Guidelines

Project for Universal Management of Airways: guidelines for tracheal extubation

Louise Ellard, Andy Higgs, Richard M. Cooper, Carin A. Hagberg, Paul A. Baker, Robert Greif, George Kovacs, J. Adam Law, Sheila N. Myatra, Ellen P. O'Sullivan, William H. Rosenblatt, Christopher H. Ross, John C. Sakles, Massimiliano Sorbello and **Nicholas C. Chrimes**

Summary

Introduction Risk evaluation, strategy formulation and preparation are important to decreasing the incidence of adverse events associated with tracheal extubation. The focus of this guideline is tracheal extubation, but many of the principles outlined are relevant to all forms of discontinuation of airway management (tracheal extubation; removal of a supraglottic airway; cessation of facemask support; and tracheostomy removal) and conversion between upper airway lifelines (facemask; supraglottic airway; and tracheal tube) or a neck airway.

Methods An international, multidisciplinary working group reviewed existing airway guidelines and published literature. A structured process for generating expert consensus statements was undertaken, which included consultation with an international advisory group comprising both airway operators and assistants, as well as human factors experts. Discrepancies between the results of these two processes were analysed and reconciled. Guidelines were generated and recommendations were categorised according to the American Heart Association classification system.

Results Risk evaluation for tracheal extubation includes assessing the risk of hypoxaemia, pulmonary aspiration and harm from airway stimulation. The patient's baseline risk as well as any potential changes since tracheal intubation should be considered. In addition to patient risks, team and situation risk factors should be considered when formulating the extubation strategy. Planned extubation is always elective, maximising ability to control the timing, environment and resources available. Deferring extubation is recommended if this will significantly decrease risk. When substituting one lifeline for another, \`conversion procedures´, characterised by the presence of a continuous guide to maintain or facilitate rapid restoration of alveolar ventilation, are safer and preferred over airway \`replacement procedures´, particularly when airway management is regarded as \`at risk´.

Discussion These guidelines assist airway practitioners from any discipline to evaluate whether tracheal extubation is \`at risk´ and link this to formulating a safe and effective strategy that addresses the specific challenges identified.

For full author affiliations, see end of article

Plain Language Summary can be found on the journal website.

Correspondence to: Nicholas C. Chrimes
Email: nicholas.chrimes@universalairway.org

Accepted: 6 August 2026
Keywords: airway management; airway strategy; difficult airway; tracheal extubation; tracheal re-intubation

Bluesky: @Chrimesy.com

X: @EllardLouise; @AndyHiggsGAA; @CarinHagberg; @PaulBakerORSIM; @kovacsgj; @jadamlaw; @SheilaMyatra; @ProfEllenO; @AirwayOnDemand; @crossermed; @JohnCSakles; @SorbelloMax; @NicholasChrimes

Key recommendations

1. Tracheal extubation warrants an equivalent level of evaluation, strategy, preparation and vigilance to that for tracheal intubation.
2. Risk evaluation for tracheal extubation should consider the patient's baseline risk (perceived risk based on evaluation before initiating airway management, supplemented with information gained during initiation of airway management) and any altered risks (changes to patient, team or situation risk factors since tracheal intubation).
3. If achieving `airway success´ with any upper airway lifeline (facemask; supraglottic airway; or tracheal tube) following tracheal extubation is not considered `rapid and reliable,´ then that airway lifeline, and therefore tracheal extubation, should be designated `at risk´.
4. The approach to extubation should provide an adequate margin of safety from hypoxaemia. The risk of hypoxaemia following tracheal extubation depends on the likelihood that tracheal re-intubation is required, the likelihood that airway management is challenging and the anticipated safe apnoea time.
5. Planned tracheal extubation is always elective, providing a wide scope to minimise risk. Tracheal extubation should be deferred whenever this will significantly decrease risk.
6. The tracheal extubation strategy should address whether it is appropriate to proceed with extubation, defer extubation or convert the tracheal tube to a tracheostomy. When proceeding to tracheal extubation, the strategy should comprise an intended approach to extubation combined with an approach to airway rescue.
7. Deferring tracheal extubation may provide time for optimisation of patient, team and situation risk factors. Conversely, even when significant challenges with tracheal extubation are anticipated, deferral is not recommended unless it is expected to decrease risks.
8. When neuromuscular blocking drugs are being used, quantitative neuromuscular monitoring is recommended to confirm return of baseline neuromuscular function before tracheal extubation.
9. Awake tracheal extubation over an airway exchange catheter is recommended if required to provide an adequate margin of safety from hypoxaemia.
10. When a tracheal tube or supraglottic airway is in situ and substitution of upper airway lifelines is required, airway conversion is preferred over airway replacement procedures, particularly when the margin of safety from hypoxaemia is reduced.

Why were these guidelines developed?

Tracheal extubation (hereafter referred to as simply extubation) outcomes have not mirrored the improvements seen in tracheal intubation outcomes. Adverse events following extubation account for a significant proportion of severe complications of airway management and are more likely to result in brain injury and death [1, 2]. Many complications of extubation result from inadequate planning [3].

What guidelines currently exist?

Professional groups worldwide have produced guidelines for initiating airway management, but guidance on extubation is more limited [4–16]. Guidelines specifically addressing extubation encourage use of more conservative techniques when airway management is `at risk´ but provide limited guidance linking risk evaluation to particular approaches to extubation [14, 15].

How do these differ from existing guidelines?

These guidelines assist airway practitioners from any discipline to evaluate whether extubation is `at risk´ and link this to formulating a safe and effective extubation strategy that addresses the specific challenges identified. The advice provided is applicable to any patient group (including adults and children) or context for care (including operating theatre, emergency department or ICU). An algorithm that facilitates providing an adequate margin of safety from hypoxaemia following extubation is included.

These guidelines are intended to supplement, not replace, existing published guidelines. They do not represent minimum standards of practice, nor are they a substitute for sound clinical judgement. Although they articulate key principles to inform clinical practice, there may be legitimate reasons why practitioners select alternative approaches in specific contexts. All recommendations assume that airway practitioners have appropriate training and experience with the devices and techniques described, and that these are applied within their scope of practice. Recommendations regarding use of specific equipment, monitoring, medications or additional staff apply where accessing the relevant resources is feasible. Where this is not the case, these recommendations should be viewed as aspirational.

Introduction

Adverse events associated with extubation are common, accounting for approximately one-third of the severe outcomes documented in the 4th National Audit Project of the Royal College of Anaesthetists (NAP4) in the UK, and are more likely to result in brain injury and death than those occurring during initiation of airway management [1, 17]. Improvements in tracheal intubation outcomes over the past 25 years are not reflected in data on adverse extubation outcomes [1, 2, 18–21]. Absence of an appropriate strategy is a recognised contributor to preventable mortality and serious morbidity during airway management [1, 20].

These guidelines focus on extubation, but many of the same considerations apply to removing supraglottic airway devices (hereafter referred to as simply supraglottic airways), removing a tracheostomy and to some degree, cessation of facemask support. As with tracheal intubation, extubation is not a single intervention but a process, involving stepwise progression to less secure modes of airway support (e.g. tracheal tube to supraglottic airway or facemask) as the patient progressively resumes independent maintenance of airway patency and ventilation. Planned extubation warrants an equivalent level of risk evaluation, strategy formulation, preparation and vigilance to that undertaken for tracheal intubation [1, 14, 15, 20, 22, 23].

Methods

The methods for developing the Project for Universal Management of Airways (PUMA) recommendations have been previously published [24]. An updated literature search has since been undertaken, including articles published up until the end of April 2026. As a member of the PUMA advisory group with interest in extubation who was independently developing an extubation algorithm in collaboration with NC, LE was invited to participate as lead author and the extubation algorithm was incorporated into the guidelines. Recommendations in this guideline are categorised according to the American Heart Association classification system [25] (available in online Supporting Information Appendix S1). A summary of this system and the clinical implications of each category of recommendation are outlined in online Supporting Information Appendix S2 [25].

The definition and rationale for use of key terminology used in this guideline are available in the PUMA online glossary (https://www.UniversalAirway.org/glossary).

