impact of basic management problems:
 - A. Difficult Ventilation
 - B. Difficult Intubation
 - C. Difficulty with Patient Cooperation or Consent
 - D. Difficult Tracheostomy
2. Actively pursue opportunities to deliver supplemental oxygen throughout the process of difficult airway management
3. Consider the relative merits and feasibility of basic management choices:



4. Develop primary and alternative strategies:



* Confirm ventilation, tracheal intubation, or LMA placement with exhaled CO₂

a. Other options include (but are not limited to): surgery utilizing face mask or LMA anesthesia, local anesthesia infiltration or regional nerve blockade. Pursuit of these options usually implies that mask ventilation will not be problematic. Therefore, these options may be of limited value if this step in the algorithm has been reached via the Emergency Pathway.

b. Invasive airway access includes surgical or percutaneous tracheostomy or cricothyrotomy.

c. Alternative non-invasive approaches to difficult intubation include (but are not limited to): use of different laryngoscope blades, LMA as an intubation conduit (with or without fiberoptic guidance), fiberoptic intubation, intubating stylet or tube changer, light wand, retrograde intubation, and blind oral or nasal intubation.

d. Consider re-preparation of the patient for awake intubation or canceling surgery.

e. Options for emergency non-invasive airway ventilation include (but are not limited to): rigid bronchoscope, esophageal-tracheal combitube ventilation, or transtracheal jet ventilation.

EMERGENCY SURGICAL AIRWAY

The “can’t intubate, can’t ventilate (CICV) scenario is a rare event with an estimated incidence of approximately 1:10000 - 1:15000 anaesthetics, although it is more likely to in the emergency setting.

A cricothyroidotomy is a technique used to establish an airway through the cricothyroid membrane (CTM). It is the final emergency airway procedure in the CICV situation.

In an emergency, a cricothyroidotomy is preferred to an emergency tracheostomy because:

- The CTM is nearly always accessible
- The CTM is fairly avascular
- Cricothyroidotomy is easily taught
- Cricothyroidotomy is minimally invasive and requires minimal equipment
- An emergency tracheostomy is more complex, associated with more bleeding, has a greater risk of posterior tracheal wall perforation, has a greater risk of lung damage and may take longer to perform.

The decision to perform a cricothyroidotomy is both patient and situation dependent and should be made earlier rather than late. The most difficult part is not the actual procedure but making the decision to perform a cricothyroidotomy.

An emergency cricothyroidotomy consists of 3 parts:

- Recognition that an airway problem exists
- Performance of the cricothyroidotomy and
- Ventilation.

There are several techniques to perform a cricothyroidotomy including:

- Needle/cannula technique
- Seldinger (wire) technique with a cuffed or uncuffed tube
- A stab technique using a wide bore cannula (QuickTrach, Nu Trake, Portex)
- Surgical technique

The need to perform a cricothyroidotomy is rare. Training and retraining are vital.

The technique first chosen by the anaesthetist in the emergency situation must provide the safest, simplest and fastest oxygenation. Usually the skills of an anaesthetist are in favour of a cannula over a scalpel and a cannula cricothyroidotomy may be the best first option.

In some situations a cannula cricothyroidotomy is all that is required, allowing a temporary solution until the patient resumes spontaneous ventilation. In other cases it provides temporary oxygenation while more complex upper airway manoeuvres (e.g. fiberoptic, surgical airway) are performed.

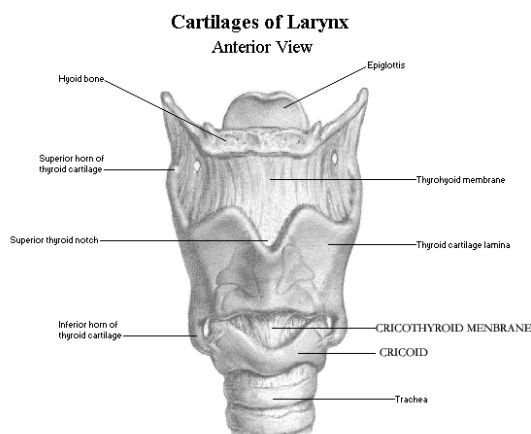
Anatomy of the cricothyroid space.

Knowledge of the anterior neck anatomy is essential.

In the child the larynx, CTM, and cricoid cartilage are smaller and harder to locate. In addition, the cricoid cartilage is easily damaged and the posterior tracheal wall is at greater risk of perforation.

Seldinger cricothyroidotomy techniques are not only more difficult to perform but contraindicated in children less than 40 kg. Needle cricothyroidotomy or a tracheostomy is the preferred options.

The CTM in adults has several desirable features, which makes it easy to perform a cricothyroidotomy in the majority of patients including:



- It is superficial and easily palpated
- It rarely calcifies
- It is relatively avascular and
- It is large enough for a 6.0 mm tube

The cricothyroid space is trapezoid shape with an area of approximately 3.5 cm². It is inferior to the thyroid cartilage, usually 1-1.5 fingerbreadths below the thyroid notch, and superior to the cricoid cartilage. The height averages 9 mm with a width of 30 mm. The structures overlying the CTM include skin and subcutaneous tissues. The vocal cords are 9.8 mm above the cricothyroid space. The superior thyroid artery is on the lateral edge of the CTM in 54% of cases. Any incision in the CTM should be in the midline.

Contraindications.

Absolute contraindications to cricothyroidotomy include crico-tracheal separation and the potential of a less invasive method of securing the airway.

Needle Cricothyroidotomy

A needle cricothyroidotomy does not protect against aspiration.

