Airway management at the end of anaesthesia: extubation and related issues

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Introduction

Peri-operative airway management involves care of the patient during and following tracheal intubation and extubation. As tracheal extubation is the logical consequence of tracheal intubation, and continued control of the airway after extubation constitutes part of the overall airway management, it appears logical that there would be a pre-formulated extubation algorithm. However, in contrast to the intubation period, no such guideline is available for the period during and immediately after extubation. This is even more surprising as the incidence of complications associated with extubation may exceed those occurring during intubation [1]. Eighteen of the 156 peri-operative claims for difficult airway management between 1985 and 1999 included in the American Society of Anesthesiologists (ASA) Closed Claims database were associated with extubation in the operating room [2]. This brief overview will review some clinically relevant complications associated with tracheal extubation and discuss possible strategies for extubation of the difficult airway.

Complications associated with extubation

The complications associated with extubation may broadly be divided into cardiovascular and respiratory ones [3]. Cardiovascular complications include tachycardia and hypertension, which may be significant in patients with pre-existing ischaemic heart disease, increased intracranial pressure or pre-eclampsia. Respiratory complications include local trauma, coughing, desaturation, breath-holding, laryngospasm, airway obstruction and aspiration.

Laryngospasm

Laryngospasm is likely to be the most frequent cause of airway obstruction following extubation. It may be provoked by sudden stimulation while the patient is in a light plane of anaesthesia, and by vocal cord irritation through secretions (e.g. saliva, blood, gastric content). Although suctioning of the oropharynx should routinely be performed, it must be performed while the patient is still deeply anaesthetised because any kind of irritation of the vocal cords at a light plane of anaesthesia may provoke laryngospasm. Extubation during application of positive airway pressure is an additional means of removing secretions from around the vocal cords. This manoeuvre may, however, provoke coughing. If tracheal tube (TT) cuff pressure has been monitored and maintained at the recommended level, extubation without prior cuff deflation may be a further means of removing secretions from above the vocal cords during extubation [4].

If risk factors for the development of laryngospasm exist, extubation during deep anaesthesia should be considered. Patients being extubated during deep levels of anaesthesia are preferably placed in the lateral (and possibly slightly Trendelenburg) position to keep the vocal cords clear of secretions during emergence.

Negative pressure pulmonary oedema

Negative pressure pulmonary oedema (NPPOe) is a relatively infrequent but potentially serious event after extubation. It is a non-cardiogenic pulmonary oedema caused by upper airway obstruction. The exact mechanism whereby upper airway obstruction precipitates pulmonary oedema is not entirely clear. The initiating event is vigorous inspiratory efforts in the presence of upper airway obstruction.
provoking pronounced negative pleural pressures. Whereas normal pleural inspiratory pressures range from -2 to -5 cmH\textsubscript{2}O, negative pressures as high as 100 cmH\textsubscript{2}O have been reported during severe episodes of upper airway obstruction. Such extremely negative pleural pressures result in negative transpulmonary pressure that leads to transudation of fluid from the pulmonary capillaries into the interstitium. The accompanying hypoxaemia increases sympathetic tone. This results in increased adrenergic state, increased left ventricular preload and afterload, altered pulmonary vascular resistance, increased, right ventricle dilatation, intraventricular septum shift to the left, left ventricular diastolic dysfunction, increased left heart loading conditions, enhanced microvascular intramural hydrostatic pressure, and negative pleural pressure. Transmission of the negative pleural pressure to the lung interstitium may result in a marked increase in transmural pressure, fluid filtration into the lung and development of pulmonary oedema.

NPPOe has been reported in a variety of clinical situations, but the exact incidence is difficult to establish from case reports. Laryngospasm is the most common cause of NPPOe. NPPOe may occur in up to 4% of all cases of laryngospasm [5]. Other less common causes include obesity, short and thick neck, history of sleep apnoea and nasopharyngeal soft tissue disorders, acute tracheal tube obstruction, laryngeal mask clench during emergence from anaesthesia, intensive hiccups during anaesthesia, aspiration, bilateral vocal cord palsy, biting of a tracheal tube and direct suctioning of the tracheal tube adapter. Young and athletic individuals are especially prone to develop NPPOe because of their ability to generate vigorous inspiratory effort that can result in extreme negative pleural pressures.