Results

Risk evaluation for tracheal extubation

A risk evaluation should be performed before extubation [1, 4, 14, 15, 20, 22, 23]. A general framework for considering patient, team and situation factors relevant to evaluating the risks of any episode of airway management will be provided in a later PUMA guideline. The following discussion is largely restricted to issues specific to extubation.

Linking evaluation to strategy

Even the most comprehensive and well-documented evaluation of the risks of airway management is of minimal value if the risks identified are not reflected in the airway strategy. Failure to develop an airway strategy that addresses identified risks appropriately is a recognised contributor to preventable mortality and serious morbidity during airway management [1, 3, 20, 26]. To facilitate linking the risk evaluation to the formulation of an appropriate extubation strategy, four questions should be considered.

Is it appropriate to consider tracheal extubation?: Determining whether it is appropriate to consider extubation requires evaluation of the domains outlined in Table 1 [1, 14, 15, 22, 23, 27–33]. These preconditions should be satisfied before considering extubation [1, 14, 15, 23].

*Is tracheal extubation `at risk´?:* Determining whether extubation is `at risk´ involves considering the risk of hypoxaemia, pulmonary aspiration, harm from airway stimulation and any other identified risks. Evaluating each of these elements requires consideration of both the patient's baseline risk and any potential changes to patient, team or situation factors since tracheal intubation. If the risk of one or more aspects of airway management is increased significantly from baseline, extubation should be designated as `at risk´. This assessment is discussed in further detail below.

Will deferring tracheal extubation decrease risk?: Planned extubation is always elective, maximising the opportunity to control the timing, environment and resources available. Consideration should be given to whether improvement in patient, team or situation risk factors will significantly reduce the risks of extubation [1, 23, 30, 34].

Table 1 Preconditions for considering tracheal extubation.

Domain	Preconditions
Respiratory	• Ability to maintain adequate* oxygen saturations at acceptable* inspired oxygen concentration, positive end-expiratory pressure and pressure support • Ventilation adequate* to maintain appropriate arterial carbon dioxide • Tracheal aspirates minimal
Haemodynamic	• Cardiovascular stability • No major ongoing blood loss
Neurological	• Adequate* conscious state anticipated • Return of baseline neuromuscular function anticipated • Adequate* pain control without restriction to ventilation or excessive sedation anticipated
Metabolic	• Adequate* body temperature • Adequate* acid–base balance
Surgical	• Imminent tracheal re-intubation not anticipated in context of challenging airway management (i.e. return to operating theatre; radiology investigations; intra- or interhospital transport) • No delayed closure of major body cavities (i.e. open abdomen, open chest)
Resources	• Team and situation factors are adequate* to safely extubate, observe and restore the patient's airway if needed
Trajectory and stability	• No anticipated significant deterioration in any of the above domains within the next 24 h, resulting in potential for airway management (e.g. evolving sepsis)

*Determine according to local policies and clinical context.

How can an adequate margin of safety from hypoxaemia be provided following tracheal extubation?: Risk evaluation inevitably involves a degree of uncertainty. The margin of safety from hypoxaemia reflects the likelihood that the patient will experience harm from desaturation if one or more elements of airway management prove unexpectedly more challenging than the risk evaluation suggests. When determining margin of safety for hypoxaemia following extubation, the practitioner should consider both the anticipated safe apnoea time and their confidence in the assessment of the anticipated challenges with each of the upper airway lifelines (facemask; supraglottic airway; and tracheal tube), noting that facemask ventilation and/or supraglottic airway insertion may not have been attempted during tracheal intubation.

Risk of hypoxaemia

The risk of hypoxaemia following extubation is influenced by the likelihood that subsequent airway management is required, the likelihood that it will be challenging, and the anticipated safe apnoea time. These risks are often interrelated.

Likelihood that subsequent airway management is required: For a variable period following extubation, all patients remain at elevated risk of requiring tracheal re-intubation, including the need for associated airway support with a facemask or supraglottic airway. Tracheal re-intubation may be required in up to 20% of patients who have undergone extubation in ICU [19, 27, 35, 36]. The need for tracheal re-intubation incurs a risk of harm from compromised airway patency, airway protection or respiratory function, and exposes the patient to an additional episode of airway management with potentially increased risks relative to those at the initial tracheal intubation episode.

The likelihood that tracheal re-intubation is required is influenced by airway- and non-airway-related factors (Table 2) [4, 14, 15, 22, 27–33, 37–42], both of which should be assessed before extubation [4, 14, 15, 31–33, 37–39].

Airway swelling may develop and progress rapidly in susceptible patients. Whilst flexible endoscopy via the tracheal tube can be useful to evaluate the airway distal to the tip of the tracheal tube [15, 43], to assess the glottis and supraglottis, the tracheal tube needs to be withdrawn. Once the bronchoscope tip is withdrawn above the glottis, coughing or other movement can easily misalign the bronchoscope and laryngeal inlet, impeding tracheal re-intubation [43, 44]. It may also prove impossible to reinsert the original tube because of swelling. Thus, if potential impediments to maintaining airway patency have already been identified, withdrawing the tracheal tube under endoscopic vision is not a reliable precaution against airway loss [4, 14, 33, 37–39]. Similarly, nasendoscopic or laryngoscopic evaluation of the glottis and supraglottis for swelling before extubation provides only limited reassurance. Where concerns exist about the adequacy of subglottic calibre, a cuff leak test can be performed;

Table 2 Airway and non-airway-related patient factors to be evaluated on history and airway evaluation before tracheal extubation or conversion.

AIRWAY-RELATED FACTORS	

History	• Original risk evaluation (before tracheal intubation) including pre-existing anatomical factors and challenges encountered during previous episodes of airway management.
	• Challenges encountered during tracheal intubation
	• Potential changes in risk factors:
	  • arising since tracheal intubation
	  • predisposing to development or progression of challenges post-extubation, including discussion with surgeon where relevant (e.g. likely progression of swelling; risk of bleeding; residual infection)

Airway evaluation	
External airway evaluation	Standard airway evaluation with particular attention to additional factors occurring since tracheal intubation (e.g. swelling; jaw wiring; halo brace). While it is not necessary to repeat external airway examination routinely before extubation, re-evaluation is recommended where elements may have changed since tracheal intubation. Re-evaluation should also be considered if there has been a prolonged interval between tracheal intubation and extubation or a change in airway operator.
Evaluation of supraglottis	• Where relevant, confirm if pharyngeal packs placed and ensure their removal • Consider need for videolaryngoscopy to assess swelling / trauma / bleeding (including examination behind the soft palate in patients \`at risk´ of a \`coroner's clot´) in appropriate patients. Beware false reassurance about ability to visualise larynx with tracheal tube in situ • Consider flexible nasendoscopy
Evaluation of glottis/ subglottis	• Consider cuff leak test • Consider ultrasound measurement of laryngeal air-column width difference
Evaluation of lower airway	• Consider flexible endoscopy via the tracheal tube to detect secretions; blood; aspiration; airway trauma; and assess tracheal tube depth (especially if use of airway exchange catheter planned) • Consider chest X-ray to detect pulmonary aspiration; gastric distention; lung collapse; pneumothorax; surgical emphysema
NON-AIRWAY RELATED FACTORS	
Respiratory	• Pre-existing or newly acquired respiratory disease impacting oxygen saturation or ventilation • Need for ongoing tracheal suction due to secretions or haemoptysis • Pre-existing or newly acquired thoracic or chest wall deformity or restriction
Neurological and behavioural	• Pre-existing or newly acquired deficits in neuromuscular function • Anticipated conscious state following cessation of sedation or anaesthesia • Anticipated level of patient co-operation following cessation of sedation or anaesthesia • Likelihood of adequate pain control
Trajectory and stability	• Anticipated significant deterioration in any of the above domains within the next 24 h, resulting in potential for airway management

however, evidence supporting the interpretation of this evaluation is conflicting [15, 23, 45–52]. While the absence of a cuff leak typically indicates an increased risk of airway loss if the tracheal tube is removed, even the presence of a large leak should not be used to justify extubation when other factors indicate a significant risk exists [46]. Ultrasound measurement to identify airway narrowing using the laryngeal air-column width difference may provide useful information in appropriately skilled hands [51, 53–55].

