The Intensive Connection

Airway management

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Current Status 2017

Completed

This module is updated and maintained by the (ARF) section

Latest Update

Second Edition

Acute Respiratory Failure

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Update Info

Learning Objectives

After studying this module on **Airway management**, you should be able to:

- Make a complete assessment of the airway
- Explain indications, contraindications and techniques for different methods of securing the airway
- Describe correct tracheal tube positioning and confirmation of tracheal tube placement
- Identify techniques to deal with the anticipated and unanticipated difficult airway
- Detail pitfalls in airway management.

eModule Information

COBATrICe competencies covered in this module:

Competencies

1. Manages the care of the critically ill patient with specific acute medical conditions
2. Describes the use of devices for circulatory or respiratory assist
3. Administers oxygen using a variety of administration devices
4. Performs fibreoptic laryngoscopy
5. Performs emergency airway management
6. Performs difficult and failed airway management according to evidence-based protocols
7. Performs endotracheal suction
8. Performs fibreoptic bronchoscopy and BAL in the intubated patient
9. Performs percutaneous tracheostomy

Faculty Disclosures:
The authors of this module have not reported any disclosures.

Duration: 7 hours

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1. Introduction

Airway management is the first step in resuscitation of the critically ill patient. There are basic airway manoeuvres that can be learned quickly by medical and non-medical staff and advanced airway manoeuvres that require training and experience to be used appropriately. Airway management may be achieved simply by confirming the patient has an unobstructed airway and by supplying supplemental oxygen. Alternatively it may require more complex interventions such as tracheal intubation, fibre optic techniques or the establishment of a surgical airway.

Note

Airway skills require knowledge, judgement and clinical practice.

The clinician who takes care of the critically ill patient should have the ability to:

- Make a rapid and complete assessment of the airway
- Secure the airway by different methods
- Be familiar with algorithms for difficult airway management.

The sources below contain much useful information on airway anatomy, causes of airway obstruction and airway management. These references should be read before completion of Task 1.

In text References

(Mort et al. 2009; Lavery and Jamison. 2008)

References

- Mort TC, Gabrielli A, Coons TJ, Behringer EC., Airway Management. In: Civetta, Taylor and Kirby's Critical Care. 4th ed., 2009, ISBN: 978-07817-6869-6
- Lavery GG, Jamison CA., Critical Care Medicine: Principles of Diagnosis and Management in the Adult. 3rd ed., 2008, ISBN: 978-0-323-04841-5

2. Assessment Of Airway

A structured physiological assessment of any critically unwell patient normally begins with an assessment of airway patency. Airway obstruction may arise from pathology affecting any level of the airway, including the mouth, pharynx, glottis, subglottis and the tracheobronchial tree.

2. 1. Airway obstruction

Table 1: Causes of airway obstruction

Anatomical region	Pathology causing airway obstruction

Mouth and oral mucosa	• Mucosal oedema
	  ◦ Anaphylaxis
	  ◦ Angioedema
	  ◦ Thermal or chemical injury
	• Inhaled foreign body
	• Inhaled blood, vomit, secretions
	• Oral cavity infections (i.e. Vincent's or Ludwig's angina)

Pharynx	• Depressed consciousness level
	• Neuromuscular weakness
	• Infective pathology
	  ◦ Abscess
	  ◦ Supraglottitis, epiglottitis
	• Extrinsic compression
	  ◦ Deep neck abscess
	  ◦ Neck haematoma
	• Pharyngeal or hypopharyngeal tumour
	• Inhaled material – foreign body, blood, vomit

Larynx	• Laryngeal oedema
	  ◦ Anaphylaxis
	  ◦ Angioedema
	  ◦ Trauma following airway instrumentation
	  ◦ Thermal or chemical injury
	  ◦ Hypothyroidism
	• Laryngeal tumour
	• Laryngospasm
	• Bilateral vocal cord palsy
	• Laryngotracheobronchitis (croup)

Subglottis and trachea	• Subglottic tumour • Subglottic stenosis • Laryngotracheobronchitis (croup) • Bronchial secretions • Bronchoconstriction • Tracheomalacia • Tracheal stenosis • Inhaled material – foreign body, blood, vomit • Extrinsic compression ◦ e.g. goitre, double aortic arch.

Airway obstruction may be either complete or partial. It can be detected through physical examination according to the “look, listen and feel” approach. This approach prioritizes a rapid assessment – looking for respiratory effort at the chest and abdomen, listening for audible breathing, and feeling for gas flow at the nose and mouth. The clinical signs of airway obstruction are explained in Table 2.

Table 2: Clinical signs of airway obstruction

Degree of airway obstruction	Clinical signs
Complete obstruction	• Silent respiratory effort • Paradoxical “see-saw” chest and abdominal movement • Increased respiratory work with accessory muscles use • Cyanosis?

Partial obstruction	• Voice change, snoring
	• Inability to swallow
	• Visible swelling
	• Tachypnoea
	• Agitation
	• Increased work of breathing
	  ◦ Accessory muscle use
	  ◦ Tracheal tug
	  ◦ Chest wall recession
	• Exhaustion
	• Stertor
	  ◦ “Snoring” noise, often pharyngeal obstruction
	• Stridor
	  ◦ Inspiratory – often laryngeal obstruction
	  ◦ Expiratory – often tracheobronchial obstruction
	  ◦ Biphasic – often glottic or subglottic obstruction

In text References
(Soar et al. 2015; Lynch. and Crawley S. 2018; Sokolovs and Tan. 2017)

References

- Soar J, Nolan JP, Böttiger BW, Perkins GD, Lott C, Carli P, Pellis T, Sandroni C, Skrifvars MB, Smith GB, Sunde K, Deakin CD, Adult advanced life support section Collaborators., European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support., 2015, PMID:26477701
- Lynch J., Crawley S.M., Management of airway obstruction, 2018, https://bjaed.org/article/S2058-5349(17)30194-4/fulltext
- Sokolovs D, Tan KW. , Ear, nose and throat emergencies, 2017, https://www.sciencedirect.com/science/article/pii/S1472029917300188

2. 2. Predicting the difficult airway

The traditional definition of a “difficult airway” is one in which a trained clinician experiences difficulty with face-mask ventilation and/or endotracheal intubation. A more comprehensive definition would also include difficulty with the insertion of a supraglottic airway and in achieving front-of-neck access (FONA), which in the critically ill population, are crucial “rescue techniques”.

In the critically ill patient, a complete assessment of anticipated airway difficulties should consider the ability to achieve:

1. Endotracheal intubation
2. Rescue oxygenation with face-mask ventilation
3. Rescue oxygenation with a supraglottic airway device
4. Rescue front-of-neck airway
5. Maintenance of physiological stability during airway management
6. Avoidance of pulmonary aspiration.

While only approximately 6% of critically ill patients have a technically difficult intubation their physiological derangement may make their airway “physiologically difficult” and place them at high risk of harm when complications arise.

In text References

(Committee on Standards and Practice et al. 2013; Crawley and Dalton. 2015; Royal College of 2018; Higgs et al. 2018; Astin et al. 2012)

2. 2. 1. Predicting difficult face-mask ventilation

If endotracheal intubation attempts have been unsuccessful face-mask ventilation provides a vital means of rescue oxygenation.

Factors that have been identified as predictors of difficult face-mask ventilation are:

- “OBESE mnemonic”
    - Obesity
    - Beard
    - Elderly (>55 years)
    - Snorer
    - Edentulous
- Modified Mallampati class of 3 or 4
- Limited jaw protrusion
- Male gender
- Radiotherapy to neck

Previous neck irradiation, which results in non-compliant, fibrotic tissue, is thought to be the most significant predictor of impossible mask ventilation.

In text References

(Higgs et al. 2018; Crawley and Dalton. 2015; Langeron et al. 2000; Kheterpal et al. 2009)

2. 2. 2. Predicting difficult supra-glottic airway insertion and ventilation

If face-mask ventilation proves impossible and endotracheal intubation has failed, a supraglottic airway (SGA) can maintain rescue oxygenation. Supraglottic airways refer to airway devices that create a seal around the glottis. Laryngeal mask airways may be first or second generation: the second generation devices have a gastric decompression port and generally facilitate intubation using a fibreoptic scope. The CombitudeTM has 2 balloons with 2 lumens and separate ventilation ports.The King LTTM has a similar design to the CombitubeTM. While it has traditionally been argued that face-mask ventilation is the most important skill in airway management, **modern guidelines prioritise the use of a SGA above facemask ventilation** as a means of rescue oxygenation

However, as with mask ventilation and endotracheal intubation, its insertion and use can be technically difficult.

Difficult ventilation through a SGA has been associated with:

- Male gender
- Age >45 years
- Short thyromental distance
- Limited neck movement

Additionally, optimal positioning of the SGA necessitates the removal of cricoid force.

In text References

(Crawley and Dalton. 2015; Langeron et al. 2000; Higgs et al. 2018; Saito et al. 2015)

2. 2. 3. Predicting difficult endotracheal intubation

Endotracheal intubation by direct laryngoscopy requires:

1. Adequate mouth opening
2. Adequate head extension
3. Adequate neck flexion

Many anatomical and pathological variables can impede endotracheal intubation through rendering the larynx inaccessible or by restricting airway instrumentation.

Table 3: Predictors of difficult endotracheal intubation
Limited mouth opening • Trismus e.g. dental abscess • Temporo-mandibular joint dysfunction • Post-radiotherapy fibrosis • Rheumatoid arthritis • Facial burns • Scleroderma • Airway syndromes
Immobility of cervical spine • Spinal immobilisation • Cervical spondylosis • Ankylosis spondylitis • Post-radiotherapy fibrosis • Klippel–Feil abnormalities of the cervical spine.
Specific medical conditions • Obesity • Advanced pregnancy e.g. Third trimester • Marfan's syndrome • Acromegaly
Airway pathology • Epiglottitis • Laryngeal oedema • Lingual tonsil hyperplasia • Ludwig's angina
Thyromental distance <6.5cm
Sternomental distance <12.5cm
Thyromental height <50mm

2. 2. 4. Cervical spine instability

Manual in-line spinal immobilisation is often employed when intubating patients with suspected or proven trauma to their cervical spine. However, precautions should also be taken when cervical spine instability occurs due to other conditions such as rheumatoid arthritis or trisomy 21.

In text References

(Crawley and Dalton. 2015; Raj and Luginbueh 2015)

2. 2. 5. Predicting difficult endotracheal intubation – scoring systems

Clinical examination can be used to anticipate the difficulty of endotracheal intubation. To this end, a variety of clinical scoring systems have been devised. However, the power for these scoring systems to accurately and consistently discriminate between unremarkable and difficult airways is lacking and many difficult intubations remain unanticipated; the risk of grade 3 or 4 intubation being as high as 5%. When patients have previously received airway management (e.g. the operating room) their clinical records should be reviewed to ascertain the ease of face-mask ventilation and previous grade of laryngoscopy (Cormack and Lehane. 1984) .

The modified Mallampati classification

Examination of the oropharynx, with the patient's mouth maximally opened and their tongue maximally protruded may predict a difficult intubation. When more pharyngeal structures are visible the intubation is more likely to be unremarkable. Conversely, when fewer pharyngeal structures are visible the intubation is more likely to be difficult. This assessment can be summarised by the modified Mallampati classification, where classes III and IV are more likely to be associated with difficult intubation.

Table 4: The modified Mallampati classification

Modified Mallampati classification	Visible anatomical structures
Class I	Uvula, faucial pillars, soft palate
Class II	Faucial pillars, soft palate (uvula concealed by tongue)
Class III	Soft palate visible
Class IV	Soft palate invisible

The Wilson Score

Wilson et al identified five anatomical features that are scored to give a prediction of difficult intubation. Each are scored from 0-2 to give a maximum score of 10. These features are:

- Obesity
- Restricted head and neck movements
- Restricted jaw movement
- Receding mandible
- Buck teeth

The MACOCHA Score
The MACOCHA Score is the only tool has been validated for predicting the difficulty of endotracheal intubation in critically ill adults. It is a graduated score ranging from 0 (anticipated easy) to 12 (anticipated very difficult) based upon seven clinical features. These features are displayed in Table 5.

Table 5: The MACOCHA score

Factors	Points
Factors related to patient	
Mallampati score III or IV	5
Obstructive sleep apnoea syndrome	2
Limited mouth opening <3 cm	1
Reduced mobility of cervical spine	1
Factors related to pathology	
Coma	1
Severe hypoxaemia (<80%)	1
Factor related to operator	
Non-anaesthesiologist	1
Total	**12**

In text References

(Crawley and Dalton. 2015; Samsoon and Young. 1987; Wilson et al. 1988; Higgs et al. 2018; De Jong et al. 2013)

2. 2. 6. Predicting difficult front-of-neck access (FONA)

Difficulty in achieving a front-of-neck airway can arise due to:

- Obesity – overlying adipose tissue, impalpable landmarks
- Previous radiotherapy
- Previous surgery e.g. tracheostomy
- Neck masses e.g. thyroid tumour, goitre
- Limited neck extension
- Fixed neck flexion
- Reduced sterno-mental distance

In text References

(Crawley and Dalton. 2015)

References

- Committee on Standards and Practice Parameters, Apfelbaum J., Hagberg C.,Caplan R., Blitt C., ASA 2003 Practice guidelines for management of the difficult airway; an updated report by the American Society of Anaesthesiologists Task Force on Management of the Difficult Airway, 2013, http://anesthesiology.pubs.asahq.org/article.aspx?articleid=1918684
- Crawley SM, Dalton AJ. , Predicting the difficult airway, 2015, https://academic.oup.com/bjaed/article/15/5/253/240658
- Royal College of Anaesthetists , 4th National Audit Project: Major Complications of Airway Management in the UK., 2018, https://www.rcoa.ac.uk/system/files/CSQ-NAP4-Full.pdf
- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine; Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182
- Astin J, King EC, Bradley T, Bellchambers E, Cook TM., Survey of airway management strategies and experience of non-consultant doctors in intensive care units in the UK., 2012, PMID:22874651
- Langeron O, Masso E, Huraux C, Guggiari M, Bianchi A, Coriat P, Riou B., Prediction of difficult mask ventilation., 2000, PMID:10781266
- Kheterpal S, Martin L, Shanks AM, Tremper KK., Prediction and outcomes of impossible mask ventilation: a review of 50,000 anesthetics., 2009, PMID:19293691
- Saito T, Liu W, Chew ST, Ti LK., Incidence of and risk factors for difficult ventilation via a supraglottic airway device in a population of 14,480 patients from South-East Asia., 2015, PMID:26052860
- Raj D, Luginbueh I, Managing the difficult airway in the syndromic child, 2015, https://www.sciencedirect.com/science/article/pii/S1743181617300148
- Cormack RS, Lehane J., Difficult tracheal intubation in obstetrics., 1984, PMID:6507827
- Samsoon GL, Young JR., Difficult tracheal intubation: a retrospective study., 1987, PMID:3592174
- Wilson ME, Spiegelhalter D, Robertson JA, Lesser P., Predicting difficult intubation., 1988, PMID:3415893
- De Jong A, Molinari N, Terzi N, Mongardon N, Arnal JM, Guitton C, Allaouchiche B, Paugam-Burtz C, Constantin JM, Lefrant JY, Leone M, Papazian L, Asehnoune K, Maziers N, Azoulay E, Pradel G, Jung B, Jaber S; AzuRéa Network for the Frida-Réa Study Group., Early identification of patients at risk for difficult intubation in the intensive care unit: development and validation of the MACOCHA score in a multicenter cohort study., 2013, PMID:23348979

2. 3. Advanced airway assessment techniques

Advanced modalities used in airway assessment can diagnose the origin of airway obstruction and aid in airway management.

Flexible nasendoscopy

- Endoscopic examination of the airway to level of the larynx
- Identify intra-luminal cause of airway obstruction
- Dynamic information regarding changes with respiration
- Quick to perform by expert
- Does not infer ease of intubation by direct laryngoscopy

Ultrasound

- Identification of cricothyroid membrane for FONA
- Locate blood vessels to avoid during FONA

Computed tomogram

- Usually performed supine – if unable to lie flat could be performed in lateral position
- May identify cause of extrinsic compression and intrathoracic lesions
- Helpful in identifying airway trauma e.g. laryngeal fracture
- Opportunity for 3D reconstruction or “virtual endoscopy”

Magnetic resonance imaging (MRI)

- Excellent imaging of soft tissue
- Normally unsuited for urgent/emergency cases – need to lie flat for prolonged period of time with airway inaccessible due to receiver coils

In text References

(Lynch. and Crawley S. 2018; Osman and Sum. 2016; Kuo et al. 2011)

References

- Lynch J., Crawley S.M., Management of airway obstruction, 2018, https://bjaed.org/article/S2058-5349(17)30194-4/fulltext
- Osman A, Sum KM., Role of upper airway ultrasound in airway management., 2016, PMID:27529028
- Kuo GP, Torok CM, Aygun N, Zinreich SJ. , Diagnostic Imaging of the Upper Airway, 2011, https://www.atsjournals.org/doi/abs/10.1513/pats.201004-032RN

2. 4. Protective reflexes

The upper airway shares a common pathway with the upper gastrointestinal tract. Protective reflexes exist to safeguard a patent airway and to prevent foreign material entering the lower respiratory tract (pulmonary aspiration). These reflexes depend on the proper functioning of the epiglottis, false and true vocal cords and the sensory supply to the mucous membrane of the pharynx.

What clinical situations/diagnoses are associated with partial or total loss of reflexes protecting patients from pulmonary aspiration?

COMPLETE TASK THEN CLICK TO REVEAL THE ANSWER

Any cause of:

Decreased level of consciousness: intoxication, overdose, brain injury, brainstem dysfunction, stroke, tumour, demyelination, polyneuritis.

Mechanical (motor) impairment of swallowing: pharyngeal tumour, pharyngeal pouch, polyneuritis.

Sensory impairment of pharynx/larynx: local anaesthesia, polyneuritis.

Patients who can swallow normally have intact airway reflexes. Normal speech makes absence of such reflexes unlikely but not impossible. If a patient tolerates an oropharyngeal airway (see later) without gagging then the protective reflexes are either absent or obtunded. The reference below will yield further detail on pharyngeal and laryngeal reflexes if required.

In text References

(Byron and Bailey 2001)

Note

Patients with a decreased level of consciousness (LOC) should be assumed to have inadequate protective reflexes until proven otherwise.

References

- Byron J, Bailey JB, Head and Neck Surgery – Otolaryngology. 3rd ed. , 2001, ISBN: 0781729084

3. Airway Interventions

The inability to establish a definitive airway may be the result of failure to optimise clinical conditions when performing airway manoeuvres. Inexperience and/or lack of skill on the part of the practitioner and lack of skilled assistance are important factors in scenarios in which airway problems are reported.