Oxygenation by low-pressure ventilation (that is, anaesthetic circuit or bag ventilation) is ineffective when used with a needle cricothyroidotomy but can be used in the CICV situation for a short period of time. Oxygenation using high flow rates of oxygen directly through the cannula by narrow tubing is more effective.

The simplest technique is to turn the oxygen flow rate to maximum and just place the end of the tubing firmly over the cannula for several seconds for each breath. Alternatively a three-way tap can connect the oxygen tubing and cannula. The tap is turned to open at all orifices. Obstructing the free orifice of the three-way tap will direct oxygen into the patient.

For optimal ventilation a jet ventilator must be used.

Needle cricothyroidotomy only allows oxygenation. It does not allow effective ventilation. Hypercarbia will occur. More importantly, unless the anaesthetist also makes an attempt to open the upper airway (jaw thrust, Guedel airway, LMA etc), barotrauma will occur.

A 14-gauge intravenous cannula and a 5 ml syringe, with 1 ml of saline, are preferred. (A 10 or 20 ml syringe means that the hand holding the syringe is further away from the cannula reducing dexterity and making insertion more difficult. A 2 ml syringe is the same length as a 5 ml syringe but has a smaller volume increasing the possible of false aspiration).

A right-handed operator should stand on the left of the patient so that the needle can be inserted caudally into the airway with the dominant hand.

The cricothyroid membrane is identified. If this is not possible, then identifying the trachea will be adequate for a cannula cricothyroidotomy. Failing this the midline of the neck should be used.

The trachea is gripped with the non-dominant hand and the needle is advanced, whilst aspirating, directing the needle 45° caudally. In patients where it is difficult to identify the anatomy it may be necessary to insert the cannula in a more perpendicular orientation.

Successful cannulation of the trachea is confirmed by the aspiration of bubbles of air. It is important to identify free aspiration up the whole length of the syringe and by releasing the barrel, actual aspiration can be distinguished from a vacuum effect.

Once the endpoint is successfully identified the non-dominant hand should move to stabilize the cannula. The cannula is advanced over the needle into the airway. This will

require more force than that involved in intravenous placement. It is essential that the cannula be always held to prevent accidental removal.

The position of cannula is confirmed by aspiration of air, again with full aspiration and release of the barrel of the syringe. If this check aspiration fails, then continue to aspirate whilst removing the cannula slightly. The cannula may be kinked or impacted against the posterior wall of the trachea.

Once the position of the cannula is confirmed, oxygenation is commenced with the best technique available. It is essential that the anaesthetist is constantly maintaining the position of the cannula. Accidental movement of the cannula may completely displace the cannula or move it into peritracheal tissue. Attempted ventilation will then cause surgical emphysema, which may make another attempt at a cricothyroidotomy impossible.

Seldinger Cricothyroidotomy

The Seldinger technique is a technique used to obtain safe access blood vessels and other hollow organs. It is named after Dr. Sven-Ivar Seldinger.

The desired vessel or cavity is punctured with a sharp hollow needle called a trocar. A round-tipped guide wire is then advanced through the lumen of the trocar, and the trocar is withdrawn. A sheath or blunt cannula can now be passed over the guide wire into the cavity or vessel.

Seldinger cricothyroidotomy kits (Melker™) contain a needle, scalpel, wire and airway with an introducer.

Familiarisation with the kit is essential before use.

The CTM is identified and a small horizontal skin incision is made in the midline immediately above the upper border of cricoid cartilage.



The needle is inserted into the trachea and its position confirmed as for a needle cricothyroidotomy. The wire is then inserted through the cannula. Difficulty in passing the wire may be due to a kink in the cannula. Withdrawing the cannula slightly should allow the wire to pass. Plenty of wire should be advanced to prevent the wire being accidentally removed during the procedure and to confirm that the wire is in the trachea.

The cannula is carefully withdrawn over the wire. A second stab incision can be made along the wire through the CTM with the scalpel to ease the introduction of the dilator and airway.

The dilator is placed inside the airway and the dilator/airway assembly is passed over the wire. Use of lubricant on the surface of the dilator and on the surface of the airway will

aid insertion. The dilator should be completely seated inside the airway. The operator should grip the dilator/airway firmly, preventing the dilator from moving backwards as the dilator/airway is advanced. The dilator may be pushed back with insertion as there is no locking mechanism on the device.

The dilator/airway assembly is advanced along the wire through the skin and CTM into the trachea. Moderate force may be required. If excessive force is required, check that the dilator is fully seated into the airway and has not been pushed back. Also check the incision and deepen/lengthen if necessary.

It is important that the end of the guide wire can always be seen during the procedure to prevent its accidental loss into the trachea.

Stab cricothyroidotomy.



The stab cricothyroidotomy kits usually contain a conical needle with an over lying sheath and 15 mm connector.

Prior incision of the skin is not required.

Puncture of the trachea is confirmed by aspiration of air and the plastic catheter is slid over the needle into trachea.

Care should be taken, as this technique can potentially injure the posterior wall of the trachea.

Scalpel/bougie cricothyroidotomy.

Seldinger and stab cricothyroidotomy kits are relatively expensive (\$100 – 200 US). The scalpel/bougie cricothyroidotomy uses minimal equipment, which should be immediately available and results in the placement of an airway that allows both oxygenation and ventilation.

The CTM is identified and stabilised with the non dominant hand. With a size 10 (or similar) scalpel in dominant hand, a horizontal stab incision is made through the cricothyroid membrane.