Following extubation, airway reflexes may be reduced, exaggerated or dysfunctional [14], any of which may increase the risk that tracheal re-intubation is required [14, 56]. Reduced upper airway reflexes may result in compromised airway patency and increase the risk of obstruction. Reduced laryngeal reflexes increase the risk of pulmonary aspiration [57]. Exaggerated laryngeal reflexes can result in partial or complete airway obstruction due to laryngospasm [29, 44, 58, 59]. Dysfunctional laryngeal reflexes can result in stridor due to paradoxical vocal cord motion [14, 60, 61].

Likelihood that subsequent airway management is challenging: The potential need for airway rescue is inherent to every episode of tracheal intubation. When considering the risk of hypoxaemia following extubation, in addition to considering the potential for challenges to arise when reinserting the tracheal tube, the possibility of encountering challenges with ventilation using a facemask or supraglottic airway must also be considered [1]. Anticipated challenges with ventilation through a facemask or supraglottic airway also increase the risk that the process of tracheal re-intubation is challenging by potentially increasing the urgency of tracheal re-intubation and via the phenomenon of composite failure whereby the occurrence of challenges with one lifeline predisposes to challenges with the others [26].

Following any attempt at airway rescue, `airway success´ is identified by confirming the presence of alveolar ventilation in combination with the ability to maintain adequate blood oxygen saturation. Prior to extubation, a decision should be made whether achieving airway success with each lifeline is expected to be `rapid and reliable´ and whether neck rescue is anticipated to be straightforward, based on re-evaluation of patient, team and situation factors [1, 15, 39, 42, 62]. To qualify as rapid, the projected time to establish alveolar ventilation using each lifeline should approximate that expected for routine performance by a skilled operator. When concluding that airway success can be reliably achieved, the airway operator should expect that a stable airway could be established with a single attempt at that lifeline if necessary.

Determining that achieving airway success is expected to be rapid and reliable does not necessarily imply that no challenges have been identified with the relevant lifeline, only that the operator is confident that they can be overcome readily. Thus, even if airway management using a given lifeline is considered advanced or complex, requiring specific technical expertise or specialised equipment, it is still reasonable for an appropriately skilled operator to reach the conclusion that airway success will be rapid and reliable in the presence of the necessary resources and adequate preparation. For example, despite a patient having adverse anatomical indicators on physical examination, an airway operator may be confident that with adequate positioning, appropriate equipment and skilled assistance, tracheal re-intubation can still be rapidly and reliably achieved. Thus, this assessment legitimately involves subjective considerations that may lead the same operator evaluating the same patient to answer differently, based on the team or situation factors that will be present in a given context.

Judging whether airway management via each of the three lifelines is expected to be rapid and reliable requires consideration of whether each of these was challenging during tracheal intubation and whether they could subsequently have been compromised further. If achieving airway success with any lifeline is not considered rapid and reliable, then it, and therefore extubation, should be designated `at risk´.

When assessing the risks of airway management following extubation, information about whether challenges were encountered with any lifelines attempted during tracheal intubation is typically available. Where the airway operator responsible for extubation was not involved with tracheal intubation, this information should be sought [14, 22, 29]. In the absence of a compelling justification to do otherwise, any lifelines that were challenging during tracheal intubation should, by default, be designated `at risk´ for airway management following extubation [14, 29, 42].

While consideration of the skill level of the airway operator performing the initial tracheal intubation is clearly relevant, caution is advised in attributing challenges encountered during tracheal intubation exclusively to the skill level of another operator. Previous challenges should not be discounted unless an obvious contributing factor has been resolved [26, 63].

Risk factors may also vary substantially between tracheal intubation and extubation, even when this interval is short. Previous challenges can be exacerbated, or new challenges may arise despite tracheal intubation having been uneventful. Changes in environment or time of day since tracheal intubation may impact team and situation factors. Patient factors may vary for multiple reasons. For example, patients may be less cooperative due to sedation, airway stimulation, pain or hypoxaemia. Processes occurring subsequent to tracheal intubation can influence anatomical risk factors acutely (Box 1) [1, 15, 23, 30, 31, 34, 43, 64–77]. Progressive anatomical distortion, due to bleeding or swelling, can influence both the risk that airway management is required and the risk that it will be challenging [15, 78–82]. If surgical interventions result in it being unfeasible to reproduce the conditions at tracheal intubation (e.g. cervical fusion) or impede airway access (e.g. halo brace), the operator should consider the increased potential for challenges with airway rescue [29, 79, 83–85]. Following extubation, anatomical risk factors may progress; therefore, their impact should be considered not just at the time of extubation but over the entire interval that the patient remains at increased risk of requiring subsequent airway management [15, 78–82].

Caution should be exercised when drawing conclusions regarding ability to obtain a view of the larynx while a tracheal tube is in situ [30, 86, 87]. Performing laryngoscopy in a patient with a tracheal tube in situ may provide false reassurance about the ease of visualising the glottis due to the existing tracheal tube splinting the airway, displacing the larynx posteriorly and providing an impermanent cue to its location [14]. Glottic oedema may be underestimated with a tracheal tube in situ and may `remould´ after removal of the tracheal tube, worsening glottic access [88, 89].

Box 1 Alterations to anatomical risks. Processes occurring subsequent to tracheal intubation with potential to impact anatomical risk factors.

Airway trauma: trauma to the airway or adjacent structures may lead to oedema; haematoma; soiling with blood/clot; tissue damage; vocal cord/recurrent laryngeal nerve injury; distorted airway anatomy; impaired venous/lymphatic drainage; and/or restricted head and neck movement.

Trauma may result from:

- Airway instrumentation at tracheal intubation (laryngoscopy; tracheal intubation; supraglottic airway placement; excessive size of airway device; excessive cuff pressure; multiple instrumentations; suboptimal positioning of the airway device).
- Nasal instrumentation (tracheal tube; nasogastric tube; temperature probe; nasopharyngeal airway; surgical instruments).
- Oesophageal instrumentation (nasogastric tube; transoesophageal echocardiography probe; endoscopes; surgical instruments).
- Surgery in or near the airway: (airway surgery; faciomaxillary surgery; thyroid surgery; cervical spine surgery; carotid surgery; other head and neck surgery). Increased duration of surgery may elevate risk.
- Recent airway, head or neck injury: may lead to evolving airway compromise or distortion following tracheal intubation.
- Excessive patient movement (e.g. in ICU) or attempted phonation with tracheal tube in situ.

Evolving airway pathology: infection; haematoma; burns; angioedema/anaphylaxis.

Dependent positioning: prone or head down.

Fluid shifts: massive transfusion; fluid overload.

Impaired airway access: halo brace; guardian suture; intermaxillary fixation device.

A key factor influencing the likelihood of encountering challenges is the urgency with which airway management is required. In addition to severely limiting opportunities to achieve airway success, time-critical airway management may increase team stress, potentially compromising performance [43, 90]. Methods employed successfully during initial tracheal intubation may prove challenging in such circumstances. Anatomical factors contributing to the likelihood of tracheal re-intubation may also increase the likelihood of encountering challenges (Box 1), both by causing airway distortion and because they are more likely to be associated with the need for time-critical interventions [4, 14, 15, 31–33, 37–39]. Tracheal re-intubation precipitated by decreased physiological reserves can also complicate airway management by compromising safe apnoea time or increasing haemodynamic instability. However, it is more common for physiological factors to result in a gradual deterioration of the patient. This generally provides time to implement a broader range of airway management options, including awake tracheal intubation [1, 6].

Safe apnoea time: If challenges with airway rescue interrupt alveolar ventilation, the likelihood and severity of hypoxaemia are influenced by the safe apnoea time. Safe apnoea time refers to the duration that blood oxygen saturation remains adequate if alveolar ventilation is interrupted. The anticipated safe apnoea time is a subjective judgement made by the airway operator. Safe apnoea time may be reduced in infants and neonates; pregnancy; obesity; pulmonary disease; and hypermetabolic states. A detailed overview of the factors impacting safe apnoea time will be provided in a PUMA guideline addressing risk evaluation. Where it is considered that the safe apnoea time following re-oxygenation of the functional residual capacity may be significantly diminished, a more conservative approach to extubation is suggested [1].