Common errors include:

- Poor patient positioning
- Failure to ensure appropriate trained assistance in the form of an Anaesthetic Nurse or Operating Department Practitioner
- Faulty light source in laryngoscope/no alternative scope
- Failure to use a longer blade in appropriate patients
- Use of inappropriate tracheal tube (size or shape)
- Lack of immediate availability of airway adjuncts.
- Inadequate anaesthesia and neuromuscular blockade

In text References

(Sagarin et al. 2005; Kluger and Short. 1999; Mayo et al. 2004; Kluger and Bullock. 2002; Robbertze, Posner and Domino. 2006)

References

- Sagarin MJ, Barton ED, Chng YM, Walls RM; National Emergency Airway Registry Investigators., Airway management by US and Canadian emergency medicine residents: a multicenter analysis of more than 6,000 endotracheal intubation attempts., 2005, PMID:16187466
- Kluger MT, Short TG., Aspiration during anaesthesia: a review of 133 cases from the Australian Anaesthetic Incident Monitoring Study (AIMS)., 1999, PMID:10209365
- Mayo PH, Hackney JE, Mueck JT, Ribaudo V, Schneider RF., Achieving house staff competence in emergency airway management: results of a teaching program using a computerized patient simulator., 2004, PMID:15599146
- Kluger MT, Bullock MF., Recovery room incidents: a review of 419 reports from the Anaesthetic Incident Monitoring Study (AIMS)., 2002, PMID:12392453
- Robbertze R, Posner KL, Domino KB., Closed claims review of anesthesia for procedures outside the operating room., 2006, PMID:16829728

3. 1. Patient positioning

Correct patient positioning is essential to facilitate successful airway management. Elevating the head 7–10 cm with a pillow under the occiput and extending the atlanto-occipital joint should align the oral, pharyngeal, and laryngeal axes to provide the best straight line from lips to glottis (sniffing position).

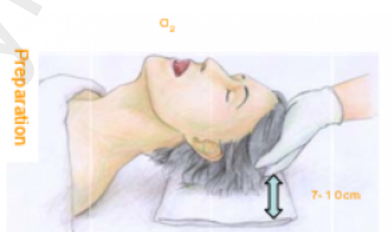

Figure 1: Kathy Mak 2004

In text References

(Mort et al. 2009; Lavery and McCloskey. 2008)

References

- Mort TC, Gabrielli A, Coons TJ, Behringer EC., Airway Management. In: Civetta, Taylor and Kirby's Critical Care. 4th ed., 2009, ISBN: 978-07817-6869-6
- Lavery GG, McCloskey BV., The difficult airway in adult critical care., 2008, PMID:18552680

3. 2. Clearing the airway

Patients who are talking normally may be assumed to have a clear airway. The inability to speak normally, particularly in an obtunded patient, may be due to airway obstruction by the tongue or by material – liquid (saliva, blood, gastric contents) or solid (teeth, broken dentures, food) – in the posterior oropharynx and nasopharynx. Children may obstruct their airway with sweets or small toys in the mouth or further down the airway.

If possible, secretions should be cleared under direct vision with a laryngoscope using a suction device. If oral suction is not possible, the nasopharyngeal route should be used. The finger sweep should be reserved for patients with an abolished gag reflex.

The indications and contraindications for the various airway manoeuvres and associated equipment/techniques are discussed briefly below.

3. 3. Airway Opening Manoeuvres

The combined head-tilt and chin lift is demonstrated in figure 2 whilst the jaw thrust is demonstrated in figure 3. Both manoeuvres are will likely be ineffective when airway obstruction is caused by a foreign body. The head-tilt is contraindicated in situations in which there is concern with regards cervical spine instability.

Figure 2:Head-tilt,Chin lift

Figure 2:Head-tilt,Chin lift

Figure 3:Jaw thrust – Fingers at the angles of the mandible displace the jaw vertically, against counter pressure by the thumbs on the maxillae

3. 4. Artificial airways

Airway opening manoeuvres alleviate obstruction but require the continued presence of a clinician. The insertion of airway adjuncts may provide a patent airway by displacing the tongue from the posterior wall of the pharynx. Any artificial airway should be looked on as a temporary adjunct – to be replaced with a more secure airway if the patient fails to improve to the point where they no longer need an artificial airway. Similarly, such airways should not be used in association with any form of prolonged positive pressure ventilation, although they may be used to facilitate bag-mask ventilation in preparation for tracheal intubation.

3. 4. 1. Nasopharyngeal airway

The nasopharyngeal airway is inserted in an attempt to alleviate airway obstruction and as a method to maintain airway patency. Figure 4 illustrates insertion.

Figure 4.2:

Contraindications to the use of the nasopharyngeal airway are:

- Adults with blocked or narrow nasal passages
- Patients with fractures of the mid-face or base of skull
- When bleeding from the nasal cavity would be disastrous.

Complications of the nasopharyngeal airway include:

- Trauma to nasal turbinates/nasal mucosa
- Bleeding from nasal cavity (especially into pharynx)
- Laryngospasm
- Gagging or coughing (less likely than with oropharyngeal airway)
- Vomiting and aspiration.

3. 4. 2. Oropharyngeal airway

An oropharyngeal airway (also known as the Guedel airway) is the most commonly used artificial airway, as it is relatively simple to insert and should avoid many of the problems associated with the nasopharyngeal airway. It is often used to facilitate oxygenation/ventilation prior to tracheal intubation. Figure 5 describes the insertion of an oropharyngeal airway.

Figure 5.2:Insert the airway in an inverted fashion over the hard palate.

Contraindications to the use of an oropharyngeal airway include (all relative):

- Inability to tolerate oropharyngeal airway (gagging/vomiting)
- Fragile dentition – including presence of prosthetics.

Complications of the oropharyngeal airway:

- Gagging or coughing
- Vomiting and aspiration
- Laryngospasm
- Trauma (teeth, mucosa, tongue etc)
- Worsening airway obstruction o Pushing tongue posteriorly o Lodgement of tip of airway in vallecula.

3. 5. Oxygenation and ventilation

Oxygenation usually requires movement of (inspired) gas down a patent airway to the alveoli. Once a patent airway is achieved, such flow may either be achieved by patient spontaneous effort or by assisted ventilation.

3. 5. 1. Manual ventilation using a mask

If the patient's spontaneous (negative pressure) breathing is either absent or inadequate it should be augmented or replaced with positive pressure ventilation. This positive pressure can be generated manually, using a bag and mask (as part of an anaesthetic circuit/breathing system), a bag-valve-mask or a non-invasive mechanical ventilator. A bag-valve-mask (also known as a BVM or e.g Ambu® bag) is a hand-held device used to provide positive pressure ventilation to a patient who is not breathing or who is breathing inadequately. Manual ventilation using a mask and anaesthetic circuit or a BVM is usually only a short-term measure in urgent situations and/or as a preparation for tracheal intubation. The airway should first be cleared using the manoeuvres described earlier. Failure to clear the airway will produce inadequate ventilation and potential gastric distension and regurgitation. Figure 6 illustrates manual ventilation.

Figure 6.2:Hand position for one-handed bag-mask ventilation. Ensure the airway is patient by extending the head and maintaining a one-handed chin lift and jaw thrust. An oropharyngeal airway may be required. Ensure the mask forms a tight seal against the face. The other hand is used to provide manual ventilation.

In text References
(Mort et al. 2009)

References

- Mort TC, Gabrielli A, Coons TJ, Behringer EC., Airway Management. In: Civetta, Taylor and Kirby's Critical Care. 4th ed., 2009, ISBN: 978-07817-6869-6

3. 6. Tracheal intubation

Main indications for tracheal intubation include:

- Abnormal anatomy
- Previous difficult intubation
- Difficult laryngoscopy of a normal larynx
- Determining the nature and extent of pathology
- Correct positioning of single and double lumen tracheal tubes
- Avoidance of dental damage in high-risk patient
- Minimising neck movement
- Direct laryngeal trauma
- Difficult laryngoscopy of a normal larynx.

It may not be useful or appropriate for:

- Open trauma of the upper airway (gross blood soiling)
- Obstruction below the cords
- A narrow glottic opening easily visible with direct laryngoscopy.

3. 7. 1. Contraindications

- Respiratory:
    - Laryngeal obstruction
    - Severe hypoxaemia
    - Worsening hypercarbia
    - Severe asthma/bronchospasm
    - Pulmonary hypertension
- Haematological:
    - Thrombocytopenia
    - Coagulopathy

3. 7. 2. Conduct of fibre optic intubation

Adequate psychological preparation is essential. Numerous sedation agents have been evaluated, including benzodiazepines, opioids such as alfentanil or remifentanil, and intravenous anaesthetic agents such as (low-dose) propofol infusion. Care must be taken not to overdose the patient and to maintain spontaneous respiration throughout. Supplemental oxygen should be provided, usually through the contralateral nostril. A nasal decongestant such as phenylephrine or xylometazoline to reduce bleeding will be useful particularly when using topical lignocaine.

Topical anaesthesia
Topical anaesthetic agents include lignocaine (lidocaine) or cocaine. Cocaine will produce vasoconstriction but has been associated with myocardial ischaemia. Nebulised lignocaine can be used but may result in high blood lignocaine levels, coughing, and bronchospasm. Anaesthesia of the vocal cords and upper trachea is usually provided by a 'spray as you go' technique using 2% lignocaine. Another potential technique is superior laryngeal and recurrent laryngeal nerve blockade.

Preparation

- Place tracheal tube on fibrescope and ensure free movement
- Tape tracheal tube lightly to fibrescope
- Check movement of fibrescope tip
- Check orientation of camera
- Reassure patient.

Passage of fibrescope and tracheal tube

- Hold fibrescope aloft and straight
- Insert into nasal passage
- Smoothly pass through nasopharynx
- Ask patient to stick out tongue
- Gently suction secretions
- Identify epiglottis
- Slowly advance towards epiglottis
- If view lost, withdraw 1–2 cm
- Smoothly pass through vocal cords (turn may be required)
- Identify tracheal rings

- Inability to obtain/maintain an unobstructed airway by other means
- Long-term prevention of airway obstruction
- Protecting the airway (lack of protective reflexes)
- Inadequate ventilation or oxygenation
- To facilitate positive pressure ventilation
- To facilitate bronchopulmonary toilet
- Life-threatening haemodynamic instability
- Combativeness that prevents emergency diagnostic studies (need for heavy sedation).
- All indications for starting invasive mechanical ventilation

When tracheal intubation is difficult, whether anticipated or not, the choice of simple manoeuvres and/or pieces of equipment can improve the chances of success.

3. 6. 1. Orotracheal intubation

Orotracheal intubation is the standard and most reliable technique for those practised in direct laryngoscopy. Normally, anaesthetic agents and neuromuscular blockade are necessary for this procedure. It is crucial to emphasise that there is no substitute for 'hands on' practice of tracheal intubation. The basic principles should be understood prior to attempting intubation. The performance of laryngoscopy is illustrated in figure 7.

Figure 7:

Figure-7

from ESICM Channel

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In text References

(McCoy and Mirakhur. 1993; McCoy et al. 1996; Konishi et al. 1997; Nishiyama et al. 1997; MacQuarrie, Hung and Law. 1999)

References

- McCoy EP, Mirakhur RK., The levering laryngoscope., 1993, PMID:8292132
- McCoy EP, Mirakhur RK, Rafferty C, Bunting H, Austin BA., A comparison of the forces exerted during laryngoscopy. The Macintosh versus the McCoy blade., 1996, PMID:8984862
- Konishi A, Sakai T, Nishiyama T, Higashizawa T, Bito H., [Cervical spine movement during orotracheal intubation using the McCoy laryngoscope compared with the Macintosh and the Miller laryngoscopes]., 1997, PMID:9028096
- Nishiyama T, Higashizawa T, Bito H, Konishi A, Sakai T., Which laryngoscope is the most stressful in laryngoscopy; Macintosh, Miller, or McCoy?., 1997, PMID:9404140
- MacQuarrie K, Hung OR, Law JA., Tracheal intubation using Bullard laryngoscope for patients with a simulated difficult airway., 1999, PMID:10451135

3. 7. Fibre optic intubation

Awake fibre optic intubation is the technique of choice with an informed, prepared patient and a trained operator with appropriate equipment. The technique ensures that spontaneous respiration and upper airway tone can be maintained.

Fibre optic intubation is particularly useful in many clinical scenarios:

- Poor mouth opening

4. Intubation

4. 1. Risks

Intubation of the critically ill patient is associated with significant risk: the reported incidence of difficult intubation is as high as 23%. Even when intubation is straightforward, hypoxaemia and cardiovascular collapse are commonplace. During instances of difficulty, rates of death or brain damage are 60 times higher in the intensive care unit (ICU) than in the anaesthetic room. For these reasons, every intubation in the critical care setting should be considered high risk.

In text References

(Martin et al. 2011; Simpson et al. 2012; Le Tacon et al. 2000; Heuer et al. 2012; Jaber et al. 2006; De Jong, Jung and Jaber. 2014; Cook et al. 2011)

References

- Martin LD, Mhyre JM, Shanks AM, Tremper KK, Kheterpal S., 3,423 emergency tracheal intubations at a university hospital: airway outcomes and complications., 2011, PMID:21150574
- Simpson GD, Ross MJ, McKeown DW, Ray DC., Tracheal intubation in the critically ill: a multi-centre national study of practice and complications., 2012, PMID:22315326
- Le Tacon S, Wolter P, Rusterholtz T, Harlay M, Gayol S, Sauder P, Jaeger A., Complications of difficult tracheal intubations in a critical care unit, 2000, PMID:11200758
- Heuer JF, Barwing TA, Barwing J, Russo SG, Bleckmann E, Quintel M, Moerer O., Incidence of difficult intubation in intensive care patients: analysis of contributing factors., 2012, PMID:22313071
- Jaber S, Amraoui J, Lefrant JY, Arich C, Cohendy R, Landreau L, Calvet Y, Capdevila X, Mahamat A, Eledjam JJ., Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study., 2006, PMID:16850003
- De Jong A, Jung B, Jaber S., Intubation in the ICU: we could improve our practice., 2014, PMID:25029179
- Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project., Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments., 2011, PMID:21447489

4. 2. Human Factors

Airway misadventures are more likely to be caused by poor non-technical skills than the inability to perform the procedure of intubation fluently. Poor anticipation of problems and suboptimal decision making when crises occur have been noted to be the most common failures. On this basis it is important that equipment is standardised, checklists and algorithms are adhered to and team-working and communication is optimised.

In text References

(Flin et al. 2013; Higgs et al. 2018)

References

- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine; Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182
- Flin R, Fioratou E, Frerk C, Trotter C, Cook TM., Human factors in the development of complications of airway management: preliminary evaluation of an interview tool., 2013, PMID:23682749

4. 3. Airway Assessment

Though there is often a time-critical element to the intubation of the critically ill patient a brief airway assessment should always be undertaken as described in the previous section. Absence of identification of the high risk airway leads to poor planning and subsequent increased morbidity and mortality. When it is recognised that an individual has specific needs the equipment, the team and the site for airway management might need to be altered.

4. 4. Positioning

The ‘sniffing position’ is defined as 35° neck flexion and 15° head extension though the height of head elevation may need to be varied according to the patient’s anatomy: horizontal alignment of the external auditory meatus with the sternum can be used as a marker for proper positioning . This position will optimise the glottis view in most patients. Intubation-related complications and time to intubation are reduced by positioning the patient in a 25 degree back-up position,. For morbidly obese patients the ‘ramped’ position improves the view at laryngoscopy.

In text References

(El-Orbany, Woehlck and Salem. 2011; Reddy et al. 2016; Khandelwal et al. 2016; Collins et al. 2004)

References

- El-Orbany M, Woehlck H, Salem MR., Head and neck position for direct laryngoscopy., 2011, PMID:21596871
- Reddy RM, Adke M, Patil P, Kosheleva I, Ridley S, Anaesthetic Department at Glan Clwyd Hospital., Comparison of glottic views and intubation times in the supine and 25 degree back-up positions., 2016, PMID:27852241
- Khandelwal N, Khorsand S, Mitchell SH, Joffe AM., Head-Elevated Patient Positioning Decreases Complications of Emergent Tracheal Intubation in the Ward and Intensive Care Unit., 2016, PMID:26866753
- Collins JS, Lemmens HJ, Brodsky JB, Brock-Utne JG, Levitan RM., Laryngoscopy and morbid obesity: a comparison of the "sniff" and "ramped" positions., 2004, PMID:15527629

4. 5. Oxygenation

Acute respiratory failure is a common indication for invasive ventilation. As already noted, intubation risks significant hypoxaemia; therefore efforts must be made to optimise oxygenation status (pre-oxygenation); maintain oxygenation during intubation (apnoeic oxygenation) and to improve oxygenation post-intubation (recruitment).

Preoxygenation:

- Preoxygenation is the administration of oxygen to a patient prior to intubation in order to extend the safe apnoea time. Through a process of ‘denitrogenation’ the functional residual capacity (FRC) of the lungs is filled with oxygen which thus acts as a reservoir during apnoea. In health, oxygen consumption is approximately 250 ml/min meaning that apnoea without desaturation may last for up to 10 minutes.
- It is known to be optimal when the end tidal O2 (ETO2) is 90% though it is important to recognise that this monitoring modality is unlikely to be available outwith anaesthetic rooms.
- Preoxygenation to an ETO2 of 90% is often impossible in the critically ill patient because of a reduction in FRC. The effect during apnoea is compounded by the increased oxygen consumption common to the critically ill.
- It can be performed using:
  - head-up tilt in order to increase FRC and,
  - a tight-fitting face mask with 15l/ min O2 and a continuous positive airway pressure (CPAP) valve,
  - over 3 minutes.
- It can alternatively be performed using non-invasive ventilation (NIV). The action of positive pressure is postulated to recruit lung whilst PEEP prevents de-recruitment and has been shown to reduce the incidence of peri-intubation hypoxaemia.
- It can also be improved by the use of high flow nasal oxygen (HFNO).
- In agitated patients preoxygenation can be facilitated by the use of small increments of ketamine.

Apnoeic Oxygenation:

- may be provided by: standard nasal cannula with oxygen supplied at 15l/ min; HFNO and face mask ventilation.

Recruitment manouevres:

- post-intubation have been shown to effectively increase pO2 at 5 and 30 minutes after intubation.

Lastly, a recent small study suggested the benefit of combining HFNO and NIV as a means to provide both pre-oxygenation and apnoeic oxygenation.

In text References

- Advance until carina visible
- Reassure patient – advance tube distally
- Ensure carina remains visible – no endobronchial intubation
- Ask assistant to hold tracheal tube
- Smoothly remove fibrescope
- Reassure patient.

In text References

(Lavery and McCloskey. 2008; Ovassapian. 1996; Popat 2001; Benumof 1996; Koerner and Brambrink. 2005; Reasoner et al. 1995; Graham et al. 1992)

References

- Lavery GG, McCloskey BV., The difficult airway in adult critical care., 2008, PMID:18552680
- Ovassapian A., Fibereoptic Endoscopy and the Difficult Airway. 2nd ed. , 1996, ISBN:0781702720
- Popat M, Practical Fibreoptic Intubation., 2001, ISBN:0750644966
- Benumof JL, Airway Management: Principles and Practice., 1996, ISBN:0815106254
- Koerner IP, Brambrink AM., Fiberoptic techniques., 2005, PMID:16408537
- Reasoner DK, Warner DS, Todd MM, Hunt SW, Kirchner J., A comparison of anesthetic techniques for awake intubation in neurosurgical patients., 1995, PMID:7772974
- Graham DR, Hay JG, Clague J, Nisar M, Earis JE., Comparison of three different methods used to achieve local anesthesia for fiberoptic bronchoscopy., 1992, PMID:1516390

3. 8. Laryngeal mask airway

The laryngeal mask airway (LMA) consists of a small mask at the end of a hollow plastic tube. It is placed 'blindly' in the lower pharynx. The laryngeal mask airway sits obliquely over the laryngeal inlet, with the (distal) tip of the mask sitting at the entrance to the upper oesophagus (posteriorly) and the base of the mask at the base of the tongue (anteriorly). The LMA does not protect the airway from aspiration but, if well positioned, positive pressure ventilation (low/moderate pressure) is possible. The use of the LMA within critical care has a role in oxygenation during cardiac arrest and as part of airway rescue algorithms in the unexpected difficult intubation. As with intubation the technique of insertion should be practised. There are very few contraindications to insertion but LMAs should not be inserted into patients with an active gag reflex and in patients with severe oropharyngeal trauma the LMA is unlikely to provide an adequate airway. When used in airway rescue situations the practitioner should be cognisant of the fact that:

- The airway is not protected from aspiration
- It may move during use and cause airway obstruction
- It does not allow high airway pressures (ventilation with poor chest/lung compliance) to be generated in the airways
- May be dangerous in supraglottic, glottic and infraglottic obstruction
- Does not always provide an adequate airway.