The scalpel blade is then rotated 90⁰ so that the blade points caudally. The scalpel blade is then pulled towards the anaesthetist, maintaining its perpendicular alignment. This

produces a triangular hole. (An alternative technique is to invert the scalpel and insert it through the incision and twist it through 90° but this requires the scalpel to be removed from the trachea at which point the airway may be lost and the un-guarded blade may cause injury to the anaesthetist).

Using the blade as a guide, insert a gum elastic bougie along the trachea feeling for the tracheal rings and/or “hold up” (confirming placement in the airway and not anterior to the neck or in the oesophagus).

Ideally, a “Frova™ intubating stylet” can be used instead of a gum elastic bougie. The Frova intubating stylet is similar to a gum elastic bougie but is more rigid. It is also hollow and has a connector that allows oxygenation through it by insufflation or jet ventilation plus a connector for the detection of end tidal carbon dioxide.

A size 6 endotracheal tube can be railroaded over the gum elastic bougie. Its insertion may be facilitated by continuous rotation.

Complications

Acute complications include:

Failure to establish an airway, prolonged attempts leading to hypoxia and asphyxia, haemorrhage, oesophageal perforation, injury to thyroid or cricoid cartilages, injury to the posterior tracheal wall, misplacement of the tube into the right or left main bronchus, creation of a false passage, aspiration, injury to the larynx and vocal cords, injury to the thyroid and parathyroid glands, surgical emphysema and pulmonary barotraumas.

Late complications include:

Hoarseness, vocal cord paralysis, dysphagia, subglottic stenosis, recurrent laryngeal nerve injury, tracheocutaneous fistula and tracheo-oesophageal fistula.

THE DIFFICULT AIRWAY IN OBSTETRICS

Maternal mortality from anaesthetic causes has reduced over the past two decades due to an increase in the use of regional anaesthesia for caesarean section. Of concern is the recent rise in deaths due to failed intubation, failed ventilation and hypoxia. The risk factors for death under general anaesthesia for caesarean section include obesity, hypertensive disorders of pregnancy and emergency surgery.

The incidence of failed intubation in obstetrics is approximately one in 300 and is up to 10 times greater than in the general population. There are important anatomical and physiologic changes that occur in pregnancy that increase the likelihood of difficult intubation and worsen maternal outcome if it does occur.

Fluid retention and weight gain are common in pregnancy. Oedema of the airway is also more common. Mucosa oedema and swelling increases the risk of airway bleeding, particularly if nasal intubation is performed.

The Mallampati score is worsened in pregnancy and in labour. The chest diameter increases with advancing pregnancy and breast enlargement can make the introduction of the laryngoscope handle more difficult. A short handled laryngoscope with a larger angle is useful. The young woman usually has her own teeth, making the view at laryngoscopy more difficult.

There is an increased risk of aspiration in pregnancy due to raised intra-abdominal pressure, slower gastric emptying (in labour) and lower gastric pH. The reduction in functional residual capacity and increased oxygen consumption make desaturation during periods of apnoea more likely.

Airway assessment

Prevention of difficult intubation includes an accurate assessment of the airway, ensuring that all the necessary equipment for securing the airway is available and appropriate skilled assistance is at hand.

A previous history of difficult intubation is important to elicit. Pre-eclampsia and excess weight gain in pregnancy increases the likelihood of difficulty.

Airway assessment tests are not highly sensitive or specific when used on their own, but their positive predictive value increases if more than one test is applied.

Mouth opening, or inter-incisor gap is measured. If it is less than four centimetres it will be more difficult to introduce a laryngoscope. Sometimes, restriction of head on neck extension will limit mouth opening. Neck mobility at the atlanto-occipital joint is assessed by placing one finger on the mentum and one on the occiput, and asking the patient to maximally extend her head.

Mallampati scoring is done to assess tongue size relative to oral cavity size. During intubation, the tongue is displaced into the floor of the mouth, so measuring the thyromental distance assesses this. Temporomandibular joint function can be assessed by asking the patient to protrude her lower teeth ahead of her upper incisors.

Management plan

Once identified, a plan for management of the difficult airway is formulated. This may include regional anaesthesia or awake intubation. It is the unidentified difficult airway that presents the greater problem. It is important to know and practice a failed intubation drill so this situation can be managed safely. Before proceeding with anaesthesia, it is important to decide (in consultation with the obstetric team) whether or not surgery needs to proceed in the event of a failed intubation, or whether the patient can be awoken.

Awake intubation techniques

The commonest awake intubation technique is flexible fiberoptic intubation. With good local anaesthesia and a small amount of sedation, it is possible to perform awake intubation with minimal discomfort for the patient. In the obstetric patient preparation of the patient will involve explanation of the procedure and gaining the cooperation of the woman, aspiration prophylaxis and an antisialogogue such as glycopyrrolate. The sitting position makes aspiration less likely, reduces aortocaval compression and allows for minimal airway obstruction.

The oral rather than the nasal route of intubation is used in pregnancy to reduce the risk of epistaxis. An oral airway that can be separated will allow the passage of an endotracheal tube and the flexible fiberoptic scope through the mouth.

Local anaesthesia of the airway can be achieved using nerve blocks, nebulised local anaesthetic or topical administration of local anaesthetic. Topical lignocaine is used in doses up to 9 mg per kg. Most local anaesthetic is swallowed when administered in this way, so toxicity is rarely a problem.

Sedation increases patient comfort and can provide amnesia and anxiolysis. It may increase the risk of airway obstruction, aspiration and can produce sedation of the baby. The most common sedative techniques include a targeted propofol infusion, remifentanyl infusion or small boluses of midazolam combined with fentanyl.