Risk of pulmonary aspiration

Patients considered at increased risk of pulmonary aspiration during tracheal intubation should still be considered as such during extubation, unless there is reason to expect that there has been a significant improvement in risk profile [1, 20, 42, 44, 91]. Pulmonary aspiration risk may also be acquired after tracheal intubation, due to surgical debris (e.g. blood or pus) from the upper airway entering the stomach or surgical manipulation of the gastrointestinal tract [42, 44]. Nasal instrumentation may cause blood to accumulate in the nasopharynx. Blood clot aspiration may cause complete airway obstruction (`coroner's clot´) [92]. Despite waiting for return of consciousness before extubation, residual sedation (potentially made worse by removal of the stimulation provided by the tracheal tube), unrecognised persistent neuromuscular blockade or impaired airway reflexes (which may persist for hours post-extubation) may predispose to pulmonary aspiration in patients with residual gastric content or significant reflux [14, 56, 57, 93]. A detailed overview of the factors impacting the risk of pulmonary aspiration will be provided in another PUMA guideline addressing risk evaluation.

Risk of harm from airway stimulation

Extubation can expose patients to similar risks from airway stimulation to those encountered during tracheal intubation [14, 94–99]. However, airway stimulation at extubation may have a greater impact due to the offset of sedatives and neuromuscular blocking drugs [100]. Airway trauma or contamination occurring after tracheal intubation (e.g. from surgery) may predispose to coughing and laryngospasm following extubation. Laryngospasm can result in significant morbidity in both adults and children due to obstruction, negative-pressure pulmonary oedema or pulmonary aspiration (secondary to gastric distention caused by application of positive pressure to treat laryngospasm) [1, 101–105]. Young children are particularly prone to apnoea triggered by airway manipulation, including extubation [106]. Airway stimulation may cause bleeding from surgical sites or complications from raised intracranial or intraocular pressure [23, 43]. Many of these issues are exacerbated if airway rescue is required, particularly if this proves challenging. The potential impact of airway stimulation during extubation should be considered so that mitigating actions can be incorporated into the extubation strategy [22, 98].

Other risks

The presence of additional risks, such as dental injury and hazards to the airway team during extubation, should also be considered [1, 107, 108].

Formulating a tracheal extubation strategy

The general requirement to formulate and clearly communicate an airway strategy addressing any issues identified as `at risk´ during evaluation applies equally to tracheal intubation, extubation and conversion between airway lifelines or a front-of-neck airway (hereafter referred to simply as a neck airway) [4, 14, 16, 22, 29]. The required components of an extubation strategy are outlined in Fig. 1. The extubation strategy should address vulnerability to harm from hypoxaemia, pulmonary aspiration, airway stimulation and any other identified risks. While the general principles for developing an extubation strategy are no different to those for tracheal intubation, specific issues warrant highlighting.

Based on the conclusions of the risk evaluation, the extubation algorithm (Fig. 2) suggests an approach to extubation that provides an adequate margin of safety from hypoxaemia. An interactive version of this algorithm will be provided in the free PUMA App (https://www.UniversalAirway.org/#app). Instructions for use, additional guidance and clinical scenarios for the extubation algorithm are provided in online Supporting Information Appendix S3 and at https://www.UniversalAirway.org/extubation/algorithm.

The extubation algorithm is intended for routine use before every extubation, even if no potential challenges have been previously identified. By prompting consideration of key factors impacting whether extubation is `at risk´, the algorithm helps determine whether it is appropriate to proceed with extubation, defer extubation or convert the tracheal tube to a tracheostomy.

When the algorithm suggests proceeding with extubation, the strategy should include an intended approach and an airway rescue plan, even when subsequent airway management challenges are not anticipated [1, 15, 110]. Three approaches to proceeding with extubation are provided by the algorithm: discretionary management; awake extubation; and awake extubation over an airway exchange catheter. These approaches reflect responses to progressively increasing levels of identified risk of hypoxaemia, aimed at maintaining an adequate margin of safety. The airway operator must determine the applicability of the algorithm's suggested approach to a given context, and it may sometimes be appropriate to select a more liberal or conservative approach. Furthermore, within each of these broad approaches, considerations other than the risk of hypoxaemia may need to be superimposed to optimise patient safety in a particular context. Discretionary management refers to the situation where the algorithm makes no specific recommendations to provide an adequate margin of safety from hypoxaemia, and airway operators may choose between alternatives for each

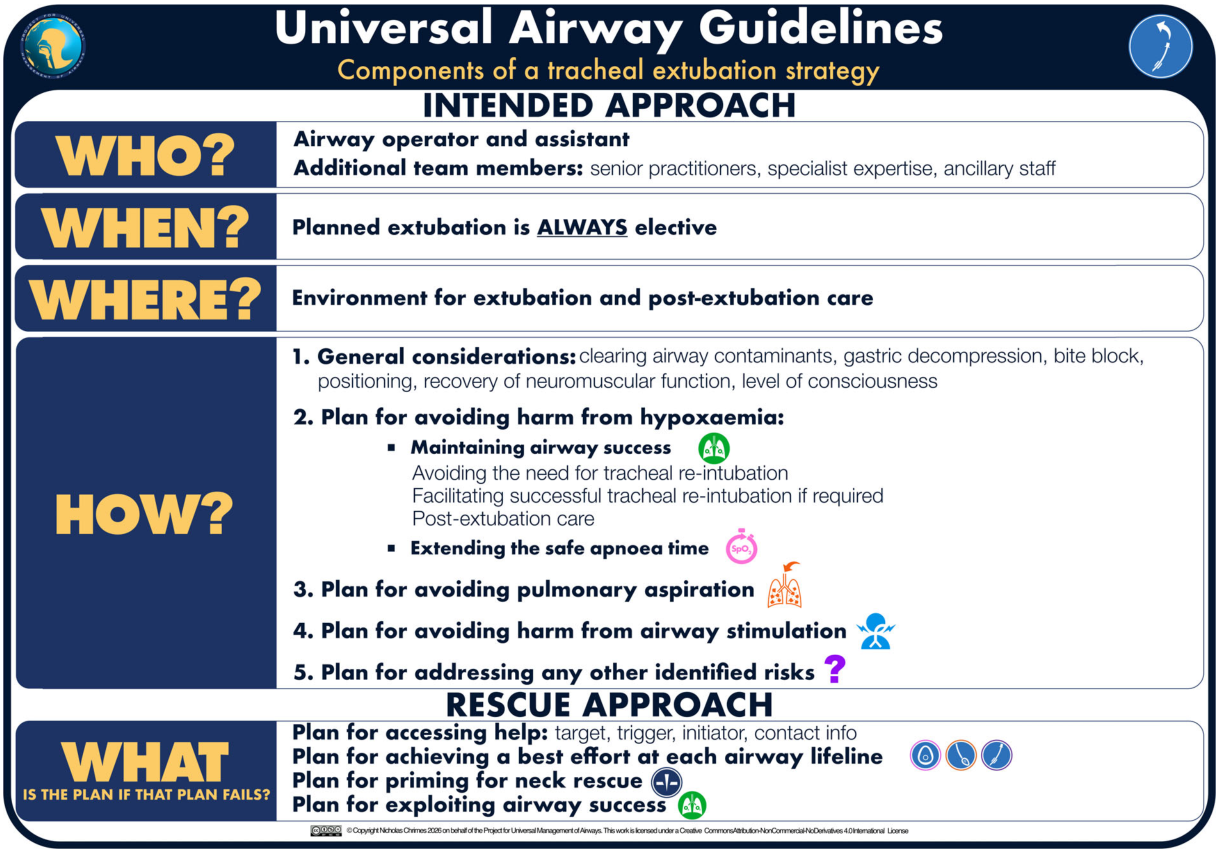

Figure 1 Components of a tracheal extubation strategy.

element of the extubation strategy, according to identified risks.