Insertion of an LMA is illustrated in figure 8.

Figure 8:

Figure 8
from **ESICM Channel**

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In text References

(Baillard et al. 2006; Miguel-Montanes et al. 2015; Weingart 2011; Patel and Nouraei. 2011; Frerk et al. 2015; Constantin et al. 2010; Jaber et al. 2016)

References

- Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I, Difficult Airway Society intubation guidelines working group., Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults., 2015, PMID:26556848
- Baillard C, Fosse JP, Sebbane M, Chanques G, Vincent F, Courouble P, Cohen Y, Eledjam JJ, Adnet F, Jaber S., Noninvasive ventilation improves preoxygenation before intubation of hypoxic patients., 2006, PMID:16627862
- Miguel-Montanes R, Hajage D, Messika J, Bertrand F, Gaudry S, Rafat C, Labbé V, Dufour N, Jean-Baptiste S, Bedet A, Dreyfuss D, Ricard JD., Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia., 2015, PMID:25479117
- Weingart SD, Preoxygenation, reoxygenation, and delayed sequence intubation in the emergency department., 2011, PMID:20378297
- Patel A, Nouraei SA., Transnasal Humidified Rapid-Insufflation Ventilatory Exchange (THRIVE): a physiological method of increasing apnoea time in patients with difficult airways., 2011, PMID:25388828
- Constantin JM, Futier E, Cherprenet AL, Chanques G, Guerin R, Cayot-Constantin S, Jabaudon M, Perbet S, Chartier C, Jung B, Guelon D, Jaber S, Bazin JE., A recruitment maneuver increases oxygenation after intubation of hypoxemic intensive care unit patients: a randomized controlled study., 2010, PMID:20426859
- Jaber S, Monnin M, Girard M, Conseil M, Cisse M, Carr J, Mahul M, Delay JM, Belafia F, Chanques G, Molinari N, De Jong A, Apnoeic oxygenation via high-flow nasal cannula oxygen combined with non-invasive ventilation preoxygenation for intubation in hypoxaemic patients in the intensive care unit: the single-centre, blinded, randomised controlled OPTINIV trial., 2016, PMID:27730283

4. 6. Cardiovascular Stability

The incidence of cardiac arrest following intubation ranges from 1.7 to 4.2%. Pre-intubation hypotension is the most consistent variable related to cardiac arrest. Furthermore, up to a third of critically ill patients suffer cardiovascular collapse - defined as SBP ≤65 mmHg at least once or ≤90 mmHg for 30 minutes despite vascular loading with up to 1000 ml and introduction of vasoactive support - after intubation even if they are haemodynamically stable pre-induction . The occurrence of cardiovascular collapse is more common in the elderly, the severely ill and those with acute respiratory failure.

Haemodynamic instability can be targeted by managing the disease process, the pharmacological agents used for induction, apnoea (leading to hypoxaemia and acidaemia) and positive pressure ventilation.

- Hypotension should be managed prior to inducing anaesthesia . Fluid resuscitation followed by the use of peripheral or central vasoconstrictors should be considered.
- Ensure at least 2 sites for intravenous access are available. In an emergency, the intra-osseous route is a viable option.
- The use of the most haemodynamically stable induction agent available is prudent.
- Apnoeic oxygenation to treat hypoxaemia or facemask ventilation to minimise acidaemia should be considered.
- Positive pressure ventilation increases intrathoracic pressure thereby decreasing venous return and thus ultimately cardiac output. The clinician should be alert to this possibility and continue fluid resuscitation and augment vasopressor use with boluses of dilute inotrope in the post-intubation phase. A recruitment manoeuvre is inadvisable during instability.

In text References

(Mosier et al. 2015; Cardenas-Garcia et al. 2015; Barnard et al. 2015)

References

- Mosier JM, Joshi R, Hypes C, Pacheco G, Valenzuela T, Sakles JC, The Physiologically Difficult Airway., 2015, PMID:26759664
- Cardenas-Garcia J, Schaub KF, Belchikov YG, Narasimhan M, Koenig SJ, Mayo PH, Safety of peripheral intravenous administration of vasoactive medication., 2015, PMID:26014852
- Barnard EB, Moy RJ, Kehoe AD, Bebarta VS, Smith JE, Rapid sequence induction of anaesthesia via the intraosseous route: a prospective observational study., 2015, PMID:24963149

4. 7. Monitoring

Standard monitoring should include pulse oximetry, capnography, blood pressure, heart rate, 3 lead ECG and (if available) end-tidal oxygenation.

In text References

(Checketts et al. 2016)

References

- Checketts MR, Alladi R, Ferguson K, Gemmell L, Handy JM, Klein AA, Love NJ, Misra U, Morris C, Nathanson MH, Rodney GE, Verma R, Pandit JJ, Association of Anaesthetists of Great Britain and Ireland., Recommendations for standards of monitoring during anaesthesia and recovery 2015: Association of Anaesthetists of Great Britain and Ireland., 2016, PMID:26582586

4. 8. Equipment and Checklist

The airway equipment available within critical care should be kept to a minimum. It is increasingly recognised that providing a plethora of choices with regards airway equipment in a crisis leads to cognitive overload and paralysis in decision making. On this basis it is recommended that a separate ‘airway rescue trolley’ is available for crises and that it is stocked such that it follows local or preferably national guidelines in managing the unexpected difficult intubation.

Before commencing induction of anaesthesia, it is recommended to perform a pre-intubation checklist; this has been shown to reduce peri-intubation complications in a multi-centre trial. The checklist targets preparation, procedure and post-procedure care. In the preparation phase the patient is fluid resuscitated, preoxygenated using NIV, sedation is prepared and two operators are called upon. Induction of anaesthesia is undertaken using either ketamine or etomidate; suxamethonium and the application of cricoid pressure. The tracheal tube position is confirmed with capnography waveform analysis; thereafter intravenous sedation is commenced; lung-protective ventilation instituted and blood pressure is supported with vasopressors.

In text References

(Greenland 2015; Jaber et al. 2006; Higgs et al. 2018; Frerk et al. 2015)

References

- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine; Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182
- Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I, Difficult Airway Society intubation guidelines working group., Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults., 2015, PMID:26556848
- Jaber S, Amraoui J, Lefrant JY, Arich C, Cohendy R, Landreau L, Calvet Y, Capdevila X, Mahamat A, Eledjam JJ., Clinical practice and risk factors for immediate complications of endotracheal intubation in the intensive care unit: a prospective, multiple-center study., 2006, PMID:16850003
- Greenland KB, Art of airway management: the concept of 'Ma' (Japanese: , when 'less is more')., 2015, PMID:26556849
- Jaber S, Jung B, Corne P, Sebbane M, Muller L, Chanques G, Verzilli D, Jonquet O, Eledjam JJ, Lefrant JY., An intervention to decrease complications related to endotracheal intubation in the intensive care unit: a prospective, multiple-center study., 2010, PMID:19921148

4. 9. Induction drugs and Neuromuscular blocking agents (NMBAs)

The choice of induction agent should take into account: the experience and confidence of the operator in using the drug; the drug’s pharmacological properties; and the patient’s physiological status. Commonly used agents are presented in the table 6 below.

Table 6: induction agents

Drug	Strengths	Weaknesses
Propofol	• Familiar to Anaesthetists • Smooth and rapid induction • Reduces Intracranial pressure (ICP)	• Causes hypotension • Painful on injection

(Benumof 1996; Ferson et al. 2001)

3. 8. 1. Developments of Laryngeal Mask Airway

In 2002 a variation of the classical LMA was introduced. It incorporates an oesophageal (posterior) cuff and lumen for venting of stomach contents. It maintains a seal with higher airway pressures than the standard LMA. Accurate fixation is required in order to maintain the distal end at the upper oesophageal sphincter.

In text References

(Cook, Lee and Nolan. 2005)

A single-use LMA-type supraglottic airway, e.g. i-gel, has a gel-filled noninflatable seal. It moulds to the pharyngeal, laryngeal and perilaryngeal structures and claims to reduce pressure on airway mucosal surfaces. When correctly inserted, the tip of the i-gel is located at the entrance to oesophagus and the 'gastric channel' allows for suctioning of the oesophagus and stomach, passing of a nasogastric tube and venting of trapped gas. It is claimed that optimum positioning is more often achieved with the i-gel.

References

- Benumof JL, Laryngeal mask airway and the ASA difficult airway algorithm., 1996, PMID:8659797
- Ferson DZ, Rosenblatt WH, Johansen MJ, Osborn I, Ovassapian A., Use of the intubating LMA-Fastrach in 254 patients with difficult-to-manage airways., 2001, PMID:11684987
- Cook TM, Lee G, Nolan JP., The ProSeal laryngeal mask airway: a review of the literature., 2005, PMID:16103390

3. 9. Surgical Cricothyroidotomy

A surgical cricothyroidotomy is performed as part of airway rescue strategies in situations where the patient cannot be intubated nor oxygenated. Figure 9 describes the technique. It is important to practice the simplest technique at regular intervals.

Figure 9:

figure 9
from ESICM Channel

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In text References

(Frerk et al. 2015; Higgs et al. 2018)

References

- Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I, Difficult Airway Society intubation guidelines working group., Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults., 2015, PMID:26556848
- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine, Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182

Ketamine	• Analgesic • Preserves upper airway reflexes • Preserves BP • Bronchodilator	• Slower onset of anaesthesia • Increases myocardial oxygen consumption • Increases ICP • Hallucinations • Nausea and vomiting
Etomidate	• Rapid onset • Cardiovascularly stable • Reduces ICP	• Painful on injection • Nausea and vomiting • Interferes with endogenous cortisol secretion
Thiopentone	• Smooth induction • Painless injection • Reduces ICP	• Not pre-made • Hypotension • Laryngospasm common • Intra-arterial injection leads to vasoconstriction • Extravasation causes pain and erythema • Contra-indicated in porphyria • Histamine-release common

Different clinical scenarios lend themselves to the use of different sedatives. For induction of anaesthesia in the patient with cardiovascular compromise etomidate and ketamine provide the best haemodynamic profiles. Though there is concern with regards the use of etomidate in sepsis because of its adrenal suppressive effects there is no definitive evidence of increased mortality when it used as a single dose. There is good evidence that ketamine is as effective as etomidate, though it should be used with caution in patients with ischaemic heart disease as it increases myocardial oxygen consumption. Propofol has many favourable properties and is widely used in the elective setting; if used in the unstable patient judicious concomitant use of a vasopressor is warranted. In those with elevated intracranial pressure (ICP) adequate cerebral perfusion pressure must be maintained to prevent secondary brain injury. Etomidate maintains perfusion whilst reducing ICP; ketamine maintains cardiovascular stability and thus can be safely used in the trauma setting since perfusion pressure will be maintained; propofol reduces ICP and is useful in the stable patient. In status epilepticus propofol is desirable so long as the patient is haemodynamically stable. Both ketamine and propofol provide bronchodilation.

The use of neuromuscular blocking agents (NMBAs) is recommended because they improve intubating conditions, facemask ventilation, supraglottic airway insertion, abolish upper airway muscle tone, optimise chest wall compliance, reduce the number of intubation attempts and reduce complications. Suxamethonium is a rapid-acting depolarising NMBA which provides excellent intubation conditions but has several significant side-effects:

- Hyperkalaemia (increase by 0.5mmol/l from baseline for 3-5 minutes in the average patient but by several mmol/ l in burns and spinal cord injury patients)
- Bradycardia
- Higher incidence of anaphylaxis and anaphylactoid reactions
- Malignant hyperthermia
- Masseter spasm
- Increased intraocular pressure

In addition, muscle fasciculations will lead to increased oxygen consumption and thus potentially increased risk for per-intubation hypoxaemia. An alternative is rocuronium, which is a non-depolarising agent. When given at a dose of 1.2mg/ kg it provides equivalent intubating conditions to suxamethonium .

In text References

(Sprung et al. 2008; Jabre et al. 2009; Higgs et al. 2018; Patanwala et al. 2011)

References

- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine; Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182
- Sprung CL, Annane D, Keh D, Moreno R, Singer M, Freivogel K, Weiss YG, Benbenishty J, Kalenka A, Forst H, Laterre PF, Reinhart K, Cuthbertson BH, Payen D, Briegel J; CORTICUS Study Group., Hydrocortisone therapy for patients with septic shock., 2008, PMID:18184957
- Jabre P, Combes X, Lapostolle F, Dhaouadi M, Ricard-Hibon A, Vivien B, Bertrand L, Beltramini A, Gamand P, Albizzati S, Perdrizet D, Lebail G, Chollet-Xemard C, Maxime V, Brun-Buisson C, Lefrant JY, Bollaert PE, Megarbane B, Ricard JD, Anguel N, Vicaut E,, Etomidate versus ketamine for rapid sequence intubation in acutely ill patients: a multicentre randomised controlled

trial., 2009, PMID:19573904
- Patanwala AE, Stahle SA, Sakles JC, Erstad BL., Comparison of succinylcholine and rocuronium for first-attempt intubation success in the emergency department., 2011, PMID:21182564

4. 10. Plan for difficulty

As has been emphasised, intubation of the critically ill patient is a high risk procedure and thus plans should be made for difficulty. Several national guidelines exist outlining processes to manage the 'failing' airway. Very recently, national guidelines specific to ICU management have been published. A plan for failure should be verbalised as part of the intubation checklist and all staff members should be clear as to what rescue strategies will be used and how many attempts at success made prior to moving to the next stage. The vortex approach emphasises avoiding repeated attempts with the same technique when difficulties arise. The priority at all times is oxygenation.

In text References

(Piepho et al. 2015; Law et al. 2013; American Society of Anesthesiologists Task Force on Management of the Difficult. 2003; Myatra et al. 2016; Chrimes and . 2016)

References

- Piepho T, Cavus E, Noppens R, Byhahn C, Dörges V, Zwissler B, Timmermann A, S1 guidelines on airway management : Guideline of the German Society of Anesthesiology and Intensive Care Medicine., 2015, PMID:26727936
- Law JA, Broemling N, Cooper RM, Drolet P, Duggan LV, Griesdale DE, Hung OR, Jones PM, Kovacs G, Massey S, Morris IR, Mullen T, Murphy MF, Preston R, Naik VN, Scott J, Stacey S, Turkstra TP, Wong DT; Canadian Airway Focus Group., The difficult airway with recommendations for management--part 1--difficult tracheal intubation encountered in an unconscious/induced patient., 2013, PMID:24132407
- American Society of Anesthesiologists Task Force on Management of the Difficult Airway., Practice guidelines for management of the difficult airway: an updated report by the American Society of Anesthesiologists Task Force on Management of the Difficult Airway., 2003, PMID:12717151
- Myatra SN, Ahmed SM, Kundra P, Garg R, Ramkumar V, Patwa A, Shah A, Raveendra US, Shetty SR, Doctor JR, Pawar DK, Ramesh S, Das S, Divatia JV, The All India Difficult Airway Association 2016 guidelines for tracheal intubation in the Intensive Care Unit., 2016, PMID:28003694
- Chrimes, N. , The Vortex: a universal 'high-acuity implementation tool' for emergency airway management, 2016, https://academic.oup.com/bja/article/117/suppl_1/i20/1744273

4. 11. Specific Circumstances

Over and above the circumstances already described there are several situations whereby intubation will be predicted to be difficult. These and their management are briefly described below.

4. 11. 1. Physiological challenges

Acute pulmonary hypertension and acute right ventricular (RV) dysfunction. The normal pulmonary circulation is a high-flow, low-pressure system. The thin-walled right ventricle tolerates acute increases in afterload poorly which leads to dilation. Dilation of the RV leads to a reduction in stroke volume and paradoxical movement of the interventricular septum which causes reduced filling and impaired contractility (as a result of the abnormal biomechanics) of the left ventricle (LV). The resulting reduction in cardiac output causes a fall in blood pressure (BP). This reduced systemic pressure and increased RV pressure impairs coronary perfusion which creates a vicious cycle whereby the RV becomes more ischaemic and thus dilates further still. Management of acute RV dysfunction relates to:

- ensuring adequate but not excessive RV filling;
- maximizing RV myocardial function with inotropic support;
- reducing pulmonary vascular resistance (PVR) with pulmonary vasodilators, oxygen, normocapnoea, avoidance of acidaemia and optimising lung volume (both atelectasis and distended lung volumes increase PVR);
- maintenance of coronary perfusion with vasoconstriction.

The principles of intubation in this scenario are:

- avoidance of intubation if possible;
- judicious use of fluid and early recourse to vasopressors. The addition of dobutamine may improve inotropy and cause pulmonary vasodilation;
- minimise hypoxaemia and hypercapnoea during intubation;

- ventilate using driving pressures less than 18cm H2O and other standard lung protection measures. Prone ventilation may improve gas exchange and reduce pulmonary artery pressures once the patient is intubated.

Metabolic acidosis. In cases of severe metabolic acidaemia due to, for example diabetic ketoacidosis, patients develop a high compensatory minute ventilation. Intubation should be avoided if possible because even a brief apnoeic period can lead to a precipitous drop in pH. Furthermore, it may be impossible to match the spontaneous minute ventilation using mandatory ventilation, thus acidaemia is exacerbated. If intubation is necessary:

- minimise apnoea;
- hyperventilate immediately after intubation and consider reversing the NMBA using sugammadex if rocuronium is used;
- continuous renal replacement therapy may allow rapid restoration of a normal acid-base status.

Cardiac tamponade. Fluctuations in pleural pressure during positive pressure ventilation are transmitted to the pericardial sac leading to reductions in right ventricular end-diastolic pressure and cardiac output in cardiac tamponade. Furthermore, cardiac arrest can follow small decreases in preload in cases of cardiac tamponade. Thus, intubation and positive pressure ventilation risk cardiac arrest by preventing adequate venous return to the right heart. On this basis, it has been suggested that intubation and positive pressure ventilation is delayed until a surgeon is available to perform thoracotomy.

Intracerebral hypertension. The goal of airway management in cases of raised ICP is to prevent secondary injury. Cerebral perfusion pressure (CPP) is the mean arterial pressure (MAP) minus the intracranial pressure (ICP). The principles of intubation of the brain injured patient are:

- use of adequate sedatives and analgesics in order to prevent deleterious hypertension which might arise as a result of the reflex sympathetic response during laryngoscopy;
- avoidance of hypotension during induction as this will lead to reduced CPP;
- intubation in the reverse Trendelenberg position if possible as this reduces ICP;
- minimisation of the apnoeic period as even small rises in pCO2 can cause a rise in ICP;
- maintenance of oxygenation throughout;
- elevation of the head immediately following intubation;
- avoidance of hyperventilation because cerebral vasoconstriction increases injury to the ischemic area.