The other options for awake intubation include awake blind nasal intubation, awake direct laryngoscopy (under topical anaesthesia), awake retrograde intubation or awake insertion of the laryngeal mask airway (LMA) followed by intubation via the LMA.

Organisational issues

The avoidance of an obstetric airway catastrophe involves good preparation. It is important to have appropriate airway equipment available before embarking on any regional or general anaesthetic technique. Skilled assistance should be available. When

teaching general anaesthesia for obstetrics, a “safe general anaesthetic technique” needs to be taught and a failed intubation drill needs to be agreed upon and practiced.

Equipment

The ‘bare minimum’ equipment required for the management of an obstetric airway includes a laryngoscope with a short handle, long blade with a wide angle, smaller endotracheal tubes (size 6.5 and 7 mm), a gum elastic bougie and laryngeal mask airway. The American Society of Anaesthetists suggests the following for airway management in areas where regional anaesthesia is performed (including the labour ward):

- a. Laryngoscope and assorted blades
- b. Endotracheal tubes with stylets
- c. Oxygen source
- d. Suction source with tubing and catheters
- e. Self-inflating bag and mask for positive pressure ventilation
- f. Medications for blood pressure support, muscle relaxation and hypnosis
- g. Qualitative carbon dioxide detector
- h. Pulse oximeter

The difficult airway trolley in the operating room should contain:

- a. Rigid laryngoscopes with blades of different design and size to those routinely used
- b. LMA
- c. Endotracheal tubes (ETT) of various sizes
- d. ETT guides (semi-rigid stylets, forceps, light wands)
- e. Retrograde intubation kit
- f. At least one device for emergency non surgical airway such as the combitube or intubating LMA
- g. Fibrescopic intubation equipment
- h. Equipment for emergency surgical airway access
- i. Exhaled CO₂ detector

j. Topical anaesthetics and vasoconstrictors

Whatever equipment is stocked, it needs to be maintained and staff should be familiar with its use.

The “Safe Obstetric GA”

Trainees should be taught a technique of general anaesthesia for obstetrics that will minimize the risk of aspiration, ensure oxygenation and hemodynamic stability.

Intubation and monitoring equipment should be ready. The obstetric team should be ready to start surgery immediately after induction. The mother is positioned in the best intubating position and with left lateral tilt to reduce aortocaval compression.

Pre-oxygenate the mother for at least three minutes with high flow oxygen, to allow for a longer period of apnoea. Aim for an end-tidal oxygen concentration of greater than 90%. Give an adequate dose of induction agent (4-7 mg per kilogram of thiopentone), have the assistant apply 20-30 N of cricoid pressure, give an adequate dose of suxamethonium (1.5-2 mg per kg) and allow enough time for it to work before attempting laryngoscopy. Insert the laryngoscope 30 seconds after the dose of suxamethonium. **DO NOT GIVE A SECOND DOSE OF SUXAMETHONIUM.**

Inubate with a cuffed oral endotracheal tube and confirm intubation with capnography and listening for breath sounds with the stethoscope before allowing surgery to proceed.

Failed intubation drill

Each hospital will have a different failed intubation drill that will depend on local resources and expertise.

To activate the drill, failed intubation must be first identified. More often than not, this is not declared early enough. A failed intubation is an emergency that requires prompt action to avoid failed oxygenation.

The first intubation attempt should be your best intubation attempt. One attempt is made with the Kessel blade, a further attempt with a bougie and a third attempt with a different laryngoscope blade is acceptable. If intubation has not been possible after three attempts, activate your failed intubation drill.

Time should not be wasted with repeated attempts at intubation. This will prolong the duration of apnoea and increase hypoxia, as well as cause trauma to the larynx, leading to increased oedema, bleeding and worsening the ability to ventilate the woman.

If there has been a failed intubation, oxygenation is the priority. 100% oxygen is administered via a bag and mask to ventilate the lungs. Expert help should be called for. Cricoid pressure should be continued unless it interferes with ventilation. Once ventilation is established, the decision to awaken the patient or proceed with surgery

needs to be made. Ideally, this decision has been discussed before induction of anaesthesia and before a difficult intubation occurs.

The decision to proceed with surgery is made based on the urgency of the situation and the ability to convert to either regional anaesthesia or perform an awake intubation. There are really only two absolute indications to continue with surgery: maternal cardiac arrest and life-threatening maternal haemorrhage. Contraindications to regional anaesthesia, the inability to perform awake intubation and sudden severe foetal distress are other reasons to continue with surgery after failed intubation (provided ventilation is possible).

If ventilation is possible and there is a need to proceed with surgery, ventilate the patient with high concentrations of inspired oxygenation and keep the patient anaesthetised with a potent halogenated inhalation agent or intravenous propofol. Consider using a LMA fastrach or proseal to help maintain ventilation, or to attempt intubation. Allow spontaneous ventilation if possible. After delivery of the baby, either maintain mask ventilation or perform oral fibreoptic intubation.

If ventilation is not possible after failed intubation, try using a two handed technique for bag and mask ventilation with a Guedel airway. Release cricoid pressure and attempt to insert a LMA. If all attempts at ventilation fail, then cricothyroid puncture and transtracheal jet ventilation or a surgical airway will be required.

The laryngeal mask airway in obstetric general anaesthesia

The laryngeal mask may be used for rescue ventilation in the failed intubation scenario. Because the tip sits at the cricopharyngeus, application of cricoid pressure may make the insertion of the LMA difficult and the presence of the LMA may interfere with the effectiveness of cricoid pressure to stop aspiration. The classic LMA will not protect the lungs from regurgitated material.

