Review Article

Extubation techniques in anaesthesia—a narrative review

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Background and Objective: Extubation has been demonstrated to be a high-risk phase of anaesthesia, despite it frequently remains an afterthought and it is the subject of relatively little research. The aim of this review article was to look at the available current evidence, guidelines and expert opinions on extubation to help provide a summary of risk stratification of patients, optimisation strategies available and approaches to extubation to help improve safety and outcomes.

Methods: A search of PubMed, EMBASE, Cochrane Library, and UpToDate was performed to identify relevant publications on extubation. Due to the relative paucity of publications, information was included from January 1990 to March 2023 and included approved guidelines, randomised controlled trials, cohort studies, case-control studies, cross-sectional studies, case series and expert opinion. Those not published in the English language, non-human studies and those concerning extubation in the intensive care setting were not included. Titles and abstracts were reviewed and those deemed clinically relevant were included, a full critical appraisal of all evidence was not performed.

Key Content and Findings: There are a wide range of approaches to extubation and the chosen process needs to be tailored to the individual patient. The key themes throughout the literature review highlighted the importance of thorough consideration, risk assessment, optimisation and planning for extubation.

Conclusions: Safe extubation can be performed using a variety of methods, practice has evolved since much of the initial research was performed and there is certainly scope for further investigation into current approaches particularly in the difficult airway.

Keywords: Extubation; awake extubation; deep extubation; difficult extubation

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Introduction

The American Society of Anaesthesiologists (ASA) defines difficult or failed tracheal extubation as the clinical situation in which anticipated, unanticipated difficulty or failure is experienced by a physician trained in anaesthesia care, leading to loss of airway patency and adequate ventilation after removal of a tracheal tube or supraglottic airway (SGA) from a patient with a known or suspected difficult airway (i.e., an "at risk" extubation) (1). Asai and colleagues found that the incidence of complications following extubation was higher than those at intubation, with 3.8% of patients experiencing airway obstruction either immediately following extubation or in the recovery area (2). In clinical practice, tracheal extubation is often underestimated and an afterthought in the planning and preparation for a case.

Historically extubation has been relatively neglected as a subject of research in anaesthesia particularly in comparison to the process of intubation and it also gets relatively little mention in the Royal College of Anaesthetists' (RCoA) training syllabus (3). Once the surgical element of a case is completed, the focus of the theatre team can become

Table 1 The search strategy summary

Items	Specification
Date of search	01/03/2023
Databases and other sources searched	PubMed, EMBASE, Cochrane Library, and UpToDate
Search terms used	Extubation, extubation guidelines, difficult extubation, extubation oxygenation, extubation positioning, extubation physiology, extubation complications, extubation risks, laryngospasm, extubation optimisation, neuromuscular blocker reversal, extubation dexmedetomidine, extubation lidocaine, extubation techniques, safe extubation, extubation strategy, deep extubation, awake extubation, supraglottic airway exchange, airway exchange catheter, staged extubation, remifentanil extubation and extubation complications
Timeframe	January 1990–March 2023
Inclusion and exclusion criteria	Titles and abstracts from core clinical journals and publications were analysed including approved guidelines, randomised controlled trials, cohort studies, case control studies, cross-sectional studies, case series and expert opinion. Those not published in the English language, non-human studies and those concerning extubation in the intensive care setting were not included
Selection process	The selection process undertaken by first author RE Reddall independently

scattered, concentration moves to the preparation of the theatre for the next case, often before the current case has been extubated. This is in contrast to the controlled conditions created for intubation and can confound any difficulties that may be encountered.

The RCoA and the Difficult Airway Society (DAS) 4th National Audit Project (NAP4) found that almost a third of major airway complications occurred during emergence and in the recovery period, further highlighting that this is a high-risk phase of anaesthesia. The majority of the problems encountered fortunately are minor however two cases resulted in death and one in severe brain injury and there were 10 emergency surgical airways attempted (4). Subsequent to these findings DAS published their guidelines for the management of tracheal extubation promoting a strategic, stepwise approach to extubation and highlighting the importance of planning and preparation. However, they also acknowledged that there were no large randomised controlled trials in extubation and therefore they took into consideration expert opinion in the form of editorials, book chapters and comments to form the basis of their recommendations (5).

This narrative review aims to summarise the established recommended practices surrounding extubation both in routine and more complex airway management, to highlight emerging evidence and areas in which further research is required. We present this article in accordance with the Narrative Review reporting checklist (available at https://joma.amegroups.com/article/view/10.21037/joma-23-21/rc).

Methods

A search of PubMed, EMBASE, Cochrane Library, and UpToDate was performed to identify relevant publications on extubation. Due to the relative paucity of publications, information was included from January 1990 to March 2023 and included approved guidelines, randomised controlled trials, cohort studies, case control studies, cross-sectional studies, case series and expert opinion. Those not published in the English language, non-human studies and those concerning extubation in the intensive care setting were not included. Titles and abstracts were reviewed and those deemed clinically relevant were included, a full critical appraisal of all evidence was not performed (*Table 1*).