In text References

(Price et al. 2010; Repessé, Charron and Vieillard-Baron. 2016; Mosier et al. 2015; Faehnrich et al. 2003; Mackersie 2010; Ho et al. 2009; Jung 2015)

4. 11. 2. Known difficult intubation

Ideally, an awake intubation should be performed in patients known to be difficult or indeed who are suspected of being difficult. Unfortunately there are several reasons why this may not be possible in the critically ill patient and recent guidelines have advised that this technique is reserved for suitably skilled and experienced clnicians. The use of HFNO in this situation has several advantages. Insertion of a supraglottic airway in order to guide passage of a fibreoptic scope allows maintenance of oxygenation and may be an alternative to the awake technique in such circumstances. Lastly, videolaryngoscopy (VL) reduces failed intubations including in patients with anticipated difficult airways. Thus, use of VL as first line by an experienced practitioner could be considered.

In text References

(Frerk et al. 2015; Higgs et al. 2018; Badiger et al. 2015; Lynch. and Crawley S. 2018; Lewis et al. 2017)

4. 11. 3. The obstructed airway

Patients may present in extremis with an obstructed airway as a result of infection or tumour. In these circumstances there is no optimal technique. The use of adrenaline nebulisers and intravenous steroids may reduce swelling and potentially buy time.

Involvement of ENT colleagues can prove invaluable:

- nasendoscopy allows visualisation of the airway;
- awake tracheostomy may be possible if the patient can comply with lying flat;
- and if not, and a general anaesthetic is required, the use of rigid scopes may be of assistance in intubation.

If general anaesthesia is necessary an intravenous induction followed by the early use of NMBAs (will improve face mask ventilation); administration of oxygenation with HFNO (prolongs apnoea time); and the use of VL is a reasonable management option. A plan for emergency front of neck access should be made prior to induction and communicated to the team.

In text References

(Lynch. and Crawley S. 2018; Nouraei et al. 2008)

4. 11. 4. Trauma

Trauma to the airway can include maxillofacial trauma, laryngotracheal trauma, and disruption of the trachea and bronchi.

- In maxillofacial trauma the main problems relate to blood in the airway making videolaryngoscopy relatively contra-indicated. Rarely, impaction of the mandibular condyls makes mouth opening impossible after induction of anaesthesia. Standard laryngoscopy is the usual choice in facial injuries but consideration to awake FONA should be given.
- Injury to the airway below the cricoid cartilage is difficult to diagnose. A high index of suspicion in conjunction with nasendoscopy, CT imaging and bronchoscopy are helpful. It is safest to instrument the trachea under direct vision whilst maintaining spontaneous ventilation in order to avoid entering a tear, creating a false passage, or disrupting the airway completely. The approach to these injuries is dependent on time and patient cooperation:
    - Awake Tracheostomy (provided the lesion is not distal to the site of surgery).
    - Awake fibreoptic intubation.
    - Fibrescope-assisted laryngoscopy whereby a small-diameter tracheal tube is placed at the larynx under direct vision, then a fibrescope is passed through the tube and into the trachea and past the lesion followed by carefully railroading the endotracheal tube. This is done before positive pressure ventilation is applied in order to prevent insufflation of gases via the tracheal injury.

4. 11. 5. Cervical spine immobilisation

Injury to the cervical spinal cord at the level of C6 vertebra places patients at high risk for requiring invasive ventilation; swelling related to the injury is liable to cause ascending weakness in the first 72 hours after injury. It is important to exclude a surgically remediable cause for changes in neurology (such as an expanding haematoma) via an MRI scan. Though rare, airway management may worsen neurological injury. Considerations when intubating patients with potentially unstable cervical spine injuries are:

- spinal immobilisation is required and will worsen view at laryngoscopy;
- retropharyngeal haematoma may be present;
- delayed gastric emptying leads to increased risk of aspiration;
- cricoid pressure might risk displacement of vertebral fragments;
- neurogenic shock risks both bradycardia and vasodilatory hypotension;
- suctioning and airway instrumentation can cause profound bradycardia;
- hypotension reduces cord perfusion and risks further secondary neurological injury;
- suxamethonium should be avoided after 48-72 hours post-injury .

Airway management options are: direct laryngoscopy under general anaesthesia; videolaryngoscopy under general anaesthesia; awake fibreoptic intubation; and asleep fibreoptic intubation via a supraglottic airway device.

In text References

(Thiboutot et al. 2009; Austin, Krishnamoorthy and Dagal 2014)

4. 11. 6. Burns

Burns to the upper airway caused by direct heat and steam injury, electrocution, or contact with corrosive chemicals can lead to marked swelling which may result in airway obstruction . Smoke inhalation meanwhile causes injury to the bronchial tree, lung parenchyma and risks systemic toxicity through carbon monoxide and cyanide poisoning. With time, airway burns will swell: the risk of difficulties during intubation rising from approximately 3.5% to 16.9% the longer the duration between injury and intubation. Conversely, lower risk patients with smoke inhalation injury only may not require intubation. If it is decided not to intubate serial nasendoscopy allows for assessment of swelling of the true and false vocal cords . When intubating the patient with burns it is important to use an uncut tube to compensate for airway swelling.

In text References

(Zatriqi et al. 2013; Esnault et al. 2014; Eastman et al. 2010; Amani, Lozano and Blome-Eberwein. 2012; Madnani, Steele and de Vries. 2006)

4. 11. 7. Mediastinal mass

Mediastinal masses can compress the major airways and vessels. In the presence of severe symptoms of cardiorespiratory compression such as positional dyspnoea, orthopnoea, stridor, syncope, and superior venacava obstruction (SVCS), administration of anaesthesia, muscle relation and institution of positive pressure ventilation may be fatal . For this reason, induction of anaesthesia should be avoided if possible. CT imaging and echocardiography provide valuable information as to the anatomy of the lesion.

- If it is impossible to avoid intubation it is important to ascertain if certain positions alleviate symptoms since repositioning of the patient under anaesthesia may be performed as a rescue manoeuvre.
- A spontaneous breathing technique is preferred since the natural negative intrapleural pressures act to maintain integrity of the airways. If the lesion is compressing the trachea an awake fibreoptic intubation allows passage of the endotracheal tube distal to the narrowing before general anaesthesia. Target controlled infusion of propofol allows maintenance of spontaneous ventilation for more distal compression.

- Use of a rapidly reversible NMBA (if required) such as rocuronium allows assessment of the response to muscle relaxation with the potential to revert to spontaneous breathing if airway occlusion occurs.
- Because front of neck access will not provide a definitive airway, contingency plans need to be made prior to inducing anaesthesia. The options include:
  - Emergency thoracotomy and tumour debulking ;
  - Femoro-femoral cardiopulmonary bypass or extracorporeal membrane oxygenation.

In text References

(Datt and Tempe. 2005; Prakash, Abel and Hubmayr. 1988; Jensen, Milne and Salerno. 1983; Kim et al. 2017)

References

- Lynch J., Crawley S.M., Management of airway obstruction, 2018, https://bjaed.org/article/S2058-5349(17)30194-4/fulltext
- Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM, Difficult Airway Society, Intensive Care Society, Faculty of Intensive Care Medicine; Royal College of Anaesthetists., Guidelines for the management of tracheal intubation in critically ill adults., 2018, PMID:29406182
- Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, Patel A, O'Sullivan EP, Woodall NM, Ahmad I, Difficult Airway Society intubation guidelines working group., Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults., 2015, PMID:26556848
- Price LC, Wort SJ, Finney SJ, Marino PS, Brett SJ., Pulmonary vascular and right ventricular dysfunction in adult critical care: current and emerging options for management: a systematic literature review., 2010, PMID:20858239
- Repessé X, Charron C, Vieillard-Baron A., Acute respiratory distress syndrome: the heart side of the moon., 2016, PMID:26627538
- Mosier JM, Joshi R, Hypes C, Pacheco G, Valenzuela T, Sakles JC, The Physiologically Difficult Airway., 2015, PMID:26759664
- Faehnrich JA, Noone RB Jr, White WD, Leone BJ, Hilton AK, Sreeram GM, Mark JB., Effects of positive-pressure ventilation, pericardial effusion, and cardiac tamponade on respiratory variation in transmitral flow velocities., 2003, PMID:12635060
- Mackersie RC, Pitfalls in the evaluation and resuscitation of the trauma patient., 2010, PMID:19945596
- Ho AM, Graham CA, Ng CS, Yeung JH, Dion PW, Critchley LA, Karmakar MK., Timing of tracheal intubation in traumatic cardiac tamponade: a word of caution., 2009, PMID:19059695
- Jung JY, Airway management of patients with traumatic brain injury/C-spine injury., 2015, PMID:26045922
- Badiger S, John M, Fearnley RA, Ahmad I, Optimizing oxygenation and intubation conditions during awake fibre-optic intubation using a high-flow nasal oxygen-delivery system., 2015, PMID:26253608
- Lewis SR, Butler AR, Parker J, Cook TM, Schofield-Robinson OJ, Smith AF, Videolaryngoscopy versus direct laryngoscopy for adult patients requiring tracheal intubation: a Cochrane Systematic Review., 2017, PMID:28969318
- Nouraei SA, Giussani DA, Howard DJ, Sandhu GS, Ferguson C, Patel A., Physiological comparison of spontaneous and positive-pressure ventilation in laryngotracheal stenosis., 2008, PMID:18577538
- Thiboutot F, Nicole PC, Trépanier CA, Turgeon AF, Lessard MR., Effect of manual in-line stabilization of the cervical spine in adults on the rate of difficult orotracheal intubation by direct laryngoscopy: a randomized controlled trial., 2009, PMID:19396507
- Austin N, Krishnamoorthy V, Dagal A, Airway management in cervical spine injury., 2014, PMID:24741498
- Zatriqi V, Arifi H, Zatriqi S, Duci S, Rrecaj Sh, Martinaj M., Facial burns - our experience., 2013, PMID:23687458
- Esnault P, Prunet B, Cotte J, Marsaa H, Prat N, Lacroix G, Goutorbe P, Montcriol A, Dantzer E, Meaudre E, Tracheal intubation difficulties in the setting of face and neck burns: myth or reality?, 2014, PMID:25151328
- Eastman AL, Arnoldo BA, Hunt JL, Purdue GF., Pre-burn center management of the burned airway: do we know enough?, 2010, PMID:20634705
- Amani H, Lozano DD, Blome-Eberwein S., Brother, have you got a light? Assessing the need for intubation in patients sustaining burn injury secondary to home oxygen therapy., 2012, PMID:22362172
- Madnani DD, Steele NP, de Vries E., Factors that predict the need for intubation in patients with smoke inhalation injury., 2006, PMID:16696366
- Datt V, Tempe DK. , Airway Management In Patients with Mediastinal Masses. , 2005, http://medind.nic.in/iad/t05/i4/iadt05i4p344.pdf
- Prakash UB, Abel MD, Hubmayr RD., Mediastinal mass and tracheal obstruction during general anesthesia., 1988, PMID:3172849
- Jensen V, Milne B, Salerno T., Femoral-femoral cardiopulmonary bypass prior to induction of anaesthesia in the management of upper airway obstruction., 1983, PMID:6336547
- Kim S, Khromava M, Zerillo J, Silvay G, Levine AI. , Anesthetic Management of a Patient With Tracheal Dehiscence Post–Tracheal Resection Surgery, 2017, http://journals.sagepub.com/doi/abs/10.1177/1089253217730906

5. Care of the Intubated Patient

5. 1. Preventing unplanned extubation

Unplanned extubation can be considered according to two categories:

1. Self-extubation – The patient deliberately removes their endotracheal or tracheostomy tube prematurely, when this had not been planned by the critical care team
2. Accidental extubation – The endotracheal or tracheostomy tube is removed accidentally. For example, due to:
    - inadequate fixation
    - patient coughing
    - position changes
    - patient transfers.

Studies report a variable incidence of unplanned extubation, with episodes occurring in between 0.3% and 14% of patients.

5. 1. 1. Risk factors for unplanned extubation

- Agitation
- Delirium
- Male gender
- Increasing patient age
- Chronic respiratory conditions
- History of previous unplanned extubation
- Lack of proper supervision
- Inadequate sedation
- Inadequate fixation of endotracheal tube
- Oral endotracheal intubation

Some of these risk factors may be influenced by confounding. For example, increasing age and chronic respiratory conditions may be associated with a longer duration of mechanical ventilation with more opportunity for unplanned extubation.

5. 1. 2. Consequences of unplanned extubation

- Successful liberation from mechanical ventilation - up to 53% do not require re-intubation
- Need for re-intubation (47%)
- Increased duration of mechanical ventilation
- Increased length of ICU stay
- Pulmonary aspiration
- Respiratory failure
- Arrhythmia
- Bronchospasm
- Cardiac arrest

Unplanned extubation leads to premature cessation of mechanical ventilation. However, not all patients will require re-intubation and to recommence mechanical ventilation; approximately 50% of patients do not require re-intubation. This may reflect the difficulty that critical care physicians experience when assessing patients' suitability for extubation. Patients are more likely not to require re-intubation if their unplanned extubation occurs during the weaning phase of mechanical ventilation. Some studies have shown an association with unplanned extubation and increased ICU and hospital mortality. However, this effect is not apparent when compared with matched controls.

5. 1. 3. Methods to prevent unplanned extubation

- Adequate fixation of endotracheal tube
- Vigilance to detect displacement
- Maintaining a fixed position of the endotracheal tube with reference to patient's teeth
- Treat delirium and agitation

In text References

(Kiekkas et al. 2013; Minnick et al. 2007; de Groot et al. 2011; Chao et al. 2017; , Frutos-Vivar and Esteban. 2011; Epstein, Nevins and Chung. 2000)

References

- Kiekkas P, Aretha D, Panteli E, Baltopoulos GI, Filos KS., Unplanned extubation in critically ill adults: clinical review., 2013, PMID:23577947
- Minnick AF, Mion LC, Johnson ME, Catrambone C, Leipzig R., Prevalence and variation of physical restraint use in acute care settings in the US., 2007, PMID:17393963
- de Groot RI, Dekkers OM, Herold IH, de Jonge E, Arbous MS., Risk factors and outcomes after unplanned extubations on the ICU: a case-control study., 2011, PMID:21232123
- Chao CM, Sung MI, Cheng KC, Lai CC, Chan KS, Cheng AC, Hsing SC, Chen CM, Prognostic factors and outcomes of unplanned extubation., 2017, PMID:28819204
- Peñuelas Ó, Frutos-Vivar F, Esteban A., Unplanned extubation in the ICU: a marker of quality assurance of mechanical ventilation., 2011, PMID:21392405
- Epstein SK, Nevins ML, Chung J., Effect of unplanned extubation on outcome of mechanical ventilation., 2000, PMID:10852766

5. 2. Endotracheal tube cuff pressure

Air is used to inflate the cuff of an endotracheal or tracheostomy tube. This allows the cuff to form a seal against the tracheal mucosa to facilitate positive pressure ventilation without an air leak. The pressure exerted by the air within the cuff must be regularly monitored with a manometer.

Low endotracheal cuff pressures are associated with:

- Ineffective mechanical ventilation (in volume-controlled modes)
- Pulmonary aspiration
- Ventilator-associated pneumonia (VAP)
- Leaks
- Autotriggering of the ventilator

High endotracheal cuff pressures are associated with:

- Necrosis of tracheal mucosa
- Tracheal stenosis

A minimum cuff pressure of at least 20 cmH2O is required to protect from the risk of VAP. Cuff pressures of greater than 30 cmH2O are associated with damage to the tracheal mucosa.

In text References

(Lorente et al. 2014; Vyas, Inweregbu and Pittard. 2002; American Thoracic and Infectious Diseases Society of. 2005; Seegobin and van Hasselt. 1984)

References

- Lorente L, Lecuona M, Jiménez A, Lorenzo L, Roca I, Cabrera J, Llanos C, Mora ML., Continuous endotracheal tube cuff pressure control system protects against ventilator-associated pneumonia., 2014, PMID:24751286
- Vyas D, Inweregbu K, Pittard A., Measurement of tracheal tube cuff pressure in critical care., 2002, PMID:11892637
- American Thoracic Society, Infectious Diseases Society of America., Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia., 2005, PMID:15699079
- Seegobin RD, van Hasselt GL., Endotracheal cuff pressure and tracheal mucosal blood flow: endoscopic study of effects of four large volume cuffs., 1984, PMID:6423162

5. 3. Humidification

The process of humidification describes the addition of water molecules to a gas. Air is normally heated and humidified during inspiration. Air that is fully saturated at room temperature (20oC) has an absolute humidity of 17 g m−3. During inspiration, as air passes distally from the nose towards the alveoli, it gains heat and humidity from the surrounding mucosa and respiratory mucus. It is heated to body temperature (37oC) and becomes fully saturated with an absolute humidity of 44 g m−3. The point at which this inspired air becomes heated and fully saturated is termed the "isothermic saturation boundary" (ISB) and, at rest, is anatomically located just distal to the carina.

Medical gases are cold and contain little water. Furthermore, endotracheal tubes and tracheostomies bypass the nose allowing cold, dry gases to be delivered to the trachea. Inhaling gas with a low humidity causes the isothermic saturation boundary to move more distally within the tracheobronchial tree and a greater proportion of water must be absorbed from the respiratory mucus.

Inadequate humidification of inspired gases is associated with:

- Tenacious, viscous secretions
- Impaired cilia function
- Impaired mucus clearance
- Obstruction of endotracheal tube/tracheostomy
- Bronchial obstruction
- Increased airway resistance
- Atelectasis
- Ventilation/perfusion mismatch
- Damage to respiratory epithelium - keratinisation, ulceration, necrosis
- Predisposition to infection

Excessive humidification of inspired gases is associated with:

- Reduced viscosity of secretions
- Increased mucus volume
- Overwhelming of normal cilia functioning
- Predisposition to infection
- Atelectasis
- Thermal injury

Humidification of inspired gases is a crucial component of caring for critically ill patients. It is essential for those with an artificial airway, and should also be considered for those receiving non-invasive ventilation (NIV) or high flow nasal cannulae (HFNC), where the rate of fresh gas flow may overwhelm the physiological humidification mechanisms.

Humidification in critical care may be facilitated by passive or active systems.

Passive systems

- Heat and moisture exchangers (HME)

Active systems

- Bubble humidifiers
- Nebulisers
- Heated humidifiers

5. 3. 1. Heat and moisture exchangers (HME)

HME devices contain a hygroscopic or hydrophobic material. During expiration, water vapour cools and condenses on the HME. During inspiration, the cool, dry gas is warmed by the HME and the condensate is vaporised.

Table 7: Advantages and disadvantages of HME devices

Advantages	Disadvantages
• Cheap • Simple • May incorporate a bacterial/viral filter • Effective, achieve 60-70% relative humidity	• Bulky • Increase dead space • Inefficient at high minute volumes (>10L min-1) • Inefficient in hypothermic patients • May become blocked by secretions • Takes 20 minutes to become effective

5. 3. 2. Bubble humidifiers

Fresh gas is humidified by bubbling through a water reservoir.

Table 8: Advantages and disadvantages of bubble humidifiers

Advantages	Disadvantages
• Cheap • Simple	• No heating of inhaled gases • Inefficient – optimal at flows <5L min-1

5. 3. 3. Nebulisers

Jet, spinning disc and ultrasonic nebulisers produce an aerosol of water droplets.