The issues relevant to determining each component of an extubation strategy are outlined below. While some of these may be dictated by the approach suggested by the extubation algorithm, numerous additional decisions not determined by the algorithm need to be incorporated into the extubation strategy (e.g. patient position, need for gastric decompression, site and duration of post-extubation care). These additional interventions may not only further contribute to minimising the risk of hypoxaemia, but also the risk of pulmonary aspiration, airway stimulation or other identified risks that the algorithm does not address.

Team, timing and environment for tracheal extubation

The unconditionally elective nature of planned extubation provides a significant opportunity to optimise the team, timing and environment. While extubation is often associated with the removal of monitoring, patient transfers between locations and multiple distractions, the same standards of monitoring, equipment and assistance apply as during tracheal intubation [1, 15, 42]. Following extubation, continuous maintenance of this level of monitoring and provision of supplementary oxygen (including during transfer between locations) is encouraged until the patient can be relied upon to maintain airway patency and ventilation independently [1, 4, 14, 15, 22, 29, 111]. When sugammadex-induced anaphylaxis occurs, this is frequently during the period surrounding extubation [112, 113], underscoring the need for continued vigilance and careful monitoring following extubation to ensure timely recognition.

Unplanned extubation, due to accidental or time-critical (e.g. tracheal tube obstruction) removal of the tracheal tube, deprives the team of the opportunity to optimise the team, timing and environment for extubation. Management of such an emergency should follow the general principles of airway rescue as per any interruption to airway patency or ventilation. Patients identified as being at high risk of accidental extubation, or in need of specialised staff or equipment for airway rescue, should have appropriate precautions in place [62]. This may include meticulous securing of the tracheal tube; bedside signage of anticipated airway challenges; documentation of the

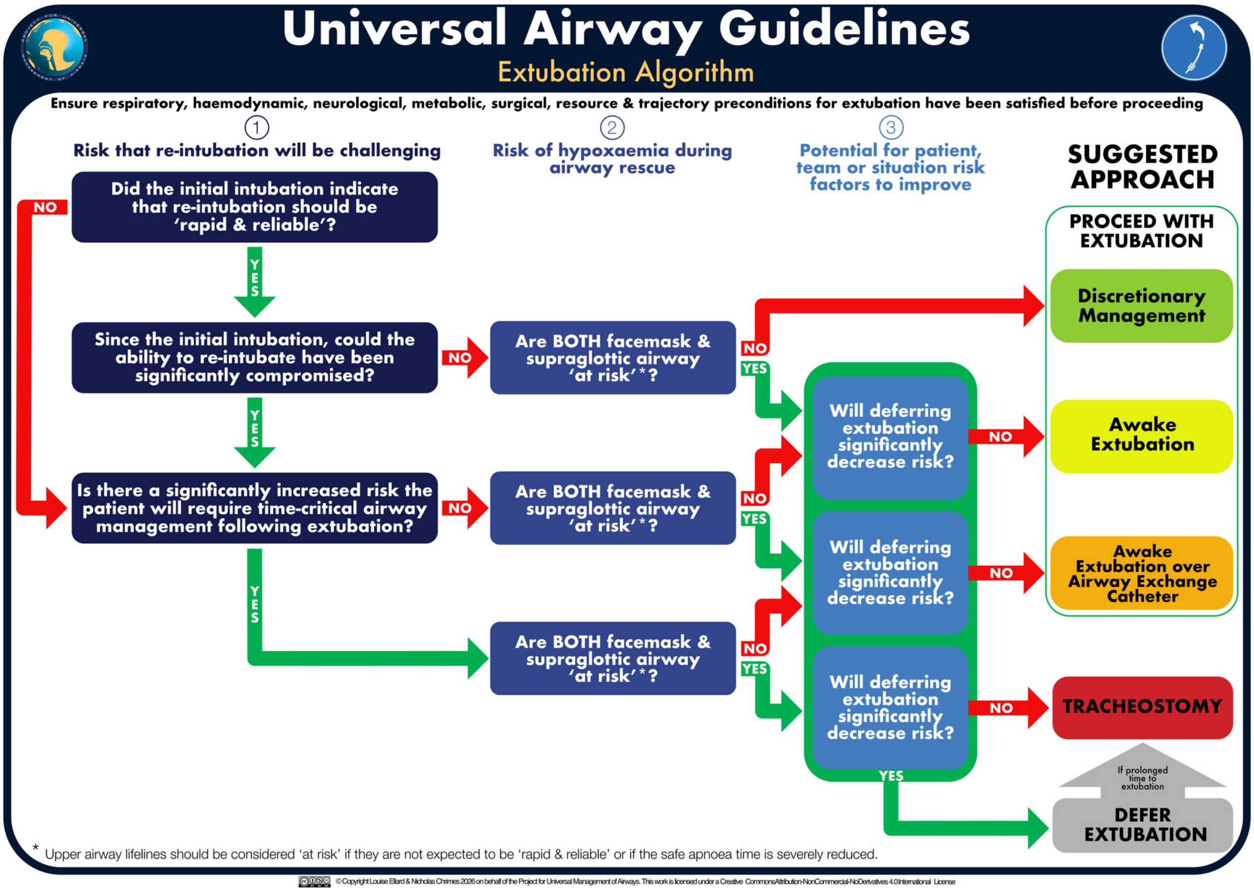

Figure 2 Tracheal extubation algorithm. This implementation tool has been designed to facilitate real-time decision making during clinical practice. Optimal use during clinical practice requires prior familiarity with the algorithm, guideline text and instructions for use [109]. Instructions for use are provided at www.UniversalAirway.org/extubation/algorithm. A high-resolution version is available for download at https://www.UniversalAirway.org/downloads. Printing and laminating this at A3 size is recommended.

tracheal re-intubation strategy; immediate availability of any equipment required for airway rescue; and contact details for timely access to any specialised staff [62].

Airway management team: Extubation should only be undertaken in the presence of an airway team capable of undertaking tracheal re-intubation and providing other forms of airway rescue if required [1, 15]. The number, experience and expertise of immediately available staff should be considered [23, 31, 58, 114], noting that environment and time of day may influence these. For complex cases, there may be a need to involve practitioners with specific expertise [1]. While supraglottic airway removal following elective surgery is often undertaken by appropriately skilled recovery staff, an airway operator should remain immediately available in case complications arise [1, 15, 115].

Timing of tracheal extubation: Deferring extubation is recommended when it will improve patient, team or situation factors that significantly decrease risk [15, 23]. This may provide time for resolution of pathology, institution of therapies (e.g. antibiotics, steroids, diuresis) or improving the environment and resources available for extubation, observation or tracheal re-intubation. Patients remain at increased risk of requiring airway rescue for a variable duration following extubation, which should be timed to avoid the potential negative impact of shift changes on the number or expertise of available staff during this period [14, 114, 116, 117].

Conversely, even when significant challenges with extubation are anticipated, deferral is not recommended unless it is expected to significantly decrease the risk of encountering, identifying or managing these [14, 29, 31, 42, 114, 118–120]. If deferring extubation does not decrease risk significantly, it only serves to transfer identified challenges to another airway practitioner, who may be less familiar with or equipped to deal with the issues involved.

Although extubation should generally be timed to minimise the risk that tracheal re-intubation will be required, in a critical care context a patient struggling to wean from ventilatory support may have a `trial of extubation´ to avoid progression to tracheostomy, despite tracheal re-intubation being probable. Such an approach is only appropriate in this context and should not be adopted if tracheal re-intubation is expected to be challenging [14, 29, 35, 121–123].

Whenever extubation is deferred, the above process of satisfying preconditions and re-evaluating risks using the algorithm should be repeated before reconsidering extubation [4, 14, 15, 31–33, 37–39].

Environment for tracheal extubation: Extubation should be performed in an environment suitable for implementing the extubation strategy that enables subsequent safe access to a location sufficiently resourced to provide appropriate observation [1, 15, 120]. This requires consideration of physical space requirements as well as availability of equipment, monitoring and access to staff. In patients at high cumulative risk, intra- or inter-hospital transfer may be required to ensure immediate access to appropriately skilled staff, specialised equipment or post-extubation observation. When imminent patient transfer is required for other reasons, deferring extubation is suggested if there are concerns about maintaining airway patency during transport after extubation [1, 14, 44, 58, 88].