What are the potential complications of extubation?

In most patients, extubation is uneventful, however a wide array of issues can be encountered ranging from minor to life-threatening. Problems encountered during emergence, extubation and in the recovery are summarised in *Table 2* in order of frequency encountered.

Coughing and bucking

While coughing and bucking may not have direct long-term

Table 2 Problems encountered at in the peri-extubation period (2,5-13)

Incidence	Effect
Very common (≥1/10)	Coughing and bucking
	Laryngospasm
	Desaturation (SpO_2 <90%)
	Breath holding
	Airway obstruction
	Hypertension/tachycardia
Common (≥1/100 to <1/10)	Inadequate reversal
	Apnoea/hypoventilation
	Residual neuromuscular blockade
Uncommon (≥1/1,000 to <1/100)	Post obstructive pulmonary oedema
	Bronchospasm
	Vomiting/aspiration
Rare (≥1/10,000 to <1/1,000)	Dental damage
Poorly quantified	Laryngeal incompetence
	Raised intracranial pressure
	Raised intraocular pressure
	Myocardial ischaemia
	Flap disruption
	Bleeding at surgical site
	Airway oedema
	Masseter spasm
	Mechanical difficulty removing tube
	Vocal cord dysfunction/paralysis

consequences, they are associated with a range of secondary issues including cardiovascular complications (myocardial ischaemia and arrhythmias), disruption of the surgical site and bleeding and an increased intracranial and intraocular pressure. Aiming for a smooth emergence, defined as a tranquil manoeuvre with minimal patient reaction and discomfort, stable vital signs, and maintenance of acceptable ventilation and oxygenation, along with a successful one is important (8).

Laryngospasm

Laryngospasm is the reflex closure of the glottis by adduction of the true and/or false cords and is caused by local stimulation of the larynx [by saliva, blood, vomitus or foreign body (including laryngoscope, airway device or tracheal tube)] or in response to other stimulation (surgery, movement, peripheral stimulation of anus or cervix) (14). It is one of the most common problems encountered at extubation and is more common in infants, smokers and patients with recent respiratory tract infections. It can cause complete or partial airway obstruction and often presents as inspiratory stridor leading to hypoxaemia and in severe cases post-obstructive pulmonary oedema and hypoxic cardiac arrest (11). The reflex is abolished in planes 2–4 of anaesthesia and so at emergence when depth is reduced patients are at increased risk. Resolution of laryngospasm can usually be achieved by the removal of the stimulus, administration of 100% Oxygen, application of positive end expiratory pressure (PEEP) and increasing the depth of anaesthesia however in some cases a low dose of muscle relaxant (suxamethonium 10 mg) or reintubation may be required. It can be prevented by ensuring removal of airway debris while the patient remains at a sufficient depth of anaesthesia, minimising head and neck movement around the emergence period, the use of total intravenous anaesthesia (TIVA) throughout the case and in some instances the use of local anaesthetics to the cords.

Reduced airway tone and aspiration

In NAP4, aspiration was found to be the most common primary cause of death in anaesthesia-related events (4). The most common reason for reduced airway patency and decreased reactivity postoperatively is thought to be the relaxation of pharyngolaryngeal muscles due to residual effects of inhalational anaesthetics and/or the inadequate reversal of neuromuscular blockade (NMB), leading to significant risk of postoperative pulmonary complications (15). Reduced airway tone is a particular problem in patients with obstructive sleep apnoea (OSA) who have an increased sensitivity to opioids and residual anaesthesia (16).

Residual NMB is associated with a reduction in pharyngeal function, increased incidence of airway obstruction and an increased risk of aspiration (17). Residual NMB can commonly present as airway obstruction. Breathing patterns and tidal volumes can appear normal despite a significant degree of residual paralysis, however the upper airway and pharynx are more sensitive to NMB and take longer to recover full function. Studies have

Table 3 Risk factors for complications at extubation

Factors	Complications
Patient factors	Severe cardiopulmonary disease
	Congenital or acquired airway pathology
	Morbid obesity
	Obstructive sleep apnoea
	Severe gastro-oesophageal reflux
	Smoking
	Complex chronic comorbidity, e.g., renal failure, congestive heart failure
	Laryngomalacia
	Rheumatoid arthritis
	Parkinson's and neuromuscular disorders
Anaesthetic factors	Difficult facemask ventilation
	Use of double lumen or large endotracheal tube
	Multiple attempts at intubation
	Excessive cuff pressure or incorrect cuff positioning
	Traumatic suctioning with Yankauer
	Prolonged intubation
Surgical factors	Recurrent laryngeal nerve damage
	Haematoma
	Oedema (secondary to surgery or head down positioning)
	Distortion of anatomy following head and neck surgery
	Posterior fossa surgery
	Inter-maxillary fixation
	Drainage of deep neck and dental abscesses

shown that pulmonary complications seem to be reduced with train-of-four ratios (TOFRs) >0.95 before tracheal extubation compared with > 0.9 emphasising the need for adequate neuromuscular monitoring and appropriate reversal before extubation (17). The use of a neuromuscular monitoring device is now mandatory however the qualitative measure using simple neuromuscular device and subjective assessment by the anaesthetist has been proven to be unreliable and it is with this that current guidelines recommend the use of a quantitative neuromuscular monitoring device (18,19).