Table 9: Advantages and disadvantages of nebulisers

Advantages	Disadvantages
• Highly efficient • Jet nebulisers are compact – can be placed close to patient	• Risk of over-saturation • Sterile water must be used to prevent bacterial contamination • Inability to heat inspired gases

5. 3. 4. Heated humidifier

The delivered fresh gas is fully saturated by passing through a heated humidification chamber, which is thermostatically controlled to a set temperature. The humidified gas is then delivered to the patient via the respiratory circuit. This circuit may contain a heating element to limit the heat loss.

Table 10: Advantages and disadvantages of heated humidifiers

Advantages	Disadvantages
• Efficient – can achieve full saturation	• Risk of bacteria colonisation • Complex • Safety mechanisms required to maintain electrical safety • Risk of condensate within respiratory circuit – may flood airway or cause ventilator dysfunction

In text References

(McNulty and Eyre. 2015; Al-Shaikh and Stacey. 2007; O'Doherty and Thomas. 1997)

References

- McNulty G, Eyre L. , Humidification in anaesthesia and critical care, 2015, https://academic.oup.com/bjaed/article/15/3/131/279283
- Al-Shaikh B, Stacey S. , Essentials of Anaesthetic Equipment. 3rd Ed. , 2007, ISBN:9780443100871
- O'Doherty MJ, Thomas SHL. , Nebuliser therapy in the intensive care unit. , 1997, https://thorax.bmj.com/content/thoraxjnl/52/suppl_2/56.full.pdf

5. 4. Endotracheal suctioning

Endotracheal suctioning is an important component of caring for intubated patients. These patients require intermittent aspiration of their respiratory secretions to remove them from their tracheobronchial tree. Failure to do so can cause:

- Accumulation of endobronchial secretions
- Blockage of an endotracheal tube or tracheostomy
- Elevated airway pressures during mechanical ventilation

- Hypoxia
- Consolidation
- Atelectasis

Endotracheal suctioning can also obtain samples for microbial analysis to guide antimicrobial therapy.

Endotracheal suctioning can be performed using an open or closed system. An open system requires disconnection from the breathing circuit so that a narrow bore suction catheter may be passed. A closed system incorporates a suction catheter into the breathing circuit so that mechanical ventilation may be continued during the suctioning procedure. Neither has any proven advantage over the other in reducing the rates of ventilator-associated pneumonia. However, closed systems are associated with less de-recruitment and limit the aerosolisation of potentially infected respiratory secretions, which may infect healthcare workers and other patients. A third option – known as semi-closed or open – involves introducing the suction catheter through the swivel port without disconnecting the ventilator circuit.

5. 4. 1. Complications of endotracheal suctioning

There are no absolute contraindications to endotracheal suctioning, however, healthcare professionals must be mindful of the potential harms. Endotracheal suctioning is associated with:

- Patient discomfort and distress (sometimes intense discomfort)
- Hypoxia
- Trauma to tracheal mucosa
- Infection
- Bronchospasm
- Tachycardia
- Raised intracranial pressure
- Lung derecruitment

Instillation of normal saline has previously been advocated to promote the clearance of tenacious secretions. However, there is no compelling evidence to support this practice and it may be associated with an increased incidence of ventilator-associated pneumonia (VAP). Consequently, its use is no longer advocated.

In text References

(American Association for Respiratory. 2010; Pedersen et al. 2009; Masterton et al. 2008)

References

- American Association for Respiratory Care., AARC Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010., 2010, PMID:20507660
- Pedersen CM, Rosendahl-Nielsen M, Hjermind J, Egerod I., Endotracheal suctioning of the adult intubated patient--what is the evidence?, 2009, PMID:18632271
- Masterton RG, Galloway A, French G, Street M, Armstrong J, Brown E, Cleverley J, Dilworth P, Fry C, Gascoigne AD, Knox A, Nathwani D, Spencer R, Wilcox M., Guidelines for the management of hospital-acquired pneumonia in the UK: report of the working party on hospital-acquired pneumonia of the British Society for Antimicrobial Chemotherapy., 2008, PMID:18445577

5. 5. Capnography

Capnography is the graphical display of the exhaled carbon dioxide partial pressure, concentration or volume, plotted against time or exhaled volume. Capnography has become a minimum standard of monitoring for critically ill patients who are ventilated via an endotracheal tube or tracheostomy and should also be used during airway management to confirm a successful endotracheal intubation and insertion of percutaneous tracheostomy. It should be used as a continuous monitor in intensive care to confirm that endotracheal tubes and tracheostomies are patent and have not dislodged.

Carbon dioxide is a product of cellular metabolism. It is delivered to the lungs via the pulmonary blood flow, is excreted in the lungs and is detected by the capnograph attached to the respiratory circuit. Therefore, abnormalities in the capnograph trace can arise from:

- Respiratory pathology
- Respiratory equipment failure
- Poor cardiac output
- Abnormalities of cellular metabolism e.g. malignant hyperthermia

5. 5. 1. Clinical uses of capnography:

- Confirmation of endotracheal intubation – excludes oesophageal intubation
- Surveillance for patency of endotracheal tube or tracheostomy
- Surveillance for dislodgement of endotracheal tube or tracheostomy
- Cardiorespiratory information from morphology of capnograph trace
- Prognostication during cardiac arrest by allowing assessment of the effectiveness of cardiac massage

The end-tidal concentration of carbon dioxide (ETCO2) represents the measured concentration of CO2 at the end of expiration. In normal lungs, and with normal cardiorespiratory interactions, this can be used to approximate the partial pressure of alveolar CO2 (PACO2) and thus for arterial CO2 (PaCO2), which is normally 0.5–0.8 kPa higher than the ETCO2. However, in critically ill patients with the potential for abnormalities of ventilation-perfusion (V̇/Q̇) matching it cannot be used as a surrogate for PaCO2.

In text References

(Kerslake and Kelly. 2017; Royal College of 2018; Soar et al. 2015; Intensive Care 2011)

5. 5. 2. The normal capnogram

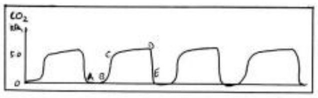

Figure 10: The Normal Capnogram

The normal capnogram consists of a series of rectangular-shaped wave forms. It can be divided into four phases:

- **Phase 1 (A-B) – Inspiration**
  - No CO2 is detected, reflecting the first part of exhalation where the last inspired gas, free of CO2 (atmospheric CO2 is neglible) filling the airways is recorded.
- **Phase 2 (B-C) – Beginning of expiration**
  - A sharp respiratory upstroke occurs due to mixing of respiratory dead-space gas (atmospheric CO2 concentration) and alveolar gas
- **Phase 3 (C-D) – Alveolar plateau**
  - Alveolar gas is exhaled
  - The concentration increases gradually over time, giving a slightly positive gradient to the capnograph – this is due to alveoli with different V̇/Q̇ ratios and longer time-constants emptying more slowly
- **Phase 4 (D-E) - Inspiration**
  - Inspiration of causes the measured concentration of CO2 to rapidly fall towards zero.

The end-tidal concentration is reflected by point "D".

In text References

(Kerslake and Kelly. 2017)

5. 5. 3. Capnography during endotracheal intubation

The detection of normal capnograph traces after at least six breaths following endotracheal intubation suggests successful endotracheal intubation.

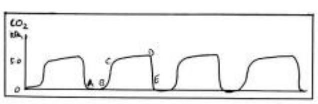

Figure 11: Successful Intubation

In text References

(Kerslake and Kelly. 2017; Clyburn and Rosen. 1994; Linko, Paloheimo and Tammisto. 1983)

5. 5. 4. Recognising oesophageal intubation

If an oesophageal intubation occurs, it can be recognised by the following:

- No CO2 detected – flat capnograph trace
- Small CO2 waveform, amplitude falling to zero over a few breaths

Figure 12: Oesophageal intubation

In contrast to alveolar gas in the respiratory system, gas within the oesophagus and stomach usually contains no CO2. During bag-mask ventilation (BMV) exhaled alveolar gas may be forced into the oesophagus and stomach. If an oesophageal intubation occurs a small amount of CO2 may be detected for a very short period of time – it will be flushed out by the action of mechanical ventilation. The initial detection of CO2 may be falsely reassuring; this scenario must be immediately identified as an oesophageal intubation.

This scenario may mimic a cardiac arrest where the loss of cardiac output causes the amplitude of the capnograph trace to rapidly fall. However, during cardiopulmonary resuscitation the action of chest compressions means that CO2 is delivered to the lungs resulting in an attenuated capnograph trace. Only if cellular respiration has absolutely ceased, or if the pulmonary arteries are completely obstructed, will the ETCO2 be undetectable via a patent ETT during CPR.

If absolutely necessary, fibreoptic bronchoscopy may be employed to confirm endotracheal intubation. It can confirm that an endotracheal tube is in the trachea if tracheal rings and the carina are visualised.

In text References

(Kerslake and Kelly. 2017; Cook and Nolan. 2011; Schwartz, Liberman and Cohen. 1995)

5. 5. 5. Pathological capnograph traces

Flat capnograph trace – no CO2 detected.

The differential diagnosis is broad and can be determined by clinical assessment of the patient and interrogation of the breathing circuit and ventilator:

1. Apnoea
2. Oesophageal intubation
3. Displaced endotracheal tube or tracheostomy
4. Disconnection of breathing circuit
5. Occluded endotracheal tube, tracheostomy or breathing circuit
6. Capnograph failure
7. Cardiac Arrest

5. 5. 6. Obstructive airway disease eg bronchospasm, chronic obstructive pulmonary disease

Figure 13: Obstructive airways diease

Features:

- Significant up-sloping gradient during the plateau phase, due to delayed emptying of alveoli with longer time constants

5. 5. 7. Sudden reduction in cardiac output eg cardiac arrest

Figure 14: Cardiac arrest

Features:

- The loss of pulmonary blood flow, with continuing ventilation, produces a capnograph trace that rapidly diminishes

- Please note, an attenuated capnograph trace is produced during ventilation with cardiopulmonary resuscitation (CPR) As a result of chest compressions a capnography trace will be variable. Indeed, if the airway is not patent during CPR then expired CO2 will be absent.

5. 5. 8. "Curare clefts"

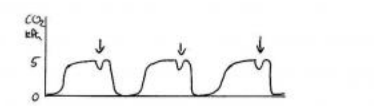

Figure 15: Curare clefts

Features:

- The patient makes an inspiratory effort during the expiratory plateau phase. This draws fresh gas past the CO2 detector.
- This signifies ventilator dys-synchrony

5. 5. 9. Cardiac oscillations

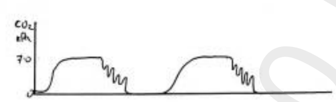

Figure 16: Cardiac oscillations

Features:

- May be observed during low respiratory rates
- Phase 4 is prolonged with intermittent peaks caused by alveolar gas forced out by cardiac pulsations.

5. 5. 10. Rebreathing of alveolar gas

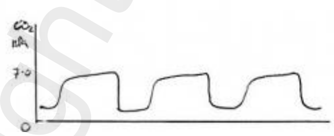

Figure 17: Rebreathing of alveolar gas

Features:

- The partial pressure of CO2 in the inspired gas is raised – the baseline is elevated.
- This is caused by inadequate fresh gas flow into the breathing circuit, causing exhaled gases to be "rebreathed".
- This is not normally seen with modern mechanical ventilators. However, it may be observed in patients ventilated with an anaesthetic resuscitation circuit (e.g. Mapleson C circuit), patients self-ventilating via a T-piece with an inadequate rate of fresh gas flow or when instrumental deadspace i.e HME of larger volume is placed distal to the CO2 sensor.

In text References

(Kerslake and Kelly. 2017; Cross and Plunkett 2014)

References

- Kerslake I, Kelly F. , Uses of capnography in the critical care unit. , 2017, https://watermark.silverchair.com/mkw062.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAaMwggGfBgkqhkiG9w0BBwagggGQMIIBjAIBADCCAYUGCSq Que7Z5RU33HlbJqG1-0km5wzBw5ObyoE_BaoT6ZZ8yJ
- Royal College of Anaesthetists, 4th National Audit Project: Major Complications of Airway Management in the UK., 2018, https://www.rcoa.ac.uk/system/files/CSQ-NAP4-Full.pdf

- Soar J, Nolan JP, Böttiger BW, Perkins GD, Lott C, Carli P, Pellis T, Sandroni C, Skrifvars MB, Smith GB, Sunde K, Deakin CD, Adult advanced life support section Collaborators., European Resuscitation Council Guidelines for Resuscitation 2015: Section 3. Adult advanced life support., 2015, PMID:26477701
- Intensive Care Society , Standards for capnography in critical care. , 2011, https://www.ics.ac.uk/ICS/guidelines-and-standards.aspx
- Clyburn P, Rosen M., Accidental oesophageal intubation., 1994, PMID:8038057
- Linko K, Paloheimo M, Tammisto T., Capnography for detection of accidental oesophageal intubation., 1983, PMID:6410667
- Cook TM, Nolan JP., Use of capnography to confirm correct tracheal intubation during cardiac arrest., 2011, PMID:22070599
- Schwartz DE, Liberman JA, Cohen NH. , Confirmation of Endotracheal Tube Position, 1995, https://journals.lww.com/ccmjournal/Citation/1995/07000/Confirmation_of_Endotracheal_Tube_Position.26.aspx
- Cross ME, Plunkett EVE, Physics, Pharmacology and Physiology for Anaesthetists: Key Concepts for the FRCA, 2014, ISBN:9781107615885

6. Extubation

It is important to attempt to extubate any patient within ICU at the earliest opportunity. This minimises the risks associated both the artificial airway and with the sedation required for tube tolerance. Indeed, the complications are time-dependent, with a longer duration of intubation resulting in increased rates of ventilator-associated pneumonia (VAP) and mortality. Extubation is not without risks however: respiratory complications at the end of routine procedures following anaesthesia are both common and have significant morbidity and mortality attached to them. Furthermore, the requirement for reintubation of critically ill patients is associated with prolonged mechanical ventilation, increased rates of VAP and mortality rates of up to 50%.

The process of extubation is therefore a crucial part of successful critical care management.

In text References

(Epstein 2009; Royal College of 2018; Peterson et al. 2005; Frutos-Vivar et al. 2011)

References

- Royal College of Anaesthetists , 4th National Audit Project: Major Complications of Airway Management in the UK., 2018, https://www.rcoa.ac.uk/system/files/CSQ-NAP4-Full.pdf
- Epstein SK, Weaning from ventilatory support., 2009, PMID:19179869
- Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW., Management of the difficult airway: a closed claims analysis., 2005, PMID:15983454
- Frutos-Vivar F, Esteban A, Apezteguia C, González M, Arabi Y, Restrepo MI, Gordo F, Santos C, Alhashemi JA, Pérez F, Peñuelas O, Anzueto A, Outcome of reintubated patients after scheduled extubation., 2011, PMID:21376523

6. 1. Routine Extubation

Routine extubation can be affected by the systemic condition of the patient, changes in airway reflexes and changes in airway anatomy.

6. 1. 1. The systemic condition of the patient

Extubation may lead to tachycardia, hypertension and venous congestion (some might say it is a true “stress-test” for the cardiovascular system) which in turn may lead to myocardial ischaemia and raised intracranial pressure. In certain patient subgroups, for example those with ischaemic heart disease and those with space occupying intracranial lesions, this can cause significant morbidity. Strategies to attenuate these responses at extubation include the use of remifentanil and dexmedotomidine.

Hypothermia in the perioperative environment is associated with increased oxygen consumption (as a result of shivering), myocardial ischaemia, increased bleeding, higher rates of wound infection and a prolonged activity of anaesthetic drugs. The physiological response to a metabolic acidosis is to increase respiratory ventilation and thus the work of breathing. A period of warming, normalisation of acid-base status and attention to euvolaemia may thus reduce the systemic risks of extubation in some patient groups. Admission to critical care for delayed extubation may be an important component of the recent improvement in outcomes for patients undergoing emergency laparotomies. Furthermore, damage control resuscitation – which necessitates delayed extubation - is now an established technique of management in the trauma setting whereby the resuscitation phase is continued in the intensive care unit pending definitive surgery.

In text References

(Rose, Cohen and DeBoer. 1996; Leech, Barker and Fitch. 1974; Nho et al. 2009; Turan et al. 2008; Reynolds, Beckmann and Kurz. 2008; NELA Project 2017; Mizobata. 2017)

6. 1. 2. Airway Reflexes

Airway reflexes related to difficulties at extubation may be exaggerated, reduced or dysfunctional.

Breath-holding, coughing and bucking can lead to tachycardia, hypertension and venous congestion. Furthermore, laryngospasm which is an exaggerated protective response to stimulation of the airway by, for example, upper respiratory tract secretions, leads to partial or complete airway obstruction. If not managed expeditiously patients will develop negative pressure pulmonary oedema and potentially transition to cardiac arrest. For this reason patients should be alert and their oropharynx cleared of secretions prior to extubation.

Reduced upper airway reflexes lead to loss of smooth muscle tone and upper airway obstruction. Patients at particular risk include the obese and those with obstructive sleep apnoea; other risks being opioids and residual neuromuscular blockade. In order to mitigate for such complications the patient should again be fully awake, free of excessive opioid, and be fully reversed of neuromuscular blockade. Adequate reversal should be confirmed using a nerve stimulator and either neostigmine or sugammadex (for rocuronium) used to ensure neuromuscular function is normalised. Consideration should be given to the use of NIV at extubation in high risk patients.

Impaired lower respiratory tract reflexes risk aspiration. For this reason a nasogastric tube should be aspirated prior to extubation.

Paradoxical vocal cord motion – caused by various contributing factors including physical exercise, airborne pollutants, gastro-oesophogeal reflux and sinusitis - describes a rare condition in which vocal cord adduction occurs on inspiration and can cause stridor following extubation. The diagnosis can only be made by direct visualisation of the vocal cords and responds to treatment with anxiolytics. Another rare condition is vocal cord paralysis caused by damage to the recurrent laryngeal nerve. Pressure on the anterior division of the recurrent laryngeal nerve due to an endotracheal tube cuff can cause vocal cord paralysis. Unilateral paralysis leads to a hoarse voice, whilst bilateral disease causes airway obstruction. Diagnosis is by fibreoptic examination.

In text References

(Difficult Airway Society Extubation Guidelines et al. 2012; Larsen, Caruso and Villariet. 2004; Ellis and Pallister. 1975)

6. 1. 3. Straightforward Extubation

The following describes a technique for the safe extubation of patients with a normal airway within ICU.

- Assess systemic status aiming for:
  - FiO2 0.4; PEEP 5 cm H2O and a successful spontaneous breathing trial
  - Haemodynamically stability
  - Awake and co-operative patient
  - Absence of or resolving metabolic acidosis
  - Optimal sedation – patient awake and co-operative
  - Full reversal of neuromuscular blockade
- Position patient head up
- Aspirate nasogastric tube
- Suction airway at orophayrnx and via endotracheal tube
- Deflate cuff and remove ETT during expiration with continued suction applied to tip of ETT.