NPPOe develops within minutes after extubation. If peripheral oxygen saturation markedly decreases during the process of extubation or shortly thereafter, NPPOe needs to be ruled out. Management involves removing the airway obstruction, administering oxygen, reducing left ventricular afterload, and non-invasively applying continuous positive airway pressure. Re-intubation is rarely necessary. In most cases, extubation-associated NPPOe is a self-limited condition that is relatively easy to manage and carries an excellent prognosis. However, as accompanying respiratory distress, tachypnoea, cyanosis, accessory muscle utilization and decrease in peripheral oxygen saturation are non-specific signs, the diagnosis of NPPOe may be delayed. Morbidity and mortality of unrecognized NPPOe may be as high as 40% and require admission to an intensive care unit [6].

Paradoxical vocal cord motion

This is an unusual, rarely diagnosed and incompletely understood cause of upper airway obstruction, but a considerable risk factor for extubation failure. It can be mistaken for refractory asthma or recurrent laryngospasm. The abnormality is functional, rather than anatomical. The cause of upper airway obstruction is vocal cord adduction during inspiration [7]. Such patients may undergo multiple tracheal extubations and re-intubations. Successful extubation in this condition has been reported after substitution of the TT with a laryngeal mask airway (LMA) under deep general anaesthesia and weaning the patient very slowly from a propofol infusion [7].

Strategy for extubation of the difficult airway

General considerations

An effective extubation strategy should have a low re-intubation rate and not cause patient discomfort. It should also enable oxygenation and ventilation and facilitate re-intubation if necessary. There are no tests with acceptable positive and negative predictive value for extubation tolerance. As even most high-risk patients will be extubated without major complications, it is imperative that any proposed extubation strategy carries less risk than simply removing the TT and hoping for the best.

As prediction of extubation success is unreliable, any extubation should be viewed as a potential re-intubation. As a logical consequence, any extubation should include a pre-formulated strategy that ensures continued oxygenation and ventilation and minimises complications in case of extubation failure. This principle applies, in particular, to patients at a priori increased risk of extubation failure. Multiple intubation attempts, need for alternative airway management techniques, a history of difficult airway management prompting the primary use of an alternative airway management technique, and certain diseases (e.g. cardiopulmonary diseases, rheumatoid and cricoarytenoid arthritis, obstructive sleep apnoea) and surgeries (e.g. thyroid, carotid, maxillofacial, cervical, posterior fossa, tracheal) are associated with an increased incidence of extubation failure and difficult re-intubation.
The approach to the patient at high risk for extubation failure should be systematic and thorough. Such an approach includes: assessment of past and current medical and surgical histories and their specific relevance to the airway and respiratory system; physical assessment of the airway by direct laryngoscopy or fibre-optic inspection, or both; and, based on those assessments, formulation of an extubation strategy that focuses on providing continuous oxygenation and ventilation post-extubation and on providing a means of facilitating reinstitution of the airway, also referred to as ‘reversible extubation’ [8].

It needs to be recognised and planned and acted accordingly that tracheal re-intubation will usually be more difficult than the initial intubation, because of the frequently emergent nature, the accompanying hypoxaemia and cardiovascular instability, the lack of patient co-operation, insufficient time for adequate preparation, and limited access to the airway (as in cases of intermaxillary or cervical fixation, cervical instability, lingual, pharyngeal and laryngeal oedema, neck swelling). Not surprisingly, then, an airway emergency and repeated intubation attempts have been associated with worse outcome, including death and brain damage [2].

The literature does not provide a sufficient basis for evaluating the benefits of a specific extubation strategy for the difficult airway. The Task Force on Management of the Difficult Airway of the American Society of Anesthesiologists (ASA) regards the concept of an extubation strategy as a logical extension of the intubation strategy [9]. It recommends that the anaesthetist should have a pre-formulated strategy for extubation of the difficult airway. The pre-formulated extubation strategy should include: consideration of the relative merits of awake extubation versus extubation before the return of consciousness; evaluation of general clinical factors that may produce an adverse impact on ventilation after the patient has been extubated; formulation of an airway management plan that can be implemented if the patient is not able to maintain adequate ventilation after extubation; and consideration of the short-term use of a device that can serve as a guide for expedited re-intubation. The pre-formulated strategy will depend on the type of surgery, the condition of the patient, and the skills and preferences of the anaesthetist.