Problems caused by surgery

Airway compromise post extubation can be a direct consequence of the surgical procedure or associated with patient positioning (prone or Trendelenburg) for surgery. Thyroid surgery, laryngoscopy, panendoscopy, maxillofacial procedures, spinal and carotid surgery can lead to airway obstruction due to oedema, haematoma, tracheomalacia and vocal cord paralysis.

Anaesthetic airway management related issues

Anaesthetic airway injury can occur as a consequence of laryngoscopy, trauma related to the insertion of SGAs and endotracheal tubes (ETT), high inflation pressure in the ETT cuff, incorrect placement of the ETT cuff, insertion of nasogastric tubes and oral suctioning with the Yankauer suction tip. The ASA closed-claims analysis of airway injury during anaesthesia showed that 33% of injuries occurred at the larynx, 19% at the pharynx, 18% at the oesophagus, 15% at the trachea, 10% at the temporomandibular joint and 5% at the nose. Of the laryngeal injuries leading to claims, vocal cord paralysis was the most common (34%) followed by granuloma (17%), arytenoid dislocation (8%) and haematoma (3%). Most (85%) of the laryngeal injuries were associated with short-term tracheal intubation and 80% followed routine (not difficult) tracheal intubation (20).

How can the risks associated with extubation be evaluated?

There are several risk factors that can be identified as increasing the potential for complications at extubation; these are listed in *Table 3* and can be divided into patient, anaesthetic and surgical factors. Patients undergoing oral or head and neck surgery accounted for almost 50% of major airway complications during emergence in NAP4 making these patients some of the highest risk (4).

The unanimous message stressed from international airway guidelines including DAS (5), The ASA Task Force Practice guidelines (1), the Canadian Airway Focus Group Airway Management guidelines (21), and the French Society of Anaesthesiologists (22) is that planning and risk stratification are key for a safe and successful extubation. They highlight that two key questions should be considered

Table 4 Risk stratification for extubation—factors to consider

Risk	Criteria
Low risk	Airway was normal/uncomplicated at induction
	Airway remains unchanged at the end of surgery
	No general risk factors present
'At risk'	Pre-existing airway difficulties—difficult at induction and may have worsened intra-operatively—including patients with obesity, OSA and those with an aspiration risk
	Peri-operative airway deterioration—airway was normal at induction but may have become difficult to manage, e.g., distorted anatomy, haemorrhage or oedema
	Restricted airway access, e.g., airway shared or head/neck movements restricted (halo fixation, mandibular wiring, surgical implants, c-spine fixation
	General risk factors—impaired respiratory function, cardiovascular instability, neurological/neuromuscular impairment, hypo/hyperthermia and abnormalities in clotting acid-base balance or electrolyte levels

OSA, obstructive sleep apnoea.

in this process:

- What is the likelihood that the patient will not tolerate extubation?
- If emergency re-intubation were required what would the predicted difficulty be?

Overall, a low risk extubation is one in which both the predicted risk of intolerance of extubation and the predicted risk of difficulty with reintubation are low. The DAS guidelines separate patients into two groups: those who are deemed a low-risk extubation and those who are an 'At risk' extubation (5); the division of these is outlined in *Table 4*.

A risk stratification and extubation plan should be considered pre-intubation and adapted if any changes occur at induction and intra-operatively. By starting the planning process, pre-intubation's possible difficulty can be communicated at the team brief so that both the anaesthetic and surgical team are aware that the extubation period requires additional consideration, concentration and time. It may also be that if the patient is considered high risk and at the end of the case extubation is deferred or an ETT is selected that could remain *in-situ* for ongoing care in intensive care unit (ICU), e.g., one with subglottic suction or avoiding an ETT that may pose challenges in ICU such as a South facing Ring, Adair & Elwyn (RAE) or flexi ETT. It may also be that an airway exchange catheter (AEC) is considered and discussion with the patient pre-operatively, setting the expectation that this may be *in-situ* on emergence may increase tolerance. Tracheostomy may also be considered and if there is a chance that this may be required, the patient can be appropriately consented by the surgical team.

How can the patient be optimised and prepared prior to extubation?

Pre-oxygenation

Consensus has not been reached on what the optimum concentration of inspired oxygen delivered to patients prior to extubation is. This remains a balance between the potential complications of hypoxia should airway obstruction occur versus the consequences of absorption atelectasis following delivery of high inspired oxygen concentrations. The DAS guidelines recommend aiming for an end expiratory oxygen concentration (FeO_2) of above 0.9 maximising pulmonary oxygen stores (5), thus providing a safe window of apnoea and delaying the onset of hypoxia should difficulties be encountered at extubation. However, it has been shown that alveolar atelectasis may occur after as little as 6 minutes at an inspired oxygen concentration of 100% (23).