Once an LMA is inserted, should the patient then breathe spontaneously and should it be used as a conduit for intubation?

The classic LMA for intubation after failed direct laryngoscopy

Blind intubation via the LMA requires a smaller tube, (size 6) and may be impeded by the epiglottic bars. It has a low success rate and may lead to laryngeal trauma or oesophageal intubation. In addition, the airway tube is too long to ensure that a normal length endotracheal tube will reach the trachea once it is passed through it. Fibreoptic intubation may be possible through the LMA, but there may be long periods of apnoea and it requires special expertise.

The intubating LMA

The intubating LMA or Fastrack, was designed to allow for the passage of an endotracheal tube without the use of a rigid laryngoscope. The endotracheal tube may be introduced over a fibre-optic scope or using a “blind” technique. The success rate using the blind technique is good and takes approximately 50 seconds. The success rate with the fibre-optic technique is higher, but it can take significantly longer (70-75 seconds).

The intubating LMA is able to accept an endotracheal tube of up to 8 mm (internal diameter). It has an epiglottic bar that is attached at the base only, so it moves out of the way of an advancing endotracheal tube and the purpose-designed endotracheal tube has a bullet tip that is more easily passed through the LMA than an ordinary PVC endotracheal tube.

The intubating LMA can be passed into the mouth of a patient with restricted mouth opening, as it will pass through a 20 mm opening with the cuff fully deflated.

The proseal LMA

The classic LMA has a low-pressure seal and high ventilatory pressures will increase the risk of gastric insufflation and gastro-oesophageal reflux and aspiration. The proseal LMA was developed to enable gastric drainage via a gastric lumen. It also has a double-cuff design to allow for higher ventilation pressures without producing a leak (30 cmH₂O). It separates the glottis and the epiglottis and can prevent aspiration of regurgitated material. Its use has been described for rescue ventilation in the failed obstetric airway. Its correct use should be learned in the elective patients first.

Conclusion

Airway catastrophes are more common in the obstetric than the general population. A thorough assessment of the airway is required. The patient should have aspiration prophylaxis when possible and a suitable plan for airway management is mandatory. Decide if surgery must proceed in the event of a failed intubation, keeping in mind that your main responsibility as the anaesthetist is to preserve the mother's life.

Before inducing general anaesthesia for an obstetric patient, have an assistant ready to perform cricoid pressure, prepare your equipment for primary intubation (including suction and oxygen supply), position the patient appropriately and have your equipment for rescue ventilation, an alternative intubation device and means of providing a needle and surgical cricothyroid access available.

The use of a laryngeal mask may help to convert a can't-intubate-can't-ventilate situation into a can't-intubate but *can*-ventilate situation. Correct insertion of the laryngeal mask needs to be learned before its use in this situation.

Remember that hypoxia is what kills the patient, not the failure to intubate. Your first priority is oxygenation and the prevention of aspiration is secondary in the failed intubation situation.

PAEDIATRIC AIRWAY

The principals of management of the paediatric and adult airway are the same: careful assessment and developing an airway management plan.

The paediatric airway is often considered to be more difficult than the adult airway however rather than being difficult, the paediatric airway is usually only different, particularly to anaesthetists who do not manage paediatric airways every day. The paediatric respiratory system has unique anatomical and physiological features, especially in the newborn till the age of 2, which alter with age.



A truly difficult paediatric airway is in fact rare, usually associated with a specific congenital abnormality or syndrome.

In fact, many of the factors that are associated with difficult airways in adults are not present in children including obesity, beards, kyphosis and arthritic bone and joint changes. Similarly, many of the factors associated with reduced or critical respiratory and/or cardiovascular reserve in adults are also not present in children, including ischaemic heart disease, smoking, chronic obstructive pulmonary disease and obesity.

Safe paediatric airway management requires an understanding of the differences in their anatomy and physiology and careful planning of the correct drug dosages of drugs and correct selection of equipment size.

Anatomy.

The entire paediatric airway is smaller and the proportions of the upper airway structures are different from adult proportions.

Infants have a proportionally larger occiput so do not require a pillow to flex their neck into a sniffing position for intubation. They may require slight extension of their head at the atlanto-occipital junction to align the three axes of the airway.

The paediatric airway has a large tongue in proportion to the oral cavity. The tongue may be more difficult to manipulate and stabilize with the laryngoscope blade. Often an oropharyngeal airway may be required with mask ventilation to prevent obstruction by the tongue. The correct size oral airway must be chosen. An airway too long may damage laryngeal structures, damage the uvula or obstruct venous and lymphatic drainage that may cause postoperative airway swelling. An airway too short will rest against the base of the tongue, pushing it posteriorly and therefore increasing airway obstruction. The appropriate size oral airway is equal to the distance between the angle of the mouth and the angle of the mandible of the patient.

Nasopharyngeal airways are occasionally useful in paediatric patients, though are usually avoided as they may cause trauma and bleeding from enlarged adenoids. The correct size nasopharyngeal airway will extend from the nares to the angle of the mandible.

Infants are obligate nasal breathers until the age of 3 to 5 months. Nasal stuffiness from upper respiratory infection may cause respiratory distress. Children also frequently have enlarged tonsils and adenoids, which may also increase the risk of airway obstruction and may make nasal intubation more difficult or traumatic.