General considerations

The following considerations may impact multiple aspects of extubation-related risk, necessitating reconciliation of conflicting requirements.

Clearing airway contaminants: Prior to extubation, the oropharynx should be suctioned carefully to remove debris or secretions that might cause airway stimulation, obstruction, pulmonary aspiration or impede subsequent tracheal re-intubation [1, 15]. Suction should remain immediately available following extubation until the patient has regained their baseline level of airway protective reflexes [1, 115]. In addition to reversing atelectasis [124, 125], sustained inflation of the lungs to near vital capacity immediately before deflating the tracheal tube cuff, and maintaining positive pressure as the tracheal tube is removed, decreases laryngeal adductor excitability and generates a passive exhalation that helps clear any airway soiling above the cuff, both of which may reduce the risk of subsequent laryngospasm [14, 126]. The sustained inflation also provides an increased oxygen reservoir if airway obstruction occurs following extubation [68]. Conversely, while using a suction catheter to remove secretions from the airway lumen before removing the tracheal tube (followed by ventilation with 100% oxygen) may be appropriate, applying suction to the lumen of the tracheal tube as it is removed is discouraged, as this promotes atelectasis and decreases the oxygen reservoir [127, 128].

Examination of the pharynx using a laryngoscope (before extubation or after removal of a supraglottic airway), including behind the soft palate for a `coroner's clot´, should be undertaken when there is potential for blood to have accumulated while any airway device was in place [1]. Laryngoscopic examination of the pharynx to confirm removal of pharyngeal packs should also be performed if these have been placed [1, 40, 129]. As the practitioner responsible for airway management during emergence, the airway operator retains responsibility for this examination, even if a pharyngeal pack has been placed by a surgeon [40]. To further reduce the risk of retention, pharyngeal packs should only be placed when considered essential; there should be verbal agreement between the airway operator and surgeon that a pharyngeal pack is to be used; and the process for their insertion and removal should be standardised [40, 129, 130]. Recommended components of such a process are that their insertion and removal should be clearly declared [129, 131], they should be added to the surgical count at the time of their placement [40, 129] and that the final count should be confirmed before extubation [40]. Use of visual cues to the presence of a pharyngeal pack (such leaving part of pack protruding from the mouth and placing labels on the patient and/or airway device) and securing the pharyngeal pack to the airway device are also recommended [132]. Clear handover regarding the presence of a pharyngeal pack in the airway is essential if a change of staff occurs during a procedure [129–131].

Gastric decompression: To minimise respiratory compromise from diaphragmatic splinting and the potential for regurgitation, decompression of the stomach via a gastric tube before extubation should be considered if significant gastric insufflation may have occurred (e.g. high pressure ventilation via a facemask or supraglottic airway or ventilation following oesophageal intubation) or where there is a risk of significant residual gastric content [14, 43].

Avoidance of diaphragmatic splinting is especially important in infants and neonates [4, 14, 133].

Placing a bite block: Sustained biting on a tracheal tube or supraglottic airway during emergence from anaesthesia can obstruct the airway, interrupting alveolar ventilation and potentially causing negative-pressure pulmonary oedema resulting in severe hypoxaemia [1, 134, 135]. Obstruction of reinforced tracheal tubes may persist even after transient compression. Use of a bite block to reduce this risk should be considered, particularly when removing a tracheal tube or supraglottic airway awake [1, 14, 15]. Bite blocks may be integrated into the airway device or improvised using commonly available items. Many supraglottic airways provide integrated bite-blocking mechanisms. The potential for improvised bite blocks (e.g. oropharyngeal airways, rolled gauze) to cause dental injury or airway obstruction should be considered and minimised [14, 44, 136, 137].

Positioning: Specifying the patient position during extubation should always form part of the strategy [14, 126]. Patient positioning has implications for airway patency; respiration; pulmonary aspiration; and ease of subsequent airway management. Surgical considerations may also influence positioning. Choice of position for extubation should balance optimal positioning for subsequent airway management with other considerations to maximise patient safety [4, 14, 58, 126, 138].

Extubating supine or ≤ 30° `head up´ (reverse Trendelenburg or Fowler's inclination) typically provides optimal access for subsequent airway interventions, including tracheal re-intubation if required. If extubation is not being undertaken with the patient in an optimal position for subsequent airway management (e.g. lateral, > 30° head up), adequate staff for urgent repositioning should be readily available [1, 4, 10, 14, 15].

Extubating in a 30° head-up position, rather than supine, has benefits including maintaining airway patency; increasing the functional residual capacity; improving diaphragmatic excursion; and decreasing alveolar collapse [6, 110]. Patients who are obese may benefit from extubation with > 30° Fowler's inclination [110, 139–142].

In patients designated `at risk´ of pulmonary aspiration, undertaking extubation in the supine position should be avoided [68, 143]. Placing these patients in the lateral position for extubation may provide some protection to the non-dependent lung if pulmonary aspiration occurs [68]. The lateral position may also help avoid airway obstruction following extubation or removal of a supraglottic airway. Extubation in a head-up position might decrease the risk of passive regurgitation but increase the risk of aspirating regurgitated or vomited material. Trendelenburg inclination has the opposite effect [143–145].

Recovery of neuromuscular function: The above, potentially stimulating interventions (suction; gastric decompression; bite block; positioning) should ideally be performed while the patient remains deeply sedated and with full neuromuscular blockade (however, once the patient is fully awake, suctioning may be repeated immediately before extubation if required) [14, 126]. Any residual neuromuscular blockade should then be antagonised while the patient remains sedated [15, 93, 146–149]. When neuromuscular blocking drugs are being used, quantitative neuromuscular monitoring is recommended to ensure return of baseline neuromuscular function before extubation [15, 93, 146, 148, 150, 151]. Incomplete antagonism of neuromuscular blockade increases the risk of hypoxaemia, pulmonary aspiration and awareness following extubation.

The use of sugammadex to antagonise neuromuscular blocking drugs is increasing globally [152–154]. While the precise incidence of sugammadex-induced anaphylaxis is currently unclear [112, 155–157], it is higher than that associated with neostigmine [158, 159]. However, this risk must be balanced against the ability of sugammadex to provide fast and reliable recovery of neuromuscular function when aminosteroid neuromuscular blocking drugs have been used, while allowing profound muscle relaxation to be maintained until immediately before extubation [157]. This has benefits in terms of providing optimal surgical and ventilatory conditions until the point of extubation while avoiding delays to recovery of neuromuscular function and reducing the significant psychological and physiological risks associated with residual neuromuscular blockade following extubation [154, 160]. Recent data indicate sugammadex may also decrease the incidence of extubation failure and unplanned ICU admission, even in patients without chronic pulmonary disease undergoing only minor procedures [161]. When quantitative neuromuscular monitoring shows sufficient recovery from an aminosteroid neuromuscular blocking drug to permit effective antagonism with neostigmine, practitioners must decide which antagonist offers the best risk:benefit profile to an individual patient.

In patients with Parkinson's disease or myasthenia gravis, administration of medications to optimise neurological or neuromuscular function should also be up to date at the time of extubation, with a plan to avoid any subsequent interruption (e.g. due to impaired oral intake) [162–165].

Level of consciousness: Extubation (or supraglottic airway removal) should be undertaken either with the patient deeply unconscious (deep extubation) or fully awake (awake extubation), avoiding intermediate planes of consciousness due to the increased risk of complications [58, 88, 126, 143, 166].

Typically, obeying commands (or showing an equivalent level of consciousness in those with communication or cognitive difficulties) indicates that the patient is `awake´ [44, 126]. Eye opening in response to verbal requests to do so may represent a non-specific reaction to stimulation rather than ability to follow instructions. Demonstrating compliance with requests to perform more specific tasks (e.g. `squeeze my hand´) avoids this ambiguity. Purposeful movements (e.g. reaching for the tracheal tube) do not reliably indicate that the patient is awake, and extubation at this threshold may predispose to serious complications.