6. 1. 4. Postobstructive pulmonary oedema (negative pressure pulmonary oedema)

Obstruction to the upper airway at extubation can lead to postobstructive pulmonary oedema. The causes of obstruction are multiple and include: laryngospasm, epiglottitis, croup, foreign airway body, ETT obstruction, laryngeal tumour, and bilateral vocal cord paralysis. The pulmonary oedema is caused by a forceful inspiratory effort against an obstructed upper airway leading to negative intrapleural pressure and thus increased pulmonary capillary hydrostatic pressure. It is more common in young men. Management involves treatment of the obstruction and supportive care. CPAP may help to expedite resolution of the oedema.

In text References
(Udeshi, Cantie and Pierre. 2010)

6. 1. 5. Acute changes to airway anatomy

Changes to airway anatomy peri-operatively may preclude safe extubation and a period of sedation and ventilation in ICU may be appropriate. These changes may be related to the anaesthetic, the surgery or due to systemic complications. The airway pathology may be caused by direct trauma, oedema, venous congestion, an alteration in anatomy or be a result of continued risk for airway soiling. Time and a reverse Trendelenburg position together with the use of parenteral steroids and diuretics will reduce oedema. Normalisation of coagulaopathy, avoidance of the Valsalva manoeuvre and surgical intervention may be required to manage bleeding complications. Antimicrobial therapies and further drainage are necessary in infectious cases. Despite these measures, in certain circumstances an elective tracheostomy may be the safest route of ongoing airway management. This should be discussed with regards the advantages and disadvantages of this approach with the multi-disciplinary team.

Causes of altered airway anatomy that might necessitate admission to ICU for ongoing airway management include:

- direct trauma and oedema
  - laryngoscopy
  - presence of airway adjuncts/ ETT
  - panendoscopy
  - biopsy of tumour
  - debulking of tumour
  - free flap reconstruction
- External injury to the neck
  - asphyxiation,
  - strangling or hanging
  - penetrating injury to the neck
- oedema
  - bi-maxillary osteotomy
  - overzealous fluid resuscitation

    - anaphylaxis
    - prolonged Trendelenberg or prone position
- venous congestion
    - radical neck dissection
    - thyroidectomy with subsequent bleeding
    - carotid artery blow out
- risk of airway soiling (risks of oedema/ venous congestion/ distortion of anatomy)
    - dental abscess incompletely drained
    - Ludwig's angina
    - bleeding post tonsillectomy/ nasal packing
- altered anatomy (risk of oedema/ venous congestion)
    - cervical spine fixation
    - placement of Halo cervical spine immobilsation
    - tracheal reconstruction (if flexion required post-operatively)
    - tracheomalacia post thyroidectomy or other causes of prolonged tracheal compression

A further group of patients may be admitted as an emergency with an 'at risk airway' or an overtly obstructed airway:

- Airway Burns
- Stridor due to a new presentation of oropharyngeal cancer
- Supraglottitis/ epiglottitis
- Blunt or penetrating trauma to head and neck
- Unstable cervical spine
- Extrinsic compression of airway due to thyroid or intrathoracic mass

The above two groups of patients together with those patients known to have intrinsic difficulties in their airway management (see airway assessment section) represent a group in whom it can be expected that extubation carries high risk. Rarely this can be managed with interventional bronchoscopy techniques, using laser or endobronchial prostheses to manage the obstruction as a result of tumours or stenosis. In most cases however, other strategies are required.

In text References

(Batuwitage, and Charters. 2017)

References

- Rose DK, Cohen MM, DeBoer DP., Cardiovascular events in the postanesthesia care unit: contribution of risk factors., 1996, PMID:8638830
- Leech P, Barker J, Fitch W., Proceedings: Changes in intracranial pressure and systemic arterial pressure during the termination of anaesthesia., 1974, PMID:4451611
- Nho JS, Lee SY, Kang JM, Kim MC, Choi YK, Shin OY, Kim DS, Kwon MI., Effects of maintaining a remifentanil infusion on the recovery profiles during emergence from anaesthesia and tracheal extubation., 2009, PMID:19864308
- Turan G, Ozgultekin A, Turan C, Dincer E, Yuksel G., Advantageous effects of dexmedetomidine on haemodynamic and recovery responses during extubation for intracranial surgery., 2008, PMID:18400140
- Reynolds L, Beckmann J, Kurz A., Perioperative complications of hypothermia., 2008, PMID:19137808
- NELA Project Team, Third Patient Report of the National Emergency Laparotomy Audit , 2017, https://www.nela.org.uk/download.php/?fn=The%20Third%20Patient%20Report%20of%20the%20National%20Emergency%20Laparotomy%20Audit%202017%20-%20Full%20Patient%20Report.pdf&mime=application/pdf&pureFn=The%20Third%20Patient%20Report%20of%20the%20National%20Em
- Mizobata Y. , Damage control resuscitation: a practical approach for severely hemorrhagic patients and its effects on trauma surgery, 2017, https://jintensivecare.biomedcentral.com/articles/10.1186/s40560-016-0197-5
- Difficult Airway Society Extubation Guidelines Group, Popat M, Mitchell V, Dravid R, Patel A, Swampillai C, Higgs A., Difficult Airway Society Guidelines for the management of tracheal extubation, 2012, PMID:22321104
- Larsen B, Caruso LJ, Villariet DB., Paradoxical vocal cord motion: an often misdiagnosed cause of postoperative stridor., 2004, PMID:15217668
- Ellis PD, Pallister WK., Recurrent laryngeal nerve palsy and endotracheal intubation., 1975, PMID:1185065
- Udeshi A, Cantie SM, Pierre E., Postobstructive pulmonary edema., 2010, PMID:20413250
- Batuwitage, B, Charters P. , Postoperative management of the difficult airway, 2017, https://academic.oup.com/bjaed/article/17/7/235/2999282

6. 2. Extubation of patients who are known to have a difficult airway

The Difficult Airway Society advocates a stepwise approach to extubation within the context of anaesthesia which can be modified to be used within the ICU. The process begins with a risk assessment, followed by preparation and patient optimisation. The endotracheal tube is then removed (if deemed safe) and plans are instituted for ongoing management and mitigation of failure.

As has already been noted a period of time and optimisation may allow improvement in the anatomy of the airway. The use of nasendoscopy or videolaryngoscopy allows serial assessment of the progress with regards this. Further imaging such as magnetic resonance imaging (MRI) gives valuable information in terms of oedema, inflammation and infection and can potentially map recovery or extension of the disease process .

For high risk patients the options over and above patient and airway optimisation already described are: extubation in a standard fashion, placement of an airway-exchange catheter (AEC), tracheostomy or extubation plus insertion of a transtracheal cannula.

6. 2. 1. Standard extubation

Oftentimes, even if a patient has a predefined difficult airway it will be possible to successfully extubate them if they have been optimised. Important considerations are:

- A management plan for failure should be made before extubation. The plan should include: symptom control (eg nebulised adrenaline and heliox); method of oxygen delivery (high flow or non-invasive ventilation); and an emergency reintubation plan ensuring all necessary equipment is at the bedside.
- Extubation should occur early in the day in order to allow assessment of its likely success or proper management in the case of failure.
- Personnel with the expertise necessary for reintubation should be available and in selected cases consideration might be given to extubation in theatre.

In text References

(Cook et al. 2011)

6. 2. 2. Extubation over an Airway Exchange Catheter (AEC)

AECs are long hollow bougies which can be placed in the trachea via the endotracheal tube prior to extubation. They are radio-opaque and have length markings on the outer surface. The 11F catheter will pass through a size 4mm ETT. Their position is confirmed by capnography and chest x-ray ensuring that the tip is mid-trachea, away from the carina. The catheter is well-tolerated and facilitates re-intubation in a manner similar to a standard bougie if required. Tracheal re-intubation using an AEC is comparable with tracheal intubation over a fibre-optic bronchoscope. If a narrow gauge AEC is used, it can be combined with a larger bore intubating catheter to ease passage of the ETT during re-intubation by decreasing the step between catheter and tracheal tube which can impinge on the vocal cords or in the piriform fossae. Oxygenation via the catheter is inadvisable since risks of barotrauma and subsequent pneumothorax are not insignificant. The AEC should be clearly labelled to prevent confusion with a nasogastric tube and the patient should remain nil by mouth until the catheter is removed. A large retrospective case series using AECs suggests successful use in preventing difficult reintubation. Important questions arising from this review were whether or not the presence of AEC increased the aggressiveness of extubation (there was a high rate of reintubation) and how long the AEC should remain in situ for (over a third required reintubation greater than 4 hours after extubation).

In text References

(Law and Duggan. 2012; Mort 2007; Biro and Priebe. 2007)

6. 2. 3. Tracheostomy

Elective tracheostomy should be considered if reliable access to the upper airway cannot be guaranteed after 7 – 10 days. The decision should be made with airway surgeons since there are risks associated with the procedure and with regards long-term outcomes particularly if cancer is the cause of airway obstruction.

6. 2. 4. Trans-tracheal cannula

A trans-tracheal cannula (placed through the cricothyroid membrane) may be placed before induction of anaesthesia and continued into the post-operative phase in patients at risk of airway obstruction. If airway management becomes difficult oxygenation is possible via a high pressure source. The risk of barotrauma, haemorrhage and infection associated with this technique mean that management within critical care is mandatory. This technique is not described as a method of extubation in ICU and cannot therefore be recommended.

In text References

(Ryan and McGuire. 2008)

References

- Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project., Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments., 2011, PMID:21447489
- Law J, Duggan L., Extubation guidelines: use of airway exchange catheters., 2012, PMID:22775371
- Mort TC, Continuous airway access for the difficult extubation: the efficacy of the airway exchange catheter., 2007, PMID:17959966
- Biro P, Priebe HJ., Staged extubation strategy: is an airway exchange catheter the answer?, 2007, PMID:17959938
- Ryan JC, McGuire B., Role of cricothyroid cannulation in head and neck surgery., 2008, PMID:18289395

6. 3. Monitoring of the patient with an at risk airway

There are many patient groups whose airway may be at risk either postoperatively or indeed as a result of infection, trauma and cancer who require higher level monitoring in critical care. Important aspects of care are:

- Nursing should occur in areas of the hospital where rapid access to clinicians with airway expertise are located
- Equipment necessary for airway interventions should be readily available and include:
- An airway rescue trolley
- Fibreoptic intubating endoscope (where possible)
- Stitch or wire cutters at bedside for specific circumstances
- Specially designed face masks with in-situ capnography lines may allow early detection of airway obstruction
- An intubation plan should be documented in the notes and signage placed at the head of the patients bed.

In text References

(Whitaker. 2011; Cook et al. 2011)

References

- Cook TM, Woodall N, Harper J, Benger J; Fourth National Audit Project., Major complications of airway management in the UK: results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: intensive care and emergency departments., 2011, PMID:21447489
- Whitaker DK., Time for capnography - everywhere., 2011, PMID:21627625

6. 4. Extubation of critically ill patients without airway difficulties

Successful extubation is dependent on two factors: the ability to tolerate spontaneous breathing without mechanical ventilatory support and the ability to maintain a patent airway once the ETT is removed. Failure due to the former is weaning failure and due to the latter is extubation failure. Extubation and weaning failure are frequently linked in the ICU population. Failure is defined as the requirement for reintubation within 48 hours of tracheal extubation. Because the use of NIV may delay the time interval to reintubation the definition may be increased to one week in these circumstances. Rates of reintubation for patients electively extubated within critical care can be as high as 20%. This is important because failed extubation is associated with prolonged mechanical ventilation, increased rates of ventilator-associated pneumonia and mortality rates of up to 50%. It is unclear why this is the case but it is plausible that vulnerable patients deteriorate during the extubation phase leading to a second ‘inflammatory hit’. Another explanation might be the concept of ‘patient self-inflicted lung injury’ whereby spontaneously breathing patients with a high respiratory drive breathe with large tidal volumes and potentially injurious transpulmonary pressure swings. In a large cohort study reintubation was independently associated with increased mortality due to the development of new complications after reintubation. In another study a worsening daily SOFA score in patients who failed extubation compared to those who did not suggested that the process of failure during the period of extubation may cause the overall clinical deterioration. The fact that patients reintubated later and for non-airway causes had a higher mortality in a further study again suggests that both the process and cause of decline during extubation are the causes of this increased mortality.

It is not feasible to have a re-intubation rate of zero. An over-cautious approach to extubation risks the complications of prolonged mechanical ventilation whereas an over-aggressive strategy risks exposing patients to the side-effects of reintubation. On this basis an optimal rate of re-intubation has been suggested to be in the range of 5–15%.

Causes of failed extubation within the ICU include:

- upper airway obstruction
- sputum retention as result of ineffective cough and high secretion load
- unresolved respiratory failure

- cardiogenic pulmonary oedema
- neuromuscular weakness
- altered consciousness
- a new complication of critical illness.

In text References

(Artime and Hagberg 2014; Cavallone and Vannucci. 2013; Boles et al. 2007; Thille, Richard and Brochard. 2013; Frutos-Vivar et al. 2011; Thille et al. 2011; Epstein and Ciubotaru. 1998; Krinsley, Reddy and Iqbal. 2012; Brochard, Slutsky and Pesenti 2017)

6. 4. 1. Extubation failure

Injuries to the airway as a result of intubation can occur at the larynx, pharynx, oesophagus, trachea and temporomandibular joint; laryngeal injuries may consist of vocal cord paralysis, granuloma formation, arytenoid dislocation and haematoma. In adults the larynx is the narrowest part of the upper airway. Movement of oversized or poorly positioned tubes, or overinflated cuffs, on the posterior glottis and arytenoids can case oedema and airflow limitation. Laryngeal oedema is exacerbated by the prone position and prolonged intubation. Upper airway obstruction following extubation occurs in up to 15% of patients who have been ventilated in ICU. Post-extubation stridor will develop within 5 minutes in nearly half of these patients and 30 minutes in 80%. The presence of respiratory distress and post-extubation stridor is thought to reflect a narrowing of the airway of more than 50%. It is important to note however that nearly half of patients with stridor or visualized laryngeal oedema in a large randomised controlled trial did not require reintubation. Thus, stridor is not a sensitive marker for clinically relevant laryngeal oedema requiring reintubation.

Risk factors for laryngeal oedema include:

- longer duration of ventilation (greater than 36 hours)
- female sex and low height to tube-diameter ratio
- traumatic or difficult intubation
- history of self-extubation
- over-inflated balloon cuff at admission to ICU

Unfortunately none of these risk factors are reliable enough to allow targeted management of laryngeal oedema.

In text References

(Peterson et al. 2005; Sandhu. 2010; François et al. 2007; Mackle, Meaney and C Timon. 2007; Darmon et al. 1992; Jaber et al. 2003)

6. 4. 2. Assessment for laryngeal oedema

Deflation of the endotracheal tube cuff should result in an air leak; measurement of the cuff leak volume, which is defined as the difference between the inspiratory volume and the expiratory volume, predicts postextubation stridor if the volume is less than 110ml; a value greater than 110ml (negative predictive value of 98%) essentially ruling out post-extubation stridor. Because this test has a high specificity but lower sensitivity many patients can be safely extubated even when the test is positive, thus absence of a cuff leak should not preclude extubation in of itself.

Ultrasound has been advocated as an alternative to the cuff leak test. Measuring the air column width (the shadow at the level of the vocal cords) before and after cuff deflation might be used to predict post-extubation stridor though studies are small and at present inconclusive.

Lastly, nasendoscopy can be performed to inspect the larynx before and after extubation and define the cause for stridor. It should be noted that there is no evidence that routine laryngoscopy reduces the need for reintubation and that instrumentation of the airway may cause further injury and swelling.

6. 4. 3. Prevention of laryngeal oedema

The smaller the endotracheal tube size the lower the risk of laryngeal oedema. Standard sizes would be 7.0mm for women and 8.0mm for men; consideration must be given to the effect of a narrower lumen on weaning and the ability to perform suction and bronchoscopy though.

The duration of intubation is also important as previously described. Delaying extubation unnecessarily should be avoided.

Cuff pressures should be monitored in order to prevent pressure ulcers. Furthermore, the semi-recumbent position and active diuresis aid in reducing laryngeal oedema.

Studies assessing the effects of parenteral steroid treatment on laryngeal oedema have produced conflicting results though a meta-analysis found that a multi-dose regimen of steroids had marked positive effects on the occurrence of laryngeal oedema and on the rate of subsequent reintubation without significant side-effects. The dilemma then, is who to treat with steroids, since many patients would not require such treatment and waiting for the effect of steroids in patients with a negative cuff leak could delay extubation (knowing that the test lacks sensitivity). It is reasonable then to reserve steroids for patients with a known swollen airway or those with high risk for a swollen airway, a negative cuff leak test and a known difficult airway.

6. 4. 4. Treatment of post-extubation stridor

Intravenous steroids (with a rapid onset of action) and nebulised adrenaline are often used to manage post-extubation stridor. The evidence for steroids is limited in this context largely being extrapolated from the studies on prophylaxis. Nebulised adrenaline 1mg in 5ml has shown promise in a short case series of adult patients.. A helium-oxygen (heliox) mixture has a lower density than oxygen and inhalation thus decreases airway resistance by encouraging laminar flow through narrowed airways. There is little evidence for heliox preventing the requirement for re-intubation but its use might buy time (whilst preparing for intubation) by reducing the work of breathing though it will rarely be available to critical care units.

Though the use of adrenaline and steroids is widespread and may reduce airway swelling, only a short period of observation should be allowed before electing to reintubate in cases of respiratory failure as a result of airway obstruction.

6. 4. 5. Suggested algorithm for management of laryngeal oedema

All patients should undergo a cuff leak test since those with a volume greater than 110ml will usually extubate successfully from an airway perspective. Those with a low cuff leak volume and other risk factors could be treated with intravenous steroids and extubation delayed by at least 12 hours. If the patient suffers stridor and respiratory distress following extubation, intravenous steroids and nebulised adrenaline should be administered. If symptoms do not resolve within 1 hour the patient should be reintubated and steroids continued.