Positioning

There is little evidence for the optimum positioning for extubation, there has however been a trend away from extubation in the left lateral +/– head down position which was historically used for the benefit of protecting the airway should vomiting or regurgitation occur and maintaining airway patency by allowing the tongue to fall forwards. A survey of UK consultant anaesthetists in 2005 found that in elective surgery 26% extubated in the head up position, 51% in supine and only 18% in left lateral and 3% in

left lateral and head down position. Head up positioning increased to 56% of cases in obesity (24).

Neuromuscular reversal

Recovery of neuromuscular airway tone and diaphragmatic function is essential to reduce both airway and respiratory complications at extubation. A TOFR >0.9 at the adductor pollicis muscle reliably represents full recovery of the airway muscles and diaphragm. Monitoring facial muscles overestimates the degree of recovery. However, if the arms are not accessible due to surgical positioning, monitoring the facial muscles but transitioning to the arms once they become available is recommended (25).

Both the ASA and European Society of Anaesthesiology and Intensive Care (ESAIC) have published new guidelines on the management of NMB during anaesthesia. In addition to other recommendations, both guidelines strongly recommend using quantitative neuromuscular monitoring (e.g., electromyography or accelerometery) rather than qualitative assessment and confirming a TOFR ≥0.9 before extubation. They also recommend using sugammadex for reversal rather than neostigmine for patients who have received rocuronium or vecuronium and who have residual block at or deeper than a TOFR of 0.4 (18,19).

Airway suctioning

Removal of debris, secretions and blood to minimise laryngospasm, aspiration and airway contamination is essential. It is recommended that this is performed under direct vision ideally with a laryngoscope to minimise trauma. Special caution must be taken if there is potential for accumulation of an occult clot, so called 'coroners clot', blood which has collected in the nasopharynx behind the soft palate following surgery. This has the potential to dislodge following extubation and can cause fatal airway occlusion (4). Suctioning of the lower airway and aspiration of gastric tubes should also be considered. Simultaneous deflation of the tracheal tube cuff and removal of the tube at the peak of a sustained inflation generates a passive exhalation and can be used to expel secretions and potentially reduce the incidence of laryngospasm and breath holding (5).

Bite block insertion

Insertion of a bite block after suctioning the pharynx can prevent occlusion of the ETT if the patient bites down on the tube during emergence. Various devices have been used to prevent biting down on the ETT including specialist devices such as the Breathsafe® Bite Block (OGM Ltd., UK) and rolled gauze. When using rolled gauze it is essential it remains clearly visible and taped to prevent accidental airway occlusion. Guedel airways are not recommended to prevent biting as they can cause dental fractures, one report found that up to 20% of cases of dental damage were due to the use of Guedel airways for this purpose (26). A strong inspiratory effort against an occluded tracheal tube can result in negative pressure pulmonary oedema (also known as post-obstructive pulmonary oedema). If biting of the ETT does occur, deflating the cuff can reduce the incidence of pulmonary oedema as it allows air to flow around the ETT.

Pharmacological attenuation of the physiologic response to extubation and coughing

In order to facilitate a smooth extubation, the principal aims are to suppress severe cough, hypertension, tachycardia, breath-holding and laryngospasm. A systematic review and network meta-analysis found that dexmedetomidine, remifentanil, fentanyl, and lidocaine all reduced the incidence of moderate to severe emergence coughing. Dexmedetomidine appeared to be the most effective medication for decreasing the frequency of moderate to severe emergence cough followed by remifentanil and fentanyl (27).

Dexmedetomidine

Dexmedetomidine is a selective α_2 adrenergic agonist, currently it remains licenced only for the provision of sedation in ICU however there is evidence that it can be used to attenuate the response to extubation including haemodynamic surges and coughing. The optimal dosing has been subject of trials in subsets of patients but has been demonstrated to be a balance between the desired effects and avoiding sedation and hypotension. Most studies have used a dose of between 0.5–1 μg/kg given slowly five to ten minutes prior to extubation. Kotak *et al.* concluded that 0.75 and 1 μg/kg doses were able to attenuate extubation response better than 0.5 μg/kg dose and provided better hemodynamic stability during emergence from anaesthesia. The dose of 1 μg/kg dexmedetomidine had more sedation and side effects, thus making 0.75 μg/kg dose the single best dose in hypertensive patients for attenuation of

Table 5 Summary of the process of extubation (5)

Step	Stage	Process
Step 1	Plan	Review and optimisation of the patient, considering the cardiovascular, respiratory, metabolic and neuromuscular status of the patient. Also taking into consideration the environment, assistance, monitoring and equipment available
Step 2	Prepare	Where a patient has been deemed to be a low risk extubation there are the options of a routine awake extubation or deep extubation. Deep extubation is a more advanced technique and requires experience both of the anaesthetist and recovery staff and close observation until the patient is fully awake
Step 3	Perform	When a patient has been deemed to be a low risk extubation there are the options of a routine awake extubation or deep extubation. Deep extubation is a more advanced technique and requires experience both of the anaesthetist and recovery staff and close observation until the patient is fully awake
Step 4	Post	This step includes the safe transfer of the patient to the recovery area with continuous delivery of oxygen, a clearly communicated handover of the patient and ongoing monitoring and care by the recovery staff

hemodynamic responses at extubation (28).