**Airway exchange catheter**

The pre-formulated extubation strategy recommended by the Task Force on Management of the Difficult Airway of the American Society of Anesthesiologists (ASA) includes consideration of the short-term use of a device that can serve as a guide for expedited re-intubation strategy [9]. This type of device is usually inserted through the lumen of the tracheal tube and into the trachea before the tracheal tube is removed. The device may be rigid to facilitate intubation and/or hollow to facilitate ventilation. The airway exchange catheter (AEC) is such a device, designed to maintain access to the airway after extubation, and may, thus, facilitate re-intubation. It is introduced through the tracheal tube before extubation and is left in situ after removal of the tube until the likelihood of re-intubation has become minimal [10, 11].

Tracheal re-intubation using an AEC is comparable with tracheal intubation over a fibre-optic bronchoscope. The difference in diameters between the AEC exchange catheter and the jacketed TT are predictive of the relative ease of tube advancement. If resistance during advancement is encountered, TT rotation may successfully release the tube from the piriform recess or arytenoid cartilage. Tracheal re-intubation can be facilitated by gentle retraction of the tongue by direct laryngoscopy.

The effectiveness and safety of AEC-facilitated re-intubation in patients with known or suspected difficult airway has been demonstrated [11]. Since tolerance of extubation cannot reliably be predicted, it is reassuring to know that an AEC facilitates re-intubation in the vast majority of patients with difficult airway. Even if the initial attempt at re-intubation fails in the presence of severe respiratory insufficiency, a jet-stylet-type AEC allows capnography, oxygen insufflation, and jet ventilation, thereby ‘bridging’ the time required to obtain additional airway equipment and qualified help. A smaller sized AEC is usually better tolerated than a large one.

However, AEC-facilitated extubation is not a fool-proof method. It does not automatically reduce the incidence of re-intubation, it has the potential for serious complications, and it is not always successful. Reliance on an AEC in case of suspected intolerance to extubation may lead to a more aggressive approach to extubation, with possibly less adherence to conservative extubation criteria. Premature removal of the AEC may lead to life-threatening hypoxemia and require an advanced airway technique to re-establish a secure airway. The optimal timing for removal of the AEC remains to be determined [8].
Thus, even when using an AEC, conventional extubation criteria should be strictly observed, and the options for direct laryngoscopy, cricothyroidotomy, fibreoptic or retrograde intubation, and jet ventilation or other techniques for re-securing the airway should be preserved. Although AEC-facilitated extubation is associated with a satisfactory success rate and patient acceptance, and does not require overly sophisticated equipment and skills, well-designed, controlled, prospective trials are necessary to ultimately determine the most effective extubation strategy [12].

**Timing of extubation**

Tracheal extubations may be performed before or after recovery of consciousness. The claimed advantage of extubation during deep anaesthesia is the avoidance of adverse reflexes associated with extubation (e.g. hypertension, tachycardia, dysrythmias, coughing, laryngospasm, myocardial ischaemia, and increased intracranial and intraocular pressures). This would be beneficial when avoidance of the haemodynamic and respiratory reflexes to extubation is advisable (e.g. following certain intracranial, ophthalmologic, or thoracic surgical procedures). The principal disadvantage of tracheal extubation during deep anaesthesia is the increased risk of upper airway obstruction and inadequate airway protection rendering the patient prone to pulmonary aspiration.

An alternative method to extubation in the awake state is substitution of an LMA for the TT during deep anaesthesia, with subsequent removal of the LMA when the patient resumes spontaneous ventilation and obeys commands. At the time of airway exchange patients must be at a sufficient depth of anaesthesia, otherwise the adverse events the substitution is intended to avoid (coughing, breath holding, laryngospasm, haemodynamic stimulation) may occur. Substitution of a LMA for the TT during deep anaesthesia may also be useful in cases of suspected tracheomalacia and laryngeal dysfunction because it facilitates fibre-optic assessment of anatomy and function of trachea and larynx after resumption of spontaneous ventilation before emergence from anaesthesia. This approach ensures adequate depth of anaesthesia, inspired oxygen concentration and ventilatory support during fibre-optic inspection. If tracheal re-intubation is required, a large bore AEC jacketed over the fibre-optic bronchoscope is introduced into the trachea, the fibre-optic bronchoscope and the LMA are removed, the TT is advanced over the AEC, and the AEC subsequently removed.