The infant larynx is said to be more “anterior” than an adults. In fact, it is higher in the neck (C3/4 compared to C4/5 in an adult) and, because the tongue is relatively large in relation to the oral cavity and mandibular space, it is tucked up beneath the posterior aspect of the tongue.



The epiglottis is large and floppy so may hide the laryngeal inlet. The hyoepiglottic ligament is not well defined and therefore manipulation of the epiglottis with the tip of the laryngoscope blade in the vallecular space is less effective than in an adult.

A straight laryngoscope blade (Miller) is often recommended in neonates and infants as the blade has a thinner side profile to fit easily into the small mouths. The straight blade can easily move the proportionally larger tongue out of the way and the tip of the blade can be placed directly beneath the large and floppy epiglottis, rather than in the vallecular space, to lift the epiglottis anteriorly.

A paraglossal straight blade laryngoscopy technique has been advocated when the standard midline laryngoscopy fails. With the head turned slightly to the left, a narrow, low profile straight laryngoscope is inserted into the extreme right side of the mouth (over the molar teeth). The blade is advanced in the space between the tongue and the lateral pharyngeal wall until the epiglottis is seen.

The improved view obtained is the result of reduced tongue compression. This leads to an improved line of sight and to reduced risk of backwards displacement of the tongue and epiglottis. This technique may be particularly useful for the patient with micrognathia who have reduced intra-oral space for the tongue displacement that is require with traditional midline laryngoscopy.

The trachea is short. The distance, at birth from the vocal cords to the carina is only 4 cm. It is easy to cause extubation with neck extension or accidental traction on the endotracheal tube. Similarly it is easy to cause endobronchial intubation either with neck flexion or slightly too much insertion of the endotracheal tube during intubation.

As small movements of the endotracheal tube can easily cause endobronchial intubation or extubation, it must always be very carefully secured to the infant and the anaesthetic circuit must be supported so that there is no traction on the airway device.

The correct insertion distance is estimated by the formula $\text{age}/2 + 12\text{cm}$. Accurate endotracheal tube must always be confirmed with auscultation of both lungs after intubation and if desaturation occurs during anaesthesia.

The cricoid, not the vocal cords as in an adult, is the narrowest part of the paediatric trachea. An endotracheal tube, which passes through the vocal cords, may still press against the tracheal wall at the level of the cricoid. Excessive subglottic pressure will cause ischaemia/oedema resulting in tracheal narrowing and airway obstruction, (post-intubation croup).

The incidence of post-intubation croup is between 0.1 to 1 %. Factors associated with an increased incidence are too large an endotracheal tube, changing the patient's position during the procedure, positions other than supine, repeated attempts at intubation, traumatic intubation, surgery longer than 1 hour, younger infant, coughing on the endotracheal tube and a previous history of croup. A concurrent upper respiratory tract infection (URTI) may or may not increase the risk of post-intubation croup.

The younger the child, the smaller the cricoid and therefore the smaller the degree of subglottic oedema required to cause critical airway obstruction. For example, assuming that the adult trachea is 8mm in diameter and the infant trachea is only 4 mm, if 1 mm of circumferential oedema occurs, the cross sectional area of the adult trachea is reduced by 44% and resistance is increased 3-fold but the infant trachea is decreased by 75% and resistance is increased 16-fold.

Subglottic stenosis is a potential delayed complication. Ninety percent of acquired subglottic stenosis is the complication of endotracheal intubation.

Traditionally un-cuffed endotracheal tubes are used in children less than 8 years of age though some anaesthetists have recently advocated cuffed endotracheal tubes.

The main concern with cuffed tubes is that the inflated cuff poses an unnecessary added risk of potential pressure ischaemia to the tracheal mucosa. Un-cuffed tubes also present a greater internal diameter for a given outer diameter than cuffed tubes.

With an un-cuffed tube, there should be an air leak after 20 cmH₂O pressure.

Cuffed tubes may have the benefits of reduced intubation attempts (if the tube selected is too small, the cuff can be further inflated), potentially reduced risk of aspiration and reduced contamination of the theatre with anaesthetic gases.

If a cuffed tube is used, the cuff pressure must be constantly monitored, especially if N₂O is used.

The selection of the correct endotracheal tube size is very important. An endotracheal tube, which is too small, will result in an unacceptably large air leak, and one, which is too large may cause post extubation airway obstruction.

There are several formulae to estimate the correct size endotracheal tube. A common formula is $ag/4 + 4$. This formula will not always predict the correct size endotracheal tube. Endotracheal tubes larger and smaller than the predicted size must always also be available.

Paediatric total deadspace is significantly increased by equipment deadspace. The Randell-Baker/Soucek facemasks have less dead space than other masks though masks with an inflated cushion may make obtaining a mask seal easier.

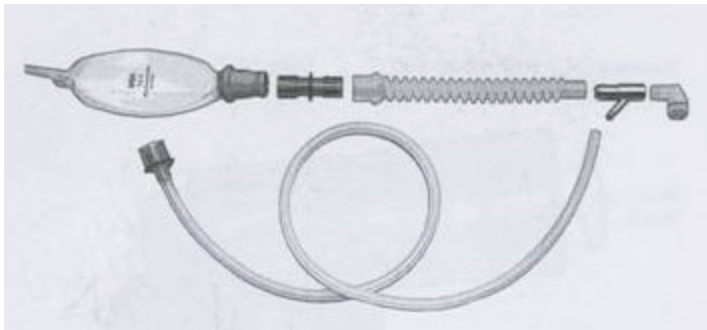
Transparent masks allow observation of respiration and regurgitation of gastric contents.