In a study in which dexmedetomidine compared to remifentanil for deep tracheal extubation in adult patients after otologic surgery, it was found that combined with 1 mean alveolar concentration (MAC) sevoflurane, dexmedetomidine 0.7 μg/kg and remifentanil provided similar rates for smooth tracheal extubation in spontaneously breathing, anaesthetised adults. Dexmedetomidine exhibited opioid-sparing effects postoperatively and was associated with less postoperative nausea and vomiting (PONV) than remifentanil (27).

Lidocaine

Lidocaine has been shown to reduce extubation coughing and sore throat, it can be applied topically to the airway prior to intubation, be given intravenously or be instilled into the ETT cuff. Topical and intravenous (IV) lidocaine work the fastest but if given at the time of intubation, may no longer be active at extubation. An IV dose of 0.5–2 mg/kg Lidocaine given perioperatively been shown to reduce coughing and sore throat at emergence (29). Using the ETT cuff as a delivery device, it has been shown that Lidocaine will pass via osmosis out of the cuff and topicalise the airway in both its alkalinised and non-alkalized form where it has been shown to improve ETT tolerance and reduce cough, agitation, and hemodynamic changes during extubation (30). However, in a network meta-analysis of medications used to reduce emergence coughing after anaesthesia, intracuff lidocaine was associated with delayed extubation times compared with placebo and with the other medications studied (31).

Opioids

A range of opioids can be used for their ability to suppress coughing at tracheal extubation, however remifentanil has the additional benefits of being ultra short acting and therefore minimising excessive sedation and prolonged respiratory depression. Studies have shown that maintaining a remifentanil infusion at an effect site concentration of 1.5–2 ng/mL does not prolong time to extubation but does reduce coughing and the associated haemodynamic surges (32,33).

Antihypertensives/esmolol

The haemodynamic response to extubation can be attenuated by directly targeting the cardiovascular system thus reducing the risk of complications particularly for example in those with significant ischaemic heart disease. Esmolol is an attractive option as its short duration of action bridges the extubation period without causing prolonged hypotension and bradycardia in the recovery area. A dose of 1.5–2 mg/kg given as a bolus 2 minutes after reversal of NMB significantly reduces systolic blood pressure and heart rate (34).

What techniques are available for extubation?

The DAS guidelines recommend a four-step process for extubation (5), these steps are summarised in *Table 5*. *Figure 1* acts as a basic decision-making framework and each method for extubation will be outlined in detail subsequently.