The depth of sedation required for deep extubation is equivalent to that required for airway instrumentation when initiating airway management. Removal of a tracheal tube or supraglottic airway under deep sedation poses an increased risk of airway obstruction or apnoea. In the absence of specific indications to do otherwise, awake extubation is usually the safest option for reducing risk of hypoxaemia and pulmonary aspiration. Deep extubation should be considered an advanced technique, only performed in the presence of a skilled operator, experienced with the technique, who can undertake airway rescue if alveolar ventilation is interrupted [14, 23, 43, 167, 168]. Deep extubation should only be performed if pulmonary aspiration risk is minimal, safe apnoea time is adequate and when there is an expectation that both tracheal re-intubation and ventilation with at least one of the other lifelines (facemask or supraglottic airway) will be rapid and reliable [4, 14, 23, 44, 58, 126, 167, 168].

Following antagonism of neuromuscular blockade, spontaneous ventilation on 100% oxygen should be established before removing the tracheal tube [14, 44]. When deep extubation is undertaken, although sedative medications may be transiently weaned to facilitate restoration of spontaneous ventilation, deep sedation should be restored before removing the tracheal tube [44, 169]. Furthermore, if adult patients react to deflation of the tracheal tube cuff (coughing, straining, altered breathing pattern) during attempted deep extubation, removal of the tracheal tube should be deferred while depth of sedation is increased [14, 44]. In children, a transient pause in regular spontaneous ventilation may occur with tracheal cuff deflation despite adequate depth of sedation. Extubation may proceed provided there is no associated abdominal wall rigidity and spontaneous ventilation promptly resumes [169].

Whether undertaking extubation deep or awake, once sedative medications have been ceased, the patient should be allowed to wake on their own gradually, with minimal physical or auditory stimulation during the emergence phase [14, 44, 143, 166]. This involves refraining from vigorous physical manipulation, excessive verbal prompting and airway stimulation during intermediate planes of consciousness. Slow, gentle, passive range-of-motion manoeuvres across large joints, to provide proprioceptive input, may accelerate the rate of emergence but using abrupt or painful stimuli to provoke arousal can precipitate coughing; straining; jaw clenching; regurgitation; laryngospasm (following deep extubation); hypertension; and tachycardia. Positive-pressure ventilation asynchronous with spontaneous ventilatory efforts may have a similar impact. Patients who have undergone deep extubation should be observed particularly closely until they are obeying commands [1, 10, 126, 167].

Plan for avoiding harm from hypoxaemia

Avoiding harm from hypoxaemia following extubation involves extending the safe apnoea time in case ventilation is interrupted, avoiding the need for tracheal re-intubation and facilitating successful tracheal re-intubation when required, all of which are supported by vigilant post-extubation care.

Extending the safe apnoea time: Re-oxygenation of the functional residual capacity to an end-tidal oxygen concentration ≥ 85% by ventilating with 100% oxygen is recommended for all patients before extubation or conversion of airway management [1, 15]. This extends the safe apnoea time by maximising the amount of oxygen in the functional residual capacity. Continuing supplementary oxygen following extubation, while the patient remains at increased risk of requiring airway support, including during intra-hospital transport, is encouraged even if oxygen saturation is normal [1, 15, 126].

Avoiding the need for tracheal re-intubation: Immediately following extubation, airway patency and ventilation should be evaluated and, if required, support provided [14]. The importance of ensuring return of baseline neuromuscular function and the impact of timing, level of consciousness, position, gastric decompression and clearing airway soiling on avoiding airway obstruction or apnoea have been discussed above. Pre-emptive insertion of a nasopharyngeal or oropharyngeal airway may be useful to avoid obstruction following removal of a tracheal tube or supraglottic airway in vulnerable patients [4, 14, 43].

When discretionary management is suggested by the extubation algorithm (Fig. 2), deep exchange of a tracheal tube for a supraglottic airway may be used to minimise the risk of upper airway obstruction post-extubation while avoiding the airway stimulation associated with awake extubation. Application of high-flow nasal oxygen, continuous positive airway pressure or noninvasive ventilation following extubation may also reduce the risk of desaturation and potentially the need for tracheal re-intubation in selected patients [15, 23, 34, 110, 170–173]. However, in a recent study, routine prophylactic use of high-flow nasal oxygen following cardiac surgery was not found to impact the incidence of respiratory complications in susceptible patients [174].

When airway rescue is at significantly increased risk of being both required and challenging, and deferring extubation will not reduce risk, conversion to a tracheostomy may be indicated [23, 30, 43, 175, 176].

Facilitating successful tracheal re-intubation: The extubation strategy should include a plan for post-extubation observation; a contingency plan for controlled tracheal re-intubation should this prove necessary; and an approach to airway rescue in case ventilation is interrupted [1, 30, 43]. As part of the approach to airway rescue, plans to achieve a best effort at each of the lifelines and for priming for neck rescue should be communicated to the team [1, 30, 177, 178]. The equipment, monitoring and expertise to optimise success at tracheal intubation, facemask ventilation, supraglottic airway placement and neck rescue should be immediately available at extubation or supraglottic airway removal [1, 4, 14]. Any interventions required initially to optimise the likelihood of success at the three lifelines should be immediately reproducible at extubation whenever feasible [4, 14]. Where it is not possible to reproduce some elements (e.g. sniffing position following cervical spine fusion) or where the risk of airway management challenges has otherwise increased since tracheal intubation (e.g. distorted airway anatomy following surgery), the extubation strategy should address this [4, 14, 22, 29, 111]. Use of an airway exchange catheter to facilitate tracheal re-intubation is discussed below.

If care of a high-risk patient is transferred between practitioners following extubation (whether from medical to nursing staff or between medical or nursing staff), verbal handover and written documentation should be provided that outline the airway concerns, warning signs, triggers for review, as well as the proposed strategy for tracheal re-intubation, including any special equipment needed and contact details for the responsible airway operator [1, 14, 15, 31, 43]. When oversight or implementation of the tracheal re-intubation strategy requires involvement of practitioners other than those initially involved in managing the patient, an operator to operator handover is recommended.

Post-extubation care: The extubation strategy should address the need for the patient to remain in a location with staff, equipment and monitoring to recognise the need for tracheal re-intubation promptly and execute the tracheal re-intubation plan safely [1, 14, 15]. The timeframe during which the patient remains at increased risk of requiring tracheal re-intubation will vary by context and must be assessed on a case-by-case basis. Patients should generally remain nil by mouth until the 'at risk' period has ended [179].

Vigilant observation and early notification of airway deterioration are essential aspects of post-extubation care that promote both avoidance of the need for tracheal re-intubation and facilitation of tracheal re-intubation when it is necessary. Patients should be observed for oxygen desaturation; increasing oxygen requirement; altered respiratory effort; decreasing level of consciousness; and onset of agitation (as a marker of hypoxaemia) [1, 15, 31]. Surgical sites near the airway should be observed for swelling; bleeding; flap-perfusion; and drain losses [64, 180]. Additional signs of progressive airway obstruction include voice change; drooling; stridor; paradoxical chest movement; tracheal retraction; intercostal recession; and ultimately a silent airway [1, 4, 14, 78].