Jaw thrust is the predominant manoeuvre to open the upper airway. The little finger is placed behind the angle of the jaw and the thumb and index fingers hold the mask in place. The other fingers should be placed on the mandibular bone and not on the soft tissues of the submandibular region as this may obstruct the airway by forcing these soft tissues and the tongue onto roof of the mouth.

The source of airway resistance differs between infants and adults. The nasal passages accounts for 25% of the total resistance to airflow in a neonate, compared with 60% in an adult. In infants, most resistance to airflow occurs in bronchial and small airways. This is because airway diameters are relatively smaller and because the supporting structures of the trachea and bronchi are more compliant.



The Ayres T Piece is usually used in children less than 20 kg as this circuit has no valves or CO₂ absorber so has minimal resistance to respiration. As there is no CO₂ absorber



the fresh gas flow rate must be 2 – 3 times minute ventilation.

A paediatric circle system is available however the work of breathing and inspiratory and expiratory resistance is lower with the Ayres T piece.

The small airways are more prone to collapse with the closing volume above the functional residual capacity. This makes atelectasis more common with general anaesthesia.

The use of some CPAP in neonates and infants to keep small airways open is useful. This can be achieved by partly occluding the tip of the Ayres T Piece circuit bag. It is very good management to always have one hand on the Circuit bag at all times. Bag movement is an instant monitor of the adequacy of respiration and that the airway is located in the correct position.

The thorax of the newborn is bell shaped and softer than adults. The ribs are horizontal rather than bucket handle. The diaphragm and intercostals muscles of an infant can easily fatigue as they have less type one slow twitch fibres.

The abdominal organs are relatively large, which does not allow much extension of the diaphragm during ventilation. Incorrect or excessive ventilation by mask or with a supraglottic device will over inflate the stomach and further impair ventilation by restricting diaphragm movement.

The paediatric airway is more reactive. Respiratory infections or foreign bodies (blood secretions, airway devices) are more likely to cause laryngospasm during light planes of anaesthesia.

The oxygen consumption of a full term newborn (4 to 6 ml/kg/min) is twice that of an adult. Even with adequate preoxygenation, which is not feasible in an uncooperative child, SaO₂ falls to less than 90% within 100 seconds.

Assessment.

A history and physical examination with specific reference to the airway must be performed in all paediatric patients requiring anaesthesia or sedation.

Although many methods exist for evaluating and predicting the difficult airway these have been validated in adults.

There are many factors that should alert the anaesthetist to a potential airway problem including:

- History of a congenital syndrome
- History of previous difficult airway
- History of previous croup
- History of repeated pneumonia
- History of asthma, allergy
- URTI (A recent URTI, within 2 weeks may increase the risk of laryngospasm, bronchospasm, increased airway secretions and desaturation).
- Snoring or noisy breathing
- Hoarse voice
- Inspiratory stridor.

Physical examination should include the following observations:

- Respiratory rate/tachypnoea
- Nasal flaring
- Use of accessory muscles
- Intercostal indrawing/tracheal tug
- Presence of stridor
- Cyanosis
- Mouth opening
- Large tonsils/large tongue
- Loose teeth
- Mallampati
- Facial expression/size of mandible/congenital syndrome

Pharmacology.

Paediatric patients are at great risk of receiving the wrong dosage of a drug. All drug dosages, including rescue drugs, should be calculated before commencing anaesthesia. The correct amount of essential anesthetic drugs should be drawn up into a labeled syringe and the excess drug discarded.

The dose of suxamethonium is 2 mg/kg.

Atropine (0.2 mg/kg) should always be available. In children less than 2 years of age atropine is generally recommended to prevent a bradycardia secondary to suxamethonium or vagal stimulation.

Alternative airway.

Laryngeal masks.

Laryngeal masks have been successfully used in infants and children and provide a secure airway, freeing the anaesthetist from holding a mask without requiring intubation. Though available in sizes for 0 to 5kg (size 1), 5 to 10kg (size 1.5), 10 to 20kg (size 2), 20 to 30kg (size 2.5) and over 30kg (size 3), they may not be advisable in children less than 10 kg in weight. In these smaller children they may not place well and even very small movements will result in a significant reduction in effective airway diameter.

In all ages, laryngeal masks are an excellent rescue airway if conventional airway management fails.

Surgical airway.

The indications for a surgical airway are the same as with an adult.

Children have small pliable and mobile larynx and cricoid cartilage making surgical cricothyrotomy extremely difficult.

Percutaneous needle cricothyrotomy with jet ventilation may be the preferred surgical airway however the cricothyroid membrane is of a small width in infants and children and the cricoid and thyroid cartilages can be easily damaged.

Percutaneous needle cricothyrotomy provides oxygenation but does not reliably provide adequate ventilation. Oxygenation can be achieved by connecting a 3.0 mm endotracheal tube connector to the catheter hub and ventilating with a self inflating bag (with the pop off valve held shut) or by directly applying high flow oxygen, through oxygen tubing to the hub of the catheter.

INHALATION BURN INJURY

Inhalation burn injury occurs in 10 - 20% of patients admitted to burns units and increases the odds ratio of mortality by 2.6. One third of patients with more than 20% burns will have an inhalation burn and this is associated with 50% mortality.

Of great importance is that the life threatening complications of inhalation burn injury (airway obstruction and lung damage) may take hours to develop and may not be maximal until 12 - 24 hours after the initial injury. Patients with an inhalation burn or suspected inhalation burn must be repeatedly reassessed and the anaesthetist should be prepared to intubate early, before airway obstruction becomes critical.

Pathophysiology.