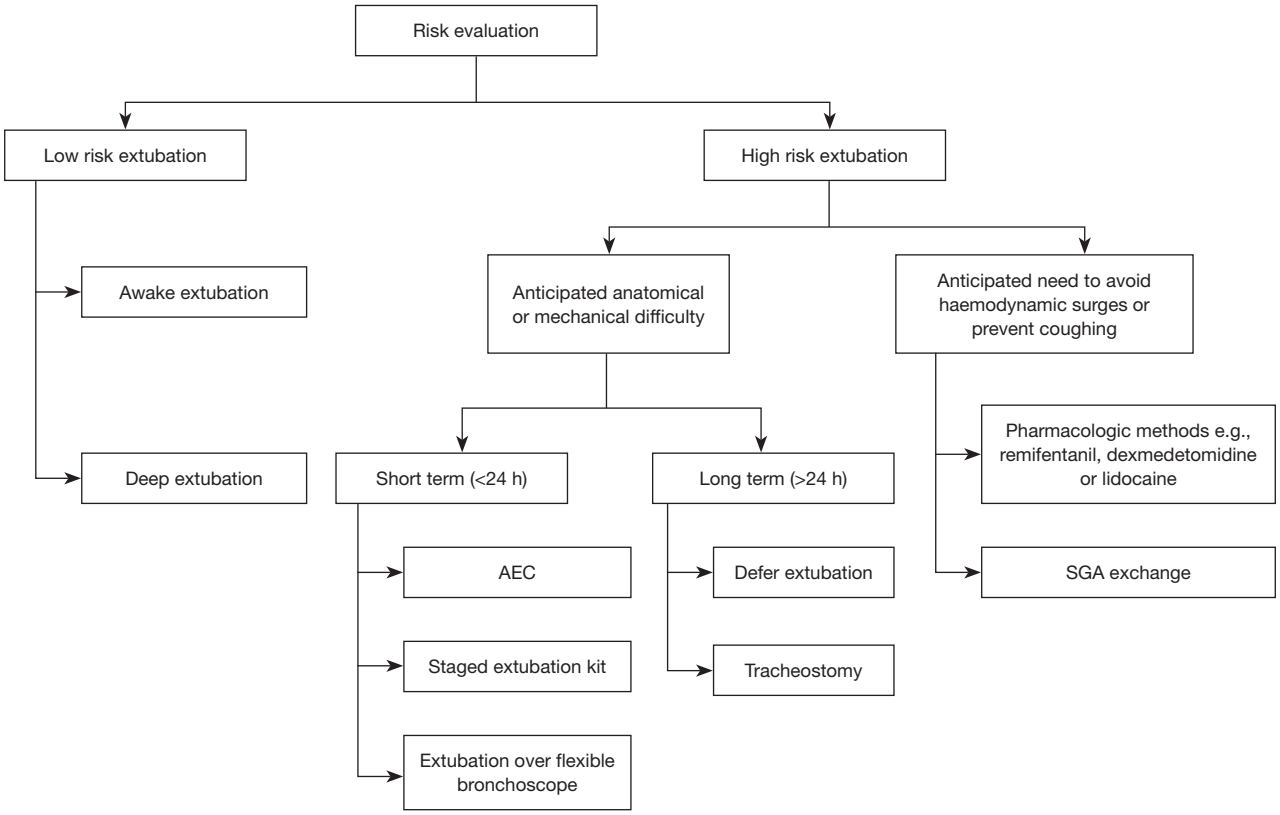

Figure 1 Options for extubation strategy, a decision tree tool. AEC, airway exchange catheter; SGA, supraglottic airway.

Low risk extubation strategies

Awake extubation

Awake extubation is a stepwise process, once each step has been completed, it is safe to proceed with the subsequent step. The below method is adapted from the DAS guidelines (5).

(I) Oxygen—deliver 100% oxygen through the breathing system;
(II) Suction—ideally under direct vision to clear secretions, blood and debris;
(III) Bite block—prevent occlusion of the ETT—insert a bite block, e.g., rolled gauze or Breathsafe Bite Block™;
(IV) Position—consider the optimum position for the patient e.g., ramped head up, left lateral head down;
(V) Reverse NMB—assess the residual block with monitoring and consider appropriate reversal, e.g., suggamadex or neostigmine;
(VI) Breathing—establish a regular spontaneous breathing pattern and adequate minute ventilation;
(VII) Avoid movement—minimise movement of the head and neck;
(VIII) Emergence—allow emergence to a state of eye opening and obeying commands;
(IX) Extubate—apply positive pressure, deflate the cuff and smoothly remove the ETT while the lung is near vital capacity;
(X) Check airway and breathing—provide 100% O_2 with anaesthetic breathing system to confirm patency of airway and adequacy of breathing.

Deep extubation

A deep extubation technique may be selected for its advantages of minimising coughing, bucking and haemodynamic surges. It is most commonly used following neurosurgical, ophthalmic and ear-nose-throat (ENT) surgery where the irritation caused by the ETT in an awake patient leads to these effects causing increased intracranial and intraocular pressures which can cause detrimental

bleeding with potentially catastrophic consequences. However, these benefits must be weighed against the potential risks due to the patient's inability to protect their airway against obstruction and aspiration. When deep extubation is improperly executed, laryngospasm and its attendant complications are more likely to occur. Although not having to wait for the recovery of consciousness may accelerate theatre turnover, this approach is more difficult to justify when anaesthetic agents having a faster elimination time are now available. Consideration must also be made for the recovery room staff as unscavenged volatile anaesthetic agents may also represent an occupational health hazard (35). It is with these factors in mind that the DAS guidelines emphasise that this technique should only performed by those experienced in its use and that the patient must be continued to be monitored by appropriately trained staff until they have fully recovered and are awake. It should not be performed in patients in which mask ventilation or reintubation would be anticipated to be difficult (5).

Once all painful and noxious stimuli have ceased a high inspired oxygen concentration (FiO_2) is provided, muscle relaxation is reversed, and adequate spontaneous respiration is established while maintaining an adequate depth of anaesthesia usually continuing whatever has been used during the case (i.e., TIVA or volatile). The pharynx should be cleared of secretions ideally with suctioning under direct vision to prevent contamination of the airway on extubation. Once these steps have been completed the cuff is gently deflated and the patient is observed to ensure continuation of adequate spontaneous breathing and then the ETT can be removed. Oxygen should then be provided, and airway patency is maintained using simple airway manoeuvres (5).