In text References

(Miller and Cole. 1996; Ochoa et al. 2009; Pluijms et al. 2015; Benjamin 1993; Fan et al. 2008; Cheng et al. 2006)

References

- Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C, Pearl R, Silverman H, Stanchina M, Vieillard-Baron A, Welte T., Weaning from mechanical ventilation., 2007, PMID:17470624
- Thille AW, Richard JC, Brochard L., The decision to extubate in the intensive care unit., 2013, PMID:23641924
- Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW., Management of the difficult airway: a closed claims analysis., 2005, PMID:15983454
- Frutos-Vivar F, Esteban A, Apezteguia C, González M, Arabi Y, Restrepo MI, Gordo F, Santos C, Alhashemi JA, Pérez F, Peñuelas O, Anzueto A, Outcome of reintubated patients after scheduled extubation., 2011, PMID:21376523
- Artime CA, Hagberg CA, Tracheal extubation., 2014, PMID:24891203
- Cavallone LF, Vannucci A., Review article: Extubation of the difficult airway and extubation failure., 2013, PMID:23302983
- Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L., Outcomes of extubation failure in medical intensive care unit patients., 2011, PMID:21765357
- Epstein SK, Ciubotaru RL., Independent effects of etiology of failure and time to reintubation on outcome for patients failing extubation., 1998, PMID:9700126
- Krinsley JS, Reddy PK, Iqbal A., What is the optimal rate of failed extubation?, 2012, PMID:22356725
- Brochard L, Slutsky A, Pesenti A, Mechanical Ventilation to Minimize Progression of Lung Injury in Acute Respiratory Failure., 2017, PMID:27626833
- Sandhu GS. , Laryngeal and Esophageal Trauma. In: Cummings Otolaryngology 6th Edition, 2010, ISBN: 9781455746965
- François B, Bellissant E, Gissot V, Desachy A, Normand S, Boulain T, Brenet O, Preux PM, Vignon P; Association des Réanimateurs du Centre-Ouest (ARCO)., 12-h pretreatment with methylprednisolone versus placebo for prevention of postextubation laryngeal oedema: a randomised double-blind trial., 2007, PMID:17398307
- Mackle T, Meaney J, C Timon C. , Tracheoesophageal compression associated with substernal goitre. Correlation of symptoms with cross-sectional imaging findings, 2007, https://www.cambridge.org/core/journals/journal-of-laryngology-and-otology/article/tracheoesophageal-compression-associated-with-substernal-goitre-correlation-of-symptoms-with-cross-sectional-imaging-findings/30BE534A3A2D13EA1CACBF690A30F60D
- Darmon JY, Rauss A, Dreyfuss D, Bleichner G, Elkharrat D, Schlemmer B, Tenaillon A, Brun-Buisson C, Huet Y., Evaluation of risk factors for laryngeal edema after tracheal extubation in adults and its prevention by dexamethasone. A placebo-controlled, double-blind, multicenter study., 1992, PMID:1642342
- Jaber S, Chanques G, Matecki S, Ramonatxo M, Vergne C, Souche B, Perrigault PF, Eledjam JJ., Post-extubation stridor in intensive care unit patients. Risk factors evaluation and importance of the cuff-leak test., 2003, PMID:12528025
- Miller RL, Cole RP., Association between reduced cuff leak volume and postextubation stridor., 1996, PMID:8874265
- Ochoa ME, Marín Mdel C, Frutos-Vivar F, Gordo F, Latour-Pérez J, Calvo E, Esteban A., Cuff-leak test for the diagnosis of upper airway obstruction in adults: a systematic review and meta-analysis., 2009, PMID:19399474
- Pluijms WA, van Mook WN, Wittekamp BH, Bergmans DC, Postextubation laryngeal edema and stridor resulting in respiratory failure in critically ill adult patients: updated review., 2015, PMID:26395175
- Benjamin B, Prolonged intubation injuries of the larynx: endoscopic diagnosis, classification, and treatment., 1993, PMID:8470867
- Fan T, Wang G, Mao B, Xiong Z, Zhang Y, Liu X, Wang L, Yang S., Prophylactic administration of parenteral steroids for preventing airway complications after extubation in adults: meta-analysis of randomised placebo controlled trials., 2008, PMID:18936064
- Cheng KC, Hou CC, Huang HC, Lin SC, Zhang H., Intravenous injection of methylprednisolone reduces the incidence of postextubation stridor in intensive care unit patients., 2006, PMID:16540947

6. 5. Weaning Failure

Risk Factors for weaning failure due to the inability to support spontaneous ventilation are multiple.

- Elderly patients (older than 65) with a medical reason for ICU admission and cardiorespiratory disease prior to admission are more likely to fail a trial of extubation.
- Further risk factors are: longer duration of ventilation prior to extubation; elevated illness severity or anaemia at the time of extubation; previous unplanned extubations; semi-recumbent positioning following extubation and need for transportation outside of the ICU.
- Impaired neurological status has been associated with failure to successfully extubate though this is not definitive: for neurosurgical patients a GCS greater than 8 was associated with successful extubation if airway protection capacity is adequate.
- Weak cough strength and high secretion load is also associated with extubation failure. Objective assessments of these parameters have not been clearly defined within critical care. In a cohort of patients with neuromuscular disease a peak cough flow of greater than 160l/minute was highly predictive of extubation or decannulation of tracheostomy: this might be extrapolated to the intensive care environment. Patients capable of vigorous cough and who require suctioning less frequently than every 2 hours also have greater chance of extubation success.
- Lastly, a positive fluid balance prior to extubation may risk failure.

Other less clearly defined risk factors for extubation failure are: delirium, sleep deprivation and ICU-acquired weakness.

- Delirium can lead to inability to comply with treatments and increases the risk of aspiration.
- Though sleep deprivation has not been evaluated in the context of ICU, it has been associated with NIV failure in acute respiratory failure.
- ICU-acquired weakness is associated with prolonged duration of mechanical ventilation, increased mortality rates and extubation failure. Ultrasound assessment of diaphragmatic function may be useful in detecting those patients at risk of prolonged weaning.

In text References

(King, Moores and Epstein. 2010; Bach and Saporito. 1996; Khamiees et al. 2001; Frutos-Vivar et al. 2006; Roche Campo et al. 2010; Sharshar et al. 2009; Garnacho-Montero et al. 2005; Kim et al. 2011; Rothaar and Epstein. 2003)

6. 5. 1. Assessment of potential weaning failure post extubation

The standard tests used to assess readiness for extubation are the T-piece trial (which involves inserting a T-piece on to the end of the ETT) or the use of low levels of pressure support with or without PEEP whilst remaining connected to the ventilator. Important considerations when deciding which test to use are:

- the technological improvements in mechanical ventilators mean that the historical requirement to provided PS to overcome the increased work imposed by the machinery is much reduced;
- upper airway resistance is increased in critically patients as a result of laryngeal oedema and therefore breathing through an ETT does not necessarily impose an increased resistance to breathing as would be found in healthy individuals. However, narrowing of the ETT after several days' ventilation as a result of secretions may increase the workload for the patient;
- the support provided by positive pressure ventilation can mask left ventricular dysfunction; a T-piece trial is more likely in these circumstances to lead to pulmonary oedema and thus diagnose a cause for extubation failure;
- lung rest (i.e reconnection to PS) for a period of 30 – 60 min after a successful SBT reduces reintubation rates.

The specificity of weaning tests for predicting successful extubation is approximately 85%; those patients passing the test but subsequently requiring reintubation is therefore 15%. The sensitivity on the other hand is difficult to determine and can only be extrapolated. It is known however that of patients who accidentally extubate only 40-60% will require reintubation. When a 2 hour T-piece test was compared with 7 cm H_2O PS over the same time period, more patients passed the PS test with no difference in reintubation rates. On the basis of current evidence it has been suggested that a T-piece approach is reserved for patients with borderline performance with PS or where there are concerns that loss of PEEP would precipitate latent cardiac dysfunction or lung failure. A collective task force recommended that the duration of SBT should be at least 30 minutes and not longer than 120 minutes. A successful spontaneous breathing trial is marked by the following characteristics :

- Respiratory rate < 35 breaths/minute
- Good tolerance of the trial
- Heart rate < 140 /minute or heart rate variability of >20%
- Arterial oxygen saturation >90% on FiO_2<0.4
- 80 < Systolic blood pressure < 180 mmHg or <20% change from baseline
- No signs of increased work of breathing or distress

Other tests which may aid in the assessment of readiness for extubation include brain natriuretic peptide (BNP), echocardiography, lung and diaphragm ultrasound, the rapid shallow breathing index and assessment of arterial gases during a SBT.

- Serial measurements of BNP used as a guide to diuresis may aid in successful extubation whilst echocardiography will confirm systolic and diastolic left ventricular dysfunction.
- Lung ultrasound during a spontaneous breathing trial can ascertain derecruitment and thus predict respiratory failure post extubation.
- A rapid shallow breathing index (f/ VT) of greater than 105 is also associated with failure to extubate.
- Lastly, hypercapnoea during a spontaneous breathing trial predicts a prolonged weaning course and increased mortality.

In conclusion, no test will determine with certainty those patients who will not require reintubation once extubated. Knowledge of risk factors and their optimisation together with the appropriate use of SBTs should aid in minimising extubation failure rates.

In text References

(Thille, Richard and Brochard. 2013; Esteban et al. 1997; MacIntyre 2013; MacIntyre et al. 2001; , Thille and Esteban. 2015; Mekontso Dessap et al. 2012; Llamas-Álvarez, Tenza-Lozano and Latour-Pérez 2017; Sellares et al. 2011)

References

- Thille AW, Richard JC, Brochard L., The decision to extubate in the intensive care unit., 2013, PMID:23641924
- King CS, Moores LK, Epstein SK., Should patients be able to follow commands prior to extubation?, 2010, PMID:20040124
- Bach JR, Saporito LR., Criteria for extubation and tracheostomy tube removal for patients with ventilatory failure. A different approach to weaning., 1996, PMID:8989078
- Khamiees M, Raju P, DeGirolamo A, Amoateng-Adjepong Y, Manthous CA., Predictors of extubation outcome in patients who have successfully completed a spontaneous breathing trial., 2001, PMID:11591570
- Frutos-Vivar F, Ferguson ND, Esteban A, Epstein SK, Arabi Y, Apezteguía C, González M, Hill NS, Nava S, D'Empaire G, Anzueto A., Risk factors for extubation failure in patients following a successful spontaneous breathing trial., 2006, PMID:17166980
- Roche Campo F, Drouot X, Thille AW, Galia F, Cabello B, d'Ortho MP, Brochard L., Poor sleep quality is associated with late noninvasive ventilation failure in patients with acute hypercapnic respiratory failure., 2010, PMID:19789439
- Sharshar T, Bastuji-Garin S, Stevens RD, Durand MC, Malissin I, Rodriguez P, Cerf C, Outin H, De Jonghe B; Groupe de Réflexion et d'Etude des Neuromyopathies En Réanimation., Presence and severity of intensive care unit-acquired paresis at time of awakening are associated with increased intensive care unit and hospital mortality., 2009, PMID:19770751
- Garnacho-Montero J, Amaya-Villar R, García-Garmendía JL, Madrazo-Osuna J, Ortiz-Leyba C., Effect of critical illness polyneuropathy on the withdrawal from mechanical ventilation and the length of stay in septic patients., 2005, PMID:15699838
- Kim WY, Suh HJ, Hong SB, Koh Y, Lim CM., Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation., 2011, PMID:21705883
- Rothaar RC, Epstein SK., Extubation failure: magnitude of the problem, impact on outcomes, and prevention., 2003, PMID:12548031
- Esteban A, Alía I, Gordo F, Fernández R, Solsona JF, Vallverdú I, Macías S, Allegue JM, Blanco J, Carriedo D, León M, de la Cal MA, Taboada F, Gonzalez de Velasco J, Palazón E, Carrizosa F, Tomás R, Suarez J, Goldwasser RS., Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. The Spanish Lung Failure Collaborative Group., 1997, PMID:9279224
- MacIntyre NR, The ventilator discontinuation process: an expanding evidence base., 2013, PMID:23709201
- MacIntyre NR, Cook DJ, Ely EW Jr, Epstein SK, Fink JB, Heffner JE, Hess D, Hubmayer RD, Scheinhorn DJ; American College of Chest Physicians; American Association for Respiratory Care; American College of Critical Care Medicine., Evidence-based guidelines for weaning and discontinuing ventilatory support: a collective task force facilitated by the American College of Chest Physicians; the American Association for Respiratory Care; and the American College of Critical Care Medicine, 2001, PMID:11742959
- Peñuelas Ó, Thille AW, Esteban A., Discontinuation of ventilatory support: new solutions to old dilemmas., 2015, PMID:25546535
- Mekontso Dessap A, Roche-Campo F, Kouatchet A, Tomicic V, Beduneau G, Sonneville R, Cabello B, Jaber S, Azoulay E, Castanares-Zapatero D, Devaquet J, Lellouche F, Katsahian S, Brochard L., Natriuretic peptide-driven fluid management during ventilator weaning: a randomized controlled trial., 2012, PMID:22997204
- Llamas-Álvarez AM, Tenza-Lozano EM, Latour-Pérez J, Diaphragm and Lung Ultrasound to Predict Weaning Outcome: Systematic Review and Meta-Analysis., 2017, PMID:28864053
- Sellares J, Ferrer M, Cano E, Loureiro H, Valencia M, Torres A., Predictors of prolonged weaning and survival during ventilator weaning in a respiratory ICU., 2011, PMID:21373820

6. 6. Prevention and management of extubation failure

The fact that the requirement for, and delay in, reintubation are associated with increased mortality means that early reestablishment of invasive mechanical ventilation in patients failing is imperative.

Prophylactic non-invasive ventilation (NIV) describes the use of NIV in the absence of respiratory failure and might be used pre-emptively in patients at high risk for reintubation. Patients with raised carbon dioxide levels and chronic respiratory disease are likely to benefit from post-extubation NIV. A large meta-analysis concluded that NIV – when used prophylactically - can decrease reintubation and ICU mortality in patients at high risk for extubation failure. Crucially though, the benefits of NIV were not found when it was used to manage established respiratory failure post-extubation. NIV in this context merely delays re-intubation and increases mortality.

High-flow nasal oxygen (HFNO) therapy is an emerging mode of respiratory support whereby humidified, heated oxygen is supplied to the patient at flows of up to 60l/ minute via soft nasal prongs. With regards extubation within the critical care environment there is emerging evidence of benefit. In patients extubated who were at high risk for reintubation, HFNO was found to be non-inferior to NIV. Furthermore, in another study by the same group assessing patients at low risk for reintubation, HFNO reduced the requirement for reintubation compared with conventional oxygen therapy.

In text References

(Agarwal et al. 2007; Ferrer et al. 2009; Esteban et al. 2004; Hernández et al. 2016; Hernández et al. 2016)

References

- Esteban A, Frutos-Vivar F, Ferguson ND, Arabi Y, Apezteguía C, González M, Epstein SK, Hill NS, Nava S, Soares MA, D'Empaire G, Alía I, Anzueto A., Noninvasive positive-pressure ventilation for respiratory failure after extubation., 2004, PMID:15190137
- Agarwal R, Aggarwal AN, Gupta D, Jindal SK., Role of noninvasive positive-pressure ventilation in postextubation respiratory failure: a meta-analysis., 2007, PMID:17971250
- Ferrer M, Sellarés J, Valencia M, Carrillo A, Gonzalez G, Badia JR, Nicolas JM, Torres A., Non-invasive ventilation after extubation in hypercapnic patients with chronic respiratory disorders: randomised controlled trial., 2009, PMID:19682735
- Hernández G, Vaquero C, Colinas L, Cuena R, González P, Canabal A, Sanchez S, Rodriguez ML, Villasclaras A, Fernández R., Effect of Postextubation High-Flow Nasal Cannula vs Noninvasive Ventilation on Reintubation and Postextubation Respiratory Failure in High-Risk Patients: A Randomized Clinical Trial., 2016, PMID:27706464
- Hernández G, Vaquero C, González P, Subira C, Frutos-Vivar F, Rialp G, Laborda C, Colinas L, Cuena R, Fernández R, Effect of Postextubation High-Flow Nasal Cannula vs Conventional Oxygen Therapy on Reintubation in Low-Risk Patients: A Randomized Clinical Trial., 2016, PMID:26975498

7. Tracheostomy

A tracheostomy is a surgically created stoma connecting the anterior neck to the trachea; the stoma is then maintained with a tracheostomy tube. The use of tracheostomies in the management of the critically ill has increased markedly since the development of a percutaneous technique, first described in 1985, which allows performance of the technique at the bedside.

In text References

(Ciaglia, Firsching and Syniec. 1985)

References

- Ciaglia P, Firsching R, Syniec C., Elective percutaneous dilatational tracheostomy. A new simple bedside procedure; preliminary report., 1985, PMID:3996056

7. 1. Indications

Tracheostomies are performed for multiple reasons, the most common being for the management of patients requiring prolonged ventilation. The benefits of a tracheostomy for such patients include increased comfort and the reduced requirement for sedation which in turn enable earlier rehabilitation; reduced trauma to the oropharynx and larynx as a result of the endotracheal tube; a theoretical reduction in the dead space and airway resistance because the patient is breathing through a shorter tube, and the potential ability to speak and eat with a tracheostomy. For patients with a high secretion load but relatively preserved oxygenation a tracheostomy will facilitate expedited transfer to a high dependency unit bed since the artificial airway allows continued bronchial toilet.

A tracheostomy may also be inserted in patients presenting with an obstructed upper airway. In an emergency setting this may be for infection, tumour or trauma. Tracheostomies may be sited electively during major head and neck cancer for the same reason. Patients may also require the procedure in order to protect the airway if they are obtunded as a result of central nervous system pathology or have a bulbar palsy. There is also a small but enlarging group of patients who require a tracheostomy for long-term ventilation due to neuromuscular pathology.

In text References

(Bersten et al. 1989)

References

- Bersten AD, Rutten AJ, Vedig AE, Skowronski GA., Additional work of breathing imposed by endotracheal tubes, breathing circuits, and intensive care ventilators., 1989, PMID:2736929

7. 2. Surgical v Percutaneous

As the percutaneous technique (PDT) has become a mainstream skill of intensivists it is generally the preferred method. The advantages of PDT relate to the procedure and to logistics. PDT can be performed more quickly and is associated with less wound infection and better cosmetic results. From a logistical perspective, PDT is preferred because there is no requirement for transfer to theatre; hospital resource allocation is improved by freeing up theatre for other procedures; it requires less planning and for all the above reasons it is cheaper.

Despite the advantages of PDT, it is contraindicated in a wide range of circumstances all of which are relative but include:

- Children (age under 16)
- Coagulopathy
- Scarring, burns, infection, radiotherapy to anterior neck
- Anterior blood vessels
- Aberrant anatomy of trachea
- Thyroid goitre
- Morbid obesity
- Short distance between cricoid and sternal notch in extended position
- Unstable cervical spine
- Difficult intubation (Cormack-Lehane grade 3 or 4)
- High FiO_2 (> 0.6) and PEEP (>10cmH_2O)

In some circumstances consideration can be given to performing the PDT in theatre with a surgeon available to manage complications.

In text References

(Higgins and Punthakee. 2007)

References

- Higgins KM, Punthakee X., Meta-analysis comparison of open versus percutaneous tracheostomy., 2007, PMID:17334304

7. 3. PDT Procedure

A pre-procedure checklist is useful to ensure adequate preparation of the patient, equipment and staff prior to the operation. Plans for difficulty should be made at this stage too. Briefly, consent should be confirmed; risk of bleeding assessed; a review of the airway made; ventilation converted to pressure-controlled-volume-guaranteed mode (to compensate for leak during the procedure) with a FiO2 of 1.0; and the stomach emptied via a nasogastric tube. The patient should be anaesthetised and neuromuscular blockade commenced. Full monitoring consistent with any anaesthetic case should be ensured and consideration given to making the pulse oximeter audible on the monitor. Emergency airway equipment should be readily available. A minimum of three staff are required: an operator, an endoscopist and a helper (often the bedside Nurse). The procedure should be performed during routine working hours such that there is potential availability of a surgeon capable of dealing with complications.

1. Ultrasound the anterior neck in order to identify anterior vessels which would preclude PDT.
2. Reposition the ETT using laryngoscopy such that the cuff is hyper-inflated above the glottis; a videolaryngoscope is useful to provide optimal views.
3. Position the patient with the neck extended to allow best access; a minimum of 3-4 cm is recommended between cricoid and sternal notch.
4. Position the bed with a slight head up tilt to encourage venous drainage.
5. Infiltrate the skin overlying the operation site with lignocaine 2% and adrenaline 1:200000 in order to provide analgesia post-operatively and reduce bleeding from small vessels.
6. Prepare the skin with antiseptic containing either chlorhexidine or iodine and drape the patient to minimise infectious complications.
7. Make a small incision in the skin. A vertical incision allows extension of the wound should the level be too high or low and avoids large vessels. A horizontal incision improves cosmesis.
8. Dissect tissues until palpation of the trachea.
9. Under bronchoscopic guidance insert a needle or cannula into the space between the 2nd and 3rd tracheal rings. The midline is preferred to reduce the risk of injury to the recurrent laryngeal nerve. Insertion of the tracheostomy between cricoid and the 1st ring increases the risk of subglottic stenosis. Lower insertion risks erosion into the brachiocephalic vessels.
10. Pass a guidewire through the cannula under direct vision. The bronchoscope ensures that no injury to the posterior tracheal wall occurs during insertion of the needle or passage of the guidewire as well as ensuring the wire passes caudally.