**Strategies to avoid haemodynamic and respiratory reflexes**

Emergence from anaesthesia and tracheal extubation is frequently associated with tracheal irritation that elicits cardiovascular [13] and respiratory reflexes [1] that may adversely affect outcome. Smooth extubation without coughing and bucking is, therefore, a necessary skill for anaesthesiologists. Various strategies have been developed to prevent such reflexes, including extubation under deep anaesthesia, administration of local anaesthetics, vasodilators, and short-acting beta-blockers and opioids.

Total intravenous anaesthesia may elicit less coughing and haemodynamic stimulation during emergence from general anaesthesia when compared with a sevoflurane-based inhalation technique [14]. Similarly, maintaining a low-dose remifentanil infusion during emergence from anaesthesia may reduce haemodynamic changes and cough reflex activities associated with tracheal extubation with minimal effects on recovery from anaesthesia [15].

**Cuff-leak test**

Assessment of upper airway patency is challenging in the intubated patient. Qualitative and quantitative cuff-leak tests have been described to assess the degree of laryngeal oedema and subsequent risk of re-intubation. An association between the absence of an audible air leak after deflation of the TT cuff and the development of post-extubation stridor has been demonstrated (qualitative cuff leak test). Patients with a cuff leak volume of <110 ml or of ~ 20% of tidal volume (quantitative cuff leak test) may be at high-risk for the presence of laryngeal oedema and subsequently for re-intubation [16]. However, the positive and negative predictive values of the air leak test are low which makes this test rather unreliable for individual risk prediction. In addition, children, the air leak test did not accurately predict problems after extubation [17]. One of the reasons for the low predictive values may be that the TT may act as a stent that keeps the airway open. As cuff deflation will not necessarily be followed by acute accumulation of mucosal oedema, patients with mild to moderate airway oedema may well have a cuff leak at the time of extubation. In addition, cuff deflation will not remove the stenting effect of the TT on supraglottic airway tissue. At various times after removal of the stenting TT, re-accumulation of tissue oedema and loss of ‘stenting’ of
supraglottic tissue may result in occlusion of the upper airway.

The overall evidence suggests that an air leak test should not be used as the sole means to determine readiness for extubation. However, it may still be worthwhile to perform it in patients at risk of airway swelling and obstruction because absence of a cuff leak will, at least, trigger discussion about subsequent airway management (i.e. delaying extubation, extubating over an AEC, or performing a tracheotomy).

**Muscle relaxation**

In patients at high-risk for extubation failure, incomplete reversal of muscle relaxation will contribute to, or even be the primary cause of upper airway obstruction after extubation. Thus, clinically adequate return of neuromuscular function following administration of muscle relaxants is essential. This can only be assured by using quantitative relaxometry [18]. If such a technique is not available, muscle relaxants must be antagonised by appropriate doses of acetylcholine esterase inhibitors or sugammadex, or ventilation needs to be continued for 3-4 h after the last dose of an intermediately long-acting muscle relaxant.

**Summary**

Most tracheal extubations are accompanied by relatively benign, transient complications. In certain settings, the risk of re-intubation is increased. Tracheal re-intubations are generally more complex because of associated hypoxia, hypercapnia, haemodynamic instability, airway obstruction and agitation. If airway management had previously been difficult, access to the airway is restricted, or the required skills, equipment, and personnel are not immediately available, tracheal extubation should be regarded as high-risk and an appropriate strategy should be employed.

**Key learning points**

- As tracheal extubation is the logical consequence of tracheal intubation, and continued control of the airway after extubation constitutes part of the overall airway management, a pre-formulated extubation strategy is mandatory.
- Laryngospasm is likely to be the most frequent cause of airway obstruction following extubation. It is the most common cause of negative pulmonary pressure oedema.
- Extubation failure is increased following multiple intubation attempts, the need for alternative airway management techniques, a history of difficult airway management prompting the primary use of an alternative airway management technique, certain surgical procedures (e.g. thyroid, carotid, maxillofacial, cervical, posterior fossa, tracheal), and with certain diseases (e.g. cardiopulmonary diseases, rheumatoid and cricoarytenoid arthritis, obstructive sleep apnoea).
- Airway exchange catheter-facilitated extubation should be considered in patients at high risk of extubation failure.
- An air leak test should not be used as the sole means to determine readiness for extubation.

**References**