High risk extubation strategies

SGA exchange

Exchange of the ETT for a laryngeal mask airway (LMA) also known as the Bailey manoeuvre by who it was first described, involves the use of a classic LMA to exchange the airway, however other SGA's are now also commonly used. The original Bailey manoeuvre process starts with the administration of 100% oxygen, ensuring either deep anaesthesia or NMB, laryngoscopy and suction under direct vision and then insertion of a deflated LMA behind the ETT which is then removed after the LMA is inflated and then the ETT cuff is deflated. The proposed benefit of leaving the ETT *in-situ* while inserting the LMA is that the ETT holds the epiglottis anteriorly and prevents it being folded or obstructing the airway when the LMA is inserted. This technique provides some airway protection and patency while avoiding the cardiovascular and respiratory stimulation that occurs during an awake extubation with an ETT. When compared with a deep extubation using a Guedel airway, the LMA provided easier airway maintenance, less coughing and initially higher median SpO_2 when compared with the Guedel airway in the recovery period (36).

AECs

AECs are long catheters designed for changing one airway device (LMA or tube) for another. They include the Cook™ AEC (standard or extra-long version for use with double lumen tubes) and the Cook™ Aintree Intubating Catheter (AIC) (William Cook Europe, Bjaeverskov, Denmark), which has a larger internal diameter to allow placement using a fibre-optic bronchoscope. In the UK, these are the only devices which are commercially available for this purpose.

Using an AEC at extubation is particularly useful in patients in which reintubation would be technically difficult, for example due to surgical airway distortion, patients with airway swelling or those in which initial intubation was difficult. This technique allows continuous airway access, and a significantly increased chance of successful reintubation should it be required. One study of patients with difficult airways showed that with their use, 87% of patients could be reintubated on the first attempt, compared with a 14% first-attempt success without the AEC (37). When properly inserted and secured, AECs are generally well-tolerated without a need for sedation or topical anaesthesia. Patients can generally talk, cough, and breathe around the device. Intolerance most often indicates that the catheter has been advanced too deeply or has not been adequately secured in the midline of the mouth. An AEC should never be inserted beyond 25 cm in an adult patient as this increases the risk of airway trauma (12), coughing and intolerance.

The initial steps for extubation are as those used for an awake extubation, preoxygenation, optimising patient position, ensuring emergency equipment is available, direct suctioning and insertion of a bite block. Just prior to removal of the ETT the AEC is inserted down the existing ETT ensuring it is inserted to the same depth by checking the markings on both the ETT and AEC are aligned.

The cuff on the ETT is then gently deflated and removed ensuring that the AEC is not advanced further. The AEC is then secured in the midline to the cheek or forehead, clearly labelled and depth documented. Supplemental oxygen can be provided via a facemask and the patient must remain nil by mouth and be nursed in a high dependency area. If the presence of the AEC causes coughing, the first consideration must be to ensure that no migration of the AEC has occurred and once this has been checked lidocaine can be injected down the AEC to improve tolerance (5). Most patients can communicate and cough with the AEC *in situ* and they can be kept in place for up to 72 hours. If the use of an AEC at the end of surgery is anticipated, explaining to the patient preoperatively that they may wake up with the catheter in place can help minimise anxiety and aide tolerance.

In the event of deterioration and need for reintubation, the method using an AEC involves positioning the patient appropriately, application of 100% O_2 with continuous positive airway pressure (CPAP) via a facemask, selecting an ETT which will easily slide over the AEC but isn't too large such that the tip will catch on the arytenoids or vocal cords and then the use of direct or indirect laryngoscopy to retract the tongue while railroading the ETT through the vocal cords. Smooth passage can be increased by ensuring the bevel is facing anteriorly and DAS advocate the use of an ETT that is provided with an intubating LMA for its soft blunt bevelled tip (5). The success rate of reintubation over an AEC has been shown to be increased if video laryngoscopy is used. In a retrospective study including 51 intubated patients who required reintubation and had no view of the glottis with direct laryngoscopy, indirect laryngoscopy was attempted to visualize reintubation over an AEC. First attempt success was reported in 47 of the 49 patients (96%). Video laryngoscopy facilitated correct manipulations while avoiding arytenoid, vocal cord, and commissural impingement or inadvertent buckling of the AEC (38).

Oxygen can be delivered down an AEC by insufflation (via a 15 mm connector at constant flow), ventilation (via an anaesthetic circuit) or jet ventilation (with a jet injector). Pressures of 15–50 psi have been described for jet ventilation (103–344 kPa) the upper limit of which is approaching unrestricted wall oxygen (400 kPa) (39). Most morbidity occurred when the AEC was used for direct ventilation rather than purely as a guide for reintubation, oxygen insufflation and jet ventilation should only be undertaken with extreme caution as barotrauma and death have been reported (40). If oxygenation is required in extremis and jet ventilation via the AEC is considered, then it is absolutely vital that there is not complete airway obstruction and that air can be expired around the catheter to avoid breath stacking and potentially fatal barotrauma. It is also crucial that the catheter remains placed in the mid trachea as migration down the respiratory tree can also result in trauma and pneumothorax.