Inhalation burns impair the respiratory system by several mechanisms including direct thermal injury, oxygen deficiency, direct toxins, and systemic toxins and by the systemic inflammatory response syndrome. X-ray changes may be delayed for 24 hours. Early chest X-ray changes are a poor prognostic sign.

Heat (thermal) injury causes immediate damage and delayed damage. The degree of direct thermal injury to the mucosa of the respiratory tract depends on the heat capacity of gas or vapour and duration of exposure. Dry gases are less injurious than saturated vapours.

The heat exchange capabilities of upper airway are so efficient that it is rare to suffer thermal injury below the glottis unless super heated particles have been inhaled (especially particles less than μm^4 or steam) however thermal injury in the upper airway will cause oedema with the potential for airway obstruction. Maximal oedema will not occur until 12 - 24 hours after the injury. Oedema usually resolves within one week. Over hydration may worsen the airway oedema.

Oxygen deficiency results in lung injury, which is maximal in 24 – 48 hours. The cause lung of oxygen deficiency is multifactorial; the fire consumes oxygen so the patient is breathing a hypoxic gas, airway obstruction reduces ventilation, airway oedema reduces oxygen diffusion, carbon monoxide reduces oxygen transport and cyanide impairs oxygen utilization.

Direct airway toxins, created by burning different fuels, include formaldehyde, chlorine, phosgene, SO_2 and NO . The inhalation of these products of combustion leads to a pulmonary inflammatory response similar to that seen after gastric aspiration.

Systemic toxins include carbon monoxide (CO) and cyanide. CO poisoning is the main cause of smoke inhalation related fatalities (up to 80% of deaths). CO binds avidly to Hb preventing oxygen binding and therefore reducing oxygen transport to organs. CO also binds to cytochrome oxidase and inhibits mitochondrial function at a cellular level. The

signs and symptoms of CO poisoning are not specific and include nausea, vomiting, headache, malaise, dyspnoea, seizures, cardiac arrhythmias and coma. CO poisoning must always be suspected if the patient is unconscious or was in an enclosed space.

Pulse oximetry (SaO₂) will read falsely high because HbCO is recognized as oxygenated Hb. HbCO can be measured with arterial blood gas analysis. A HbCO of > 20% is a significant poisoning. Greater than 60% is life threatening.

Cyanide binds to cytochrome a-a₃ complex, which is essential for electron transport during oxidative phosphorylation. Cyanide toxicity presents with coma, apnoea, cardiac arrhythmias and severe lactic acidosis.

Diagnosis.

Because life-threatening complications may be delayed, the anaesthetist must have a high degree of suspicion, repeatedly reassess the patient and be prepared to act early.

The diagnosis of an inhalation burn is clinical, (SaO₂ and chest X-rays are not useful). Inhalation burns should be suspected if there is a history of the patient being in an enclosed space (e.g. car), loss of consciousness, impaired mental state, associated head injury or a steam burn.

Physical examination may reveal subtle signs including singed eyebrows and nasal hairs. More significant signs include facial burns, oropharyngeal burns, dysphonia and the use of accessory muscles. Stridor is a significant sign however only 20% of patients with an airway burn present with stridor.

An altered conscious state or impaired mental state may be due to hypoxia or CO and cyanide poisoning.

Immediate indicators for endotracheal intubation include stridor, hypoxaemia, facial burns with a low conscious level, facial burns and full thickness neck burns, full thickness burns of lips and nose and oropharyngeal oedema.

Imminent signs of airway obstruction include stridor, tracheal tug, intercostals recession and a paradoxical (see-saw) breathing pattern.

Intubation should be performed without delay if oedema or blistering is seen on laryngoscopic examination.

Management.

The management of any emergency should be airway, breathing, circulation, primary survey and secondary survey.

The specific management principals of an inhalation burn injury are:

- Airway and ventilation
- Fluid resuscitation
- Pain management.

Airway and ventilation management.

Every patient with a suspected inhalation burn needs repeated clinical assessment. This may include repeated awake direct laryngoscopy to look for airway erythema or blistering.

The anaesthetist should be prepared to intubate before the airway deteriorates.

Bag mask ventilation, supraglottic airways, laryngoscopy and endotracheal intubation and a surgical airway are all difficult in the patient with an inhalation burn.

Facial oedema and peri-oral oedema will make obtaining a mask seal difficult. Oropharyngeal oedema and glottic oedema may prevent a supraglottic airway from being placed in the correct position. Higher airway pressures will be required to overcome obstruction from oropharyngeal oedema and glottic oedema and decreased airway compliance.

Upper airway oedema and reduced neck mobility will make intubation more difficult. Neck burns may make a surgical airway extremely difficult.

The anaesthetist must fully assess the patient, act early and have a complete plan including a plan for failed intubation or ventilation. The plan will depend on the condition of the patient, the urgency, the resources available and the skill of the anaesthetist.

The goal of every plan is to establish an airway (endotracheal or surgical) before airway obstruction and or severe lung injury occurs.

Awake flexible fibre-optic bronchoscopy allows airway assessment and intubation without airway compromise however it is not always available or anaesthetists may not be skilled in its use.

For patients where an immediate airway is needed or who are not co-operative or in whom a difficult airway is not anticipated, the best plan may be for a rapid sequence induction, direct laryngoscopy and intubation (plus a prepared failed intubation plan).

In co-operative patients where difficulty is anticipated the anaesthetist may choose to use regional airway anaesthesia to assess the difficulty followed by rapid sequence intubation or awake regional anaesthesia intubation depending on the assessment.