At this stage different techniques can be employed.

Ciaglia serial dilation

1. Pass a short dilator over the guidewire, and then remove the dilator over the guidewire.
2. Pass a guide sheath over the guidewire.
3. Pass dilators of increasing size over the guide sheath until the stoma is of adequate size to accept the tracheostomy tube. The tracheostomy tube is inserted over the sheath and dilator.

Single tapered dilation

1. Pass a short dilator and then remove over the guidewire.
2. Pass a guide sheath and large gradually tapered dilator over the guidewire.
3. Remove the large dilator and pass the tracheostomy tube (preloaded onto a stiffener) over the wire and guide sheath into the trachea.

Grigg’s technique

1. Using specialised forceps (Howard Kelly forceps) dilate the trachea over the guidewire to the desired size.
2. Insert the tracheostomy tube over the wire into the trachea.

Balloon dilation

Despite extensive investigation into the timing of tracheostomy in critical care there is no benefit to early (before 8 days) tracheostomy with regards mortality, ventilator-associated pneumonia, laryngotracheal complications and ICU length of stay. However, evidence does support tracheostomy as a means to reduce duration of mechanical ventilation and that early tracheostomy (performed before 7 days) shortens the duration of MV and hospital stay and reduces the incidence of complications for patients with acute spinal injury. In addition, a single-centre study suggested tracheostomy may shorten length of stay and thus reduce costs in the trauma setting.

In text References

(Raimondi et al. 2017; Hyde et al. 2015)

References

- Raimondi N, Vial MR, Calleja J, Quintero A, Cortés Alban A, Celis E, Pacheco C, Ugarte S, Añón JM, Hernández G, Vidal E, Chiappero G, Ríos F, Castilleja F, Matos A, Rodriguez E, Antoniazzi P, Teles JM, Dueñas C, Sinclair J, Martínez L, Von der Osten I, Ve, Evidence-based guides in tracheostomy use in critical patients., 2017, PMID:28188061
- Hyde GA, Savage SA, Zarzaur BL, Hart-Hyde JE, Schaefer CB, Croce MA, Fabian TC, Early tracheostomy in trauma patients saves time and money., 2015, PMID:25441577

7. 5. Complications

Complications of tracheostomies can be defined as early, intermediate and late and are listed below.

Immediate:

- Bleeding
- Hypoxia
- Loss of airway
- Pneumothorax and surgical emphysema
- Air embolism (high risk during extracorporeal membrane oxygenation)
- Posterior tracheal wall injury
- Recurrent laryngeal nerve injury
- Tracheal ring fracture potentially leading to formation of granulation tissue
- Misplacement of tracheostomy which if not recognised will lead to rapid hypoxaemia and cardiac arrest
- Raised intracranial pressure

Intermediate

- Atelectasis
- Wound infection
- Dislodgement of tracheostomy
- Blockage of tracheostomy

Late

- Infection
- Tracheomalacia
- Tracheal stenosis
- Tracheo-oesophageal fistula
- Fistulation to innominate artery
- Tracheal granuloma formation
- Delayed wound closure
- Swallow dysfunction
- Permanent voice changes

In order to minimise the immediate complications prudent patient selection, together with the use of ultrasound, capnography and bronchoscopy are useful. An operator with expertise in the procedure should be immediately available at the bedside. In addition, processes within the department whereby a surgeon can be readily available also aid in minimising the risks. A recruitment manoeuvre immediately post-operatively may mitigate atelectasis caused by the loss of PEEP.

Bleeding is a risk associated with tracheostomy from the moment the procedure is performed. Early bleeding is often related to bleeding at the wound edge. This can be managed with normalisation of coagulation and direct pressure at the site followed by transfer to theatre for definitive haemostasis by surgeons. Delayed bleeding is often caused by erosion of the tracheal tube through the trachea and into a vessel.

Though uncommon the effects can be catastrophic. Immediate management should be to secure the airway with a cuffed tube placed distal to the erosion. Emergency Anaesthetic assistance is advised since the easiest option is to place a standard endotracheal tube. If possible digital pressure compressing the vessel against the sternum may control bleeding pending the arrival of surgical support.

There were 14 cases of displaced tracheostomy that occurred within intensive care reported during a national audit of airway complications. Strikingly, half of these patients died. Significant factors associated with death included lack of access to capnography and the placement of inappropriately sized tubes in obese patients. Another early complication of tracheostomy insertion is blockage of the tube due to secretions or blood clots. Humidification, as well as regular suctioning and assessment of the inner cannula should minimise the risk of the tube becoming occluded. In an emergency, suctioning followed by changing of the inner cannula should invariably resolve the issue.

As with any surgical wound the tracheostomy site may become infected. Invariably stomal infections can be managed with antibiotics. It is important to be alert to the rare possibility of the development of necrotising infections, mediastinitis and sternoclavicular joint osteomyeltitis which are associated with a high mortality. Tracheitis has a spectrum of presentation ranging from mild inflammation to multiple shallow necrotic ulcers and has been reported to occur at a rate of 23 to 480 per 100, 000 procedures .

Though rare, trachea-oesophageal fistula has a high mortality. Ensuring no injury to the posterior wall of the trachea during insertion and preventing excessive tracheal tube cuff pressures are the best means to prevent this occurrence.

Longitudinal studies suggest tracheal stenosis is no more likely after tracheostomy than prolonged intubation. Stenosis is the most significant long-term complication associated with tracheostomy however. The site of stenosis may be subglottic, stomal or at the cuff site. Risk factors for stomal site stenosis are: sepsis, stomal infection, hypotension, advanced age, male gender, steroids, tight fitting or oversized cannula, excessive tube motion, prolonged placement, and disproportionate excision of anterior tracheal cartilage during tracheostomy creation. The risks for cuff site stenosis are: female sex, older age, prolonged tube placement, and excess cuff pressure, though the use of high-volume, low-pressure cuffs has decreased the incidence by about 10-fold. Patients are usually asymptomatic until 50–75% of the trachea is occluded and stridor may occur when the tracheal diameter is 5mm. Patients who are clinically asymptomatic at rest can develop significant symptoms under stress with an incidence for percutaneous tracheostomy of 6–7%. Significant respiratory symptoms following discharge from critical care in patients who have had a tracheostomy warrants investigation and follow-up by ENT surgeons.

In text References

(McGrath et al. 2012; Cipriano et al. 2015; Dulguerov et al. 1999; Sue and Susanto. 2003; Cipriano et al. 2015)

References

- McGrath BA, Bates L, Atkinson D, Moore JA; National Tracheostomy Safety Project., Multidisciplinary guidelines for the management of tracheostomy and laryngectomy airway emergencies., 2012, PMID:22731935
- Cipriano A, Mao ML, Hon HH, Vazquez D, Stawicki SP, Sharpe RP, Evans DC, An overview of complications associated with open and percutaneous tracheostomy procedures., 2015, PMID:26557488
- Dulguerov P, Gysin C, Perneger TV, Chevrolet JC., Percutaneous or surgical tracheostomy: a meta-analysis., 1999, PMID:10470774
- Sue RD, Susanto I., Long-term complications of artificial airways., 2003, PMID:14535220

7. 6. Tracheostomy Tubes

There are several types and manufacturers of tracheostomy tubes and it is important to have an understanding of the individual tubes available. The dimensions of tracheostomy tubes are given by their inner diameter, outer diameter, length, and curvature. It is noteworthy that tubes - which at first sight are similar in size - may have different lengths despite the same inner diameter or have different internal diameters despite the same outer diameter, for example. This is particularly important when changing tracheostomy tubes.

Tracheostomies with an inner cannula allow intermittent cleaning of the internal lumen of the device without having to change the tube. Some manufacturers produce a tube in which the 15-mm attachment (for connection to a ventilator or self-inflating bag) is on the inner cannula such that if the inner cannula is inspected in an emergency it must be replaced in order to connect a capnograph or to provide ventilation via a self-inflating bag. It is therefore crucial that staff caring for patients with tracheostomies have an understanding of the variations available and the specific type of tracheostomy each individual patient has in situ. Though the inner cannula improves safety it may also increase the work of breathing as a result of the reduced internal diameter. For obese patients tubes have been manufactured which either have an extra proximal length or an adjustable phlange. Different tubes will fit different patients.

Other features of a tracheostomy tubes to consider are the presence or absence of a cuff or fenestrations and the use of subglottic suctioning. A cuff permits ventilation and protects the airway from micro-aspiration. As weaning progresses the cuff may be deflated intermittently to allow air flow through the glottis thus reducing the work of breathing and enabling speech. Once a patient is liberated from the ventilator, an uncuffed tube provides the above advantages as well as reducing the risk of airway obstruction. A fenestrated tube has windows in the posterior portion of the tube above the cuff which allow increased airflow through the native airway (though there is there is a

1. Pass a short dilator and then remove over the guidewire.
2. Preload the tracheostomy tube over the modified angioplasty balloon dilation device.
3. Insert the balloon so that its midpoint sits at the anterior tracheal wall.
4. Inflate the balloon with saline to a pressure of 11 atmospheres for 15 seconds.
5. Deflate the balloon.
6. Railroad the tracheostomy over the device into the trachea.

To complete the procedure the following steps should be employed:

1. Bronchoscopy allows visualisation of the tracheostomy tube passing into the trachea and inflation of the cuff.
2. Once the tracheostomy has been placed, remove the guide wire and stiffeners.
3. Pass a suction catheter down the tracheostomy in order to remove blood and secretions.
4. Pass the bronchoscope through the tracheostomy tube to ensure the tube is in the correct position before positive pressure ventilation.
5. Pass the bronchoscope to the carina and measure the distance from the carina to the tip of the tube.
6. Connect the ventilator.

The tracheostomy should be sutured or tied in place and plans made for sedation, analgesia, deep vein thrombosis prophylaxis and weaning of ventilation communicated to the bedside nurse. Routine chest x-ray is not indicated unless clinically indicated. See figure 18 for a description of the singledilator technique.

Figure 18:

figure 18
from ESICM Channel

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In general, there are advantages and disadvantages to the various techniques. Though comparative studies suggest the single tapered dilation technique is marginally easier, safer and quicker to perform it seems more important that the technique used has been well practised by the operator. The Griggs' procedure may be useful in places with resource constraints as forceps can be reused and no special kit is required whilst the balloon dilation method may be useful in situations whereby neck extension is contraindicated (though this is at present theoretical based on the direction of forces applied during the procedure).

In text References

(Tobler WD et al. 2012; Byhahn et al. 2000; Al-Ansari and Hijazi. 2006; Cianchi et al. 2010)

References

- Tobler WD Jr, Mella JR, Ng J, Selvam A, Burke PA, Agarwal S., Chest X-ray after tracheostomy is not necessary unless clinically indicated., 2012, PMID:22167261
- Byhahn C, Wilke HJ, Halbig S, Lischke V, Westphal K., Percutaneous tracheostomy: ciaglia blue rhino versus the basic ciaglia technique of percutaneous dilational tracheostomy., 2000, PMID:11004042
- Al-Ansari MA, Hijazi MH., Clinical review: percutaneous dilatational tracheostomy., 2006, PMID:16356203
- Cianchi G, Zagli G, Bonizzoli M, Batacchi S, Cammelli R, Biondi S, Spina R, Peris A, Comparison between single-step and balloon dilatational tracheostomy in intensive care unit: a single-centre, randomized controlled study, 2010, https://www.sciencedirect.com/science/article/pii/S0007091217335912#!

7. 4. Timing of Tracheostomy

higher incidence of granuloma formation). Tracheostomy tubes that provide a suction port above the cuff act to reduce incidence of VAP; retrograde flow of gas above the cuff to exit via the larynx also allows speech. Silicone tracheostomy tubes can be used for patients who require long-term ventilation; in theory the material increases patient comfort and requires less frequent tube changes.

In text References

(Black and Allan 2017; McGrath et al. 2016)

References

- Black E, Allan R, Medical High Dependency Unit series, Article 4: Tracheostomy management., 2017, PMID:29300797
- McGrath B, Lynch J, Wilson M, Nicholson L, Wallace S, Above cuff vocalisation: A novel technique for communication in the ventilator-dependent tracheostomy patient., 2016, PMID:28979454

7. 7. Routine care

A national (UK) audit project assessing the use and complications of tracheostomies reported that the vast majority of wards cared for less than 2 patients with tracheostomies per month. In addition, a French study found an increased mortality for patients with tracheostomy cared for outwith the ICU. Because of this, guidelines mandated training for all staff caring for patients with tracheostomies. The National Tracheostomy Safety Project recommends that patients with a tracheostomy should have the details of that tracheostomy clearly displayed at the bedside. Any patient with a tracheostomy should also have equipment available at the bedside for emergencies and this should include:

- an emergency algorithm to act as an aide memoir for staff;
- a Mapelson C circuit to attach to the device to assess whether or not airflow is occurring through the tracheostomy tube;
- a non-breathing mask to be applied to the upper airway in all emergencies in case the tube has been dislodged and the patient can breathe through their mouth;
- suction catheters to both remove secretions and assess the patency of the tracheostomy;
- a 10ml syringe in order to deflate the cuff of the tube;
- scissors and a stitch cutter to allow removal of sutures or tube tie should the tracheostomy become partially dislodged;
- tracheal dilators to aid re-insertion of a new tube (generally this is in the realms of an ENT surgeon);
- a spare tracheostomy tube of the same size and a size smaller so that experts may be able to change the tube;
- an airtight occlusive dressing to apply to the front of the neck should the tracheostomy be removed to allow breathing through the upper airway;
- and finally a paediatric face mask which allows controlled ventilation via the stoma (again this is the premise of an expert).

In addition, it is vital that these patients and their care-providers have emergency access to capnography and fibreoptic bronchoscopes to allow confirmation of tube position.

Humidification and cuff pressure measurement is as per routine tube management. Regular changing and or inspection of the inner cannula should be undertaken at least every 8 hours so as to minimise the risk of the inner cannula becoming occluded with secretions.

The first tracheostomy tube change should be undertaken by the operating team and usually takes place no earlier than 7 days following insertion of the tube. Though there is little evidence to guide timing; replacement of the tube earlier than one week risks loss of the patent stoma particularly in percutaneously placed devices. The use of an airway exchange catheter and fibreoptic scope improves the safety of the first change.

In text References

(National Confidential Enquiry into Patient Outcomes and 2014; McGrath. 2014; Intensive Care Society) 2008)

References

- National Confidential Enquiry into Patient Outcomes and Death , Tracheostomy Care: On the Right Trach?, 2014, http://www.ncepod.org.uk/2014tc.html
- McGrath BA. , Comprehensive Tracheostomy Care: The National Tracheostomy Safety Project Manual, 2014, ISBN:9781118792773
- Intensive Care Society (ICS), Standards for the Care of Adult Patients with a Temporary Tracheostomy. , 2008, https://www.theawsomecourse.co.uk/ICS/ICS%20Tracheostomy%20standards%20(2014).pdf

7. 8. Weaning and decannulation

As with extubation, weaning with a view to decannulation should be initiated as early as possible. Once established on minimal ventilator settings the patient is transitioned to either a T-piece (with the tracheostomy cuff remaining inflated) or Tracheal mask (during which the cuff is deflated). Deflation of the cuff is dependent on the patient being able to protect their airway from microaspiration. Swallowing can be assessed by trained nurses or specialists. Occasionally, videofluoroscopy or nasendoscopic examination may be required to assess for a 'safe swallow'.

The process might proceed thus:

1. Provided deflation of the cuff does not lead to excess fatigue or aspiration of oropharyngeal secretions the duration of cuff deflation is steadily increased.
2. Increased airflow through the upper airway is improved by converting to a smaller, cuffless tube with fenestrations. This improves bulbar and glottis strength.
3. The use of a speaking valve further improves glottic strength and the patient's psychological state as they begin to communicate.
4. A trial with a tracheostomy tube 'cap' for a period prior to decannulation highlights whether or not there is any residual upper airway obstruction prior to tube removal.

The use of a decannulation checklist ensures safe removal of the artificial airway. Before removal of the device the following should be considered:

- Reason for tracheostomy resolved.
- No planned interventions that would require an artificial airway.
- Minimal oxygen requirements for greater than 24 hours.
- Respiratory rate less than 30.
- Tolerating cuff deflation for at least 24 hours.
- Strong cough.
- Minimal respiratory secretions.
- Neurologically and haemodynamically stable.

7. 9. Tracheostomy Emergencies

When dealing with any tracheostomy emergency a step-wise approach will provide a fast and effective resolution of the problem in most circumstances and we advocate adoption of guidelines in all hospitals.

When approaching the bedside it is crucial to know at an early stage what the indication for the tracheostomy was and when and how the procedure was performed. Examples of thought processes might be as described below.

1. The procedure was performed for upper airway obstruction thus standard management of the upper airway will be at the very least challenging and experts will be required immediately.
2. The procedure was performed percutaneously less than 72 hours ago and so the stoma may close over should the tube become dislodged. Reintubation may be the safest option.
3. The patient is weaning via an uncuffed tube. The tracheostomy has been present for a month. The patient may no longer require the tracheostomy and re-insertion should be straightforward.
4. Because the upper airway was liable to become oedematous postoperatively a Bjork flap was created in order that the risks of re-insertion of a tracheostomy tube would be reduced. In these circumstances it is important to differentiate between stay sutures and sutures attached to a Bjork flap which is a flap of anterior trachea sutured to the skin of the neck. Tension on the sutures attached to this flap might pull through the trachea. The Bjork flap allows easier replacement of the tracheostomy tube since the stoma is held open and is sometimes preferred in cases whereby loss of the trans-tracheal route to the airway might be disastrous.

In emergencies the temptation to replace dislodged tubes blindly must be avoided as this can lead to the creation of a false passage which, particularly if it then has positive pressure ventilation applied to it, can result in surgical emphysema and complete inability to oxygenate the patient. Partial dislodgement or displacement is more difficult to recognise since the tube remains attached to the patient. The tracheostomy tip may be within the subcutaneous tissues of the anterior neck or abutting the posterior tracheal wall. Under such circumstances: the patient will suffer symptoms and signs of respiratory distress; there will be no movement of air via the device; an inability to pass a suction catheter and no capnography trace present. Blockage of the tube due to secretions or blood clots should be managed by suctioning followed by changing of the inner cannula.

In text References

(McGrath. 2014)

References

- McGrath BA. , Comprehensive Tracheostomy Care: The National Tracheostomy Safety Project Manual, 2014, ISBN:9781118792773

8. Conclusion

Appropriate management of the airway is the cornerstone of good resuscitation. It requires good judgment (airway assessment), skill (airway manoeuvres) and constant reassessment of both the patient's condition and the efficacy of medical interventions. While complex procedures are sometimes life-saving and always carry the ability to impress the uninitiated, it is important to realise that the timely application of simple airway manoeuvres are often very effective and may avoid the need for further intervention.