Staged extubation kits

Sets specifically developed to allow a staged extubation when difficulty is anticipated have been developed and released by Cook Medical™ and are licenced in the UK and many countries internationally. They consist of a 0.035-in (external diameter) 145 cm long flexible wire which is used in the same approach as the AEC and left *in situ* following extubation. The proposed advantage is reduced airway irritation and better tolerance than an AEC. In the event of airway deterioration necessitating reintubation a 14-Fr catheter is first advanced over the wire and subsequently an ETT is then advanced over the catheter and the wire and catheter are then removed. It has been highlighted that caution needs to be exercised as there is a potential for dislodgment or oesophageal placement of the wire and therefore appropriate patient selection, meticulous technique, adequate checks to ensure successful reintubation of the trachea prior to ventilation with capnography and a clear plan for if failure is encountered is vital (41).

Extubation over flexible bronchoscope

This technique can be considered if there is suspicion of laryngeal paralysis, tracheomalacia or tube entrapment. An LMA is sited as outlined earlier, and the patient is allowed to resume spontaneous ventilation while anaesthesia is maintained. A flexible bronchoscope is then advanced through the LMA, allowing visualisation of the anatomy and assessment of laryngeal function. If required, reintubation can be facilitated via the use of a Cook™ AIC over the flexible bronchoscope and once the intubation catheter position has been confirmed in the trachea the bronchoscope and LMA are removed and an ETT is railroaded over the AIC (36).

Remifentanil extubation

As previously discussed, patients can be extubated with a

Table 6 Drugs used in airway compromise

Drug	Dose	Notes
Adrenaline	1 mg (nebulised)	Can reduce airway oedema but usually only a temporising measure until other treatments instituted
Hydrocortisone	100 mg (IV)	Can reduce airway oedema resulting from direct injury to the airway but have no effect if obstruction is due to a mechanical cause such as a haematoma
		The efficacy of all steroids is equal if adequate doses are given and should be given early in patients who are at a high risk of airway oedema and continued for at least 12 hours. Studies have shown that single doses prior to extubation are ineffective (42)
Heloix	30:70 mix (inhaled)	Heloix can be used to buy time but is often not readily available and the benefits may be limited due to the reduced FiO_2 that can be delivered (43)

IV, intravenous.

remifentanil infusion running, this technique can provide a beneficial combination of a tube tolerant patient who is also fully awake and able to follow commands. The smooth extubation this allows can be highly desirable in certain groups of patients, such as those who have undergone ENT, maxillofacial, neurosurgical or plastic surgical procedures. The infusion can either be commenced at the end of surgery or if it has been running throughout it is continued, other anaesthetic agents are ceased and recovery from NMB is ensured. The patient is allowed to wake gently, without stimulus and once able to obey commands and a stable respiratory pattern has been established the ETT is removed. Careful titration is required such that the patient remains ETT tolerant but also has adequate spontaneous respiration, this may require the patient to be prompted to take deep breaths and so this technique requires practice to get the timing and dosing correct (5). It is important to remember that adequate post operative analgesia must have been provided prior to waking as the analgesia provided by the Remifentanil will wear off rapidly following cessation and flushing of the cannula is vital to avoid further respiratory depression in the recovery area.

Deferring extubation and elective surgical tracheostomy

Extubation is an entirely elective process and in some circumstances, it may be unsafe to remove a tracheal tube at the end of surgery. It may be necessary due to pre-operative airway problems, following intraoral free flap surgery, in the presence of an obstructing tumour, significant oedema or bleeding in or around the airway to defer. The options available are to keep the existing ETT *in situ*, exchange the existing ETT for a more appropriate ETT and delay extubation or to perform an elective tracheostomy.

Prolonged intubation is associated with glottic damage and so if significant short-term improvements are not anticipated in a patient with a critical airway, an elective tracheostomy should be considered and discussed with the surgical team. Such a decision should balance the risk benefit and likely chance of success in securing a compromised airway on an emergency basis following extubation. An elective tracheostomy may be safer choice than a prolonged attempt or multiple attempts to re-establish an airway if difficulty arises. The additional benefits of siting an elective tracheostomy include allowing the patient to wake without the need for continued sedation and therefore earlier and increased participation in physiotherapy and ability to communicate.

Post extubation airway difficulty

Signs of airway compromise such as stridor, obstructed breathing patterns, agitation, increased drain output and airway bleeding should be acted upon quickly by recovery staff. Following the application of 100% O_2, sitting the patient upright, encouraging deep breathing and gentle suctioning assessment of the cause and review by both the anaesthetist and surgeons is crucial. *Table 6* outlines some treatments which can be used to temporise the airway until definitive management is decided.

Conclusions

Extubation is an underestimated period of risk in the process of anaesthesia delivery. Complications can be avoided by careful consideration of potential difficulties, clear

communication, adequate preparation and optimisation of the patient, equipment and environment. Awake extubation remains the most appropriate technique for most patients however in the instances where the potential for airway compromise is perceived to be high, alternative strategies can be employed. The evidence base for extubation remains very limited and so many of the recommendations and guidelines are based on case reports and expert opinion. Future research is needed in the form of robust standardised trials in order for more precise guidance on best practice to be made.

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Footnote

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