Plan for avoiding pulmonary aspiration

Protective sequence extubation comprises a set of interventions to be used in patients designated 'at risk' of pulmonary aspiration, analogous to the components of rapid sequence intubation (Fig. 3) [1, 14, 15, 68, 93, 143, 146–148, 150, 151, 181, 182]. Many of these represent good practice for any extubation, regardless of pulmonary aspiration risk, but are particularly important for reducing

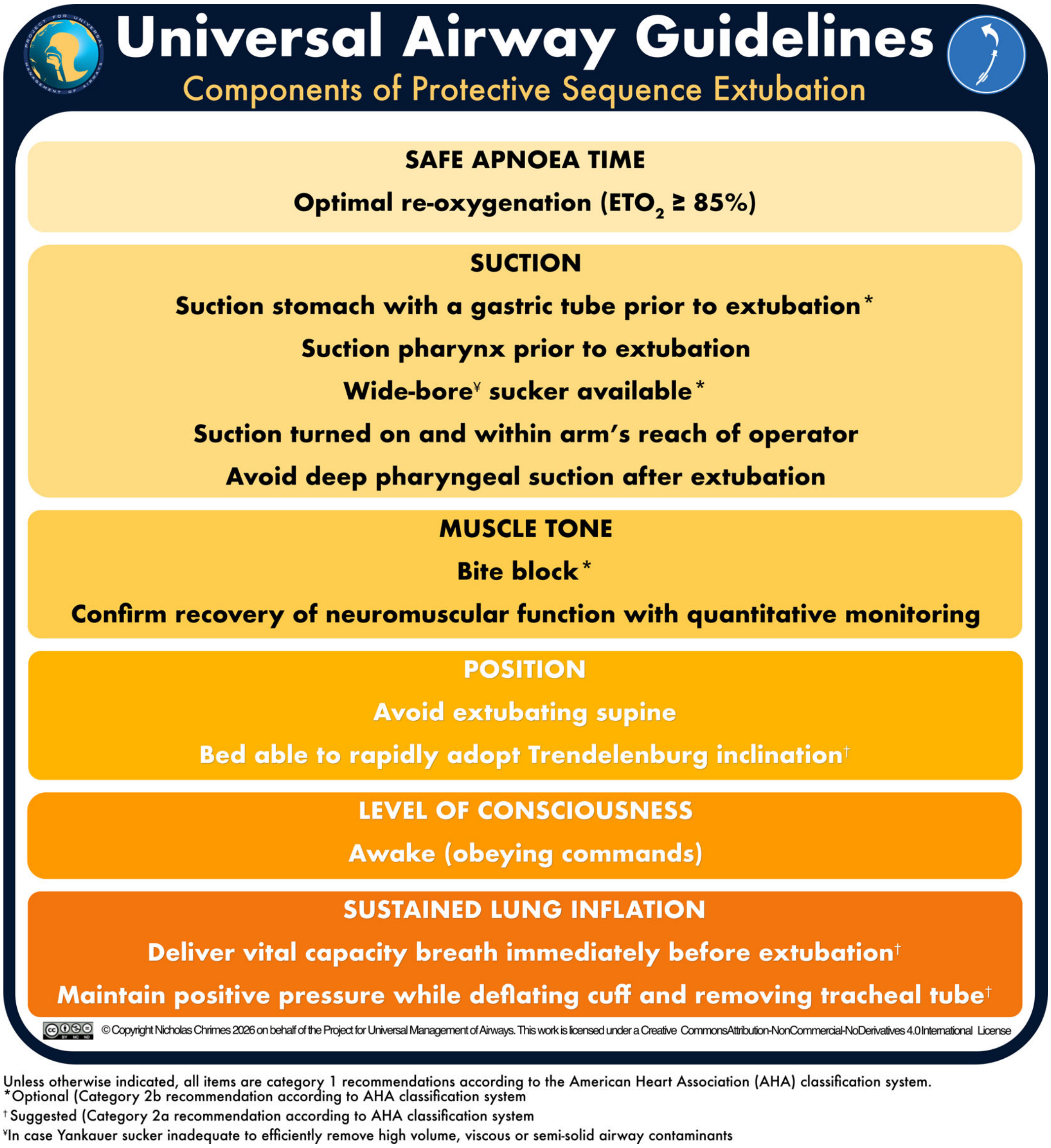

Figure 3 Components of protective sequence extubation [1, 14, 15, 68, 93, 143, 146–148, 150, 151, 181, 182]. A high-resolution version is available for download at https://www.UniversalAirway.org/downloads. Printing and laminating at A3 size is recommended. ETO_2, end-tidal oxygen.

the incidence and severity of pulmonary aspiration-related harm during extubation of `at risk´ patients.

Patients designated `at risk´ of pulmonary aspiration should undergo awake extubation to maximise the likelihood that airway-protective reflexes have returned [14, 182]. As discussed above, deliberate stimulation during emergence to provoke responses from a patient and hasten extubation may have adverse consequences. In addition, once stimulation ceases, a subsequent decrease in conscious state following extubation may result in loss of airway protective reflexes, predisposing to pulmonary aspiration.

Particular attention should be paid to optimising re-oxygenation of the functional residual capacity [1, 15]. This maximises the safe apnoea time in case of interruptions to ventilation occurring due to airway obstruction (from aspiration of foreign material or subsequent laryngospasm) or the need to suction regurgitated material from the airway before applying positive pressure. Use of a bite block should be considered in patients designated `at risk´ of aspiration [1, 14, 15]. If biting obstructs the tracheal tube during awake extubation, deflating the cuff to avoid negative-pressure pulmonary oedema is undesirable in

Table 3 Techniques for reducing harm from airway stimulation during extubation.

Technique	Target complications	Examples
Lidocaine*	Hypertension Laryngospasm Coughing Straining	Topical at tracheal intubation (spray to cords; ointment on tracheal tube cuff) Intracuff during tracheal intubation Intravenous at tracheal extubation†
Sedative/analgesics	Hypertension Laryngospasm Coughing Straining	Opioids† Dexmedetomidine†
Antihypertensives	Hypertension	Beta blockers Clonidine† Magnesium†
Reduce stimulating interventions	Hypertension Laryngospasm Coughing Straining	Deep tracheal extubation†,‡ (including deep exchange of tracheal tube for supraglottic airway) Nasotracheal intubation Avoidance of stimulation at intermediate planes of unconsciousness

*Observe safe doses, especially where combinations or other local anaesthesia is used.
†Use caution if awake tracheal extubation is the suggested approach.
‡Does not reduce the risk of laryngospasm.

these patients. The impact of clearing airway contaminants, gastric decompression, position, antagonism of neuromuscular blockade and providing a sustained vital capacity breath have been discussed above.

Plan for avoiding harm from airway stimulation

Deep extubation or supraglottic airway removal decreases the risk of sympathetic stimulation, coughing, straining and bronchospasm [143, 183], but is associated with an increased risk of upper airway obstruction [184]. Barring contraindications, deep removal of airway devices is common practice in children, as in this population airway reactivity and the risk of associated complications are increased when removing these awake [15, 169, 185]. Conversely, in adults, supraglottic airways typically produce minimal airway stimulation and can be removed awake, barring specific issues. Deep exchange of a tracheal tube for a supraglottic airway before emergence may be useful to minimise airway stimulation if no contraindications exist [14, 15, 23, 143, 183, 186–188]. Deep extubation or exchange of a tracheal tube for a supraglottic airway are not appropriate techniques for minimising airway stimulation in the presence of increased pulmonary aspiration risk or where the suggested approach from the extubation algorithm is anything other than 'discretionary management' [15, 23, 166]. Suctioning of secretions that might provoke laryngospasm or bronchospasm and the importance of avoiding airway stimulation during intermediate planes of unconsciousness have been discussed above. Other techniques to reduce harm from airway stimulation are outlined in Table 3 [14, 15, 23, 44, 121, 189–207].

Preparation for tracheal extubation

The extubation checklist addresses the requirements for safe extubation, controlled tracheal re-intubation (if this becomes necessary) and airway rescue via both upper airway and neck (if airway obstruction or apnoea occurs; Fig. 4). While the extubation checklist may be used as a prompt during preparation for extubation, its primary role is to verify that critical preparation tasks have already been completed [208]. When extubation is anticipated to be challenging, using the extubation checklist in a team setting with a challenge-response format, immediately before commencing the extubation sequence (Fig. 5), is encouraged [4, 208–211]. Instructions for using the tools in Figs. 4 and 5 are provided in online Supporting Information Appendix S4 and at www.UniversalAirway.org/extubation/checklist.

Airway exchange catheters

Airway exchange catheters are specially designed long, fine tracheal re-intubation guides that are placed into the trachea before extubation and remain there after the tracheal tube is removed, until the patient is no longer at increased risk of requiring tracheal re-intubation.

Indications for using an airway exchange catheter

Awake extubation over an airway exchange catheter is recommended if considered necessary to provide an adequate margin of safety from hypoxaemia [4, 5, 14, 15, 23, 212–214]. The extubation algorithm offers guidance as to when this is the case. While airway exchange catheters do not guarantee that tracheal re-intubation will be achieved, in the hands of operators proficient in their use, these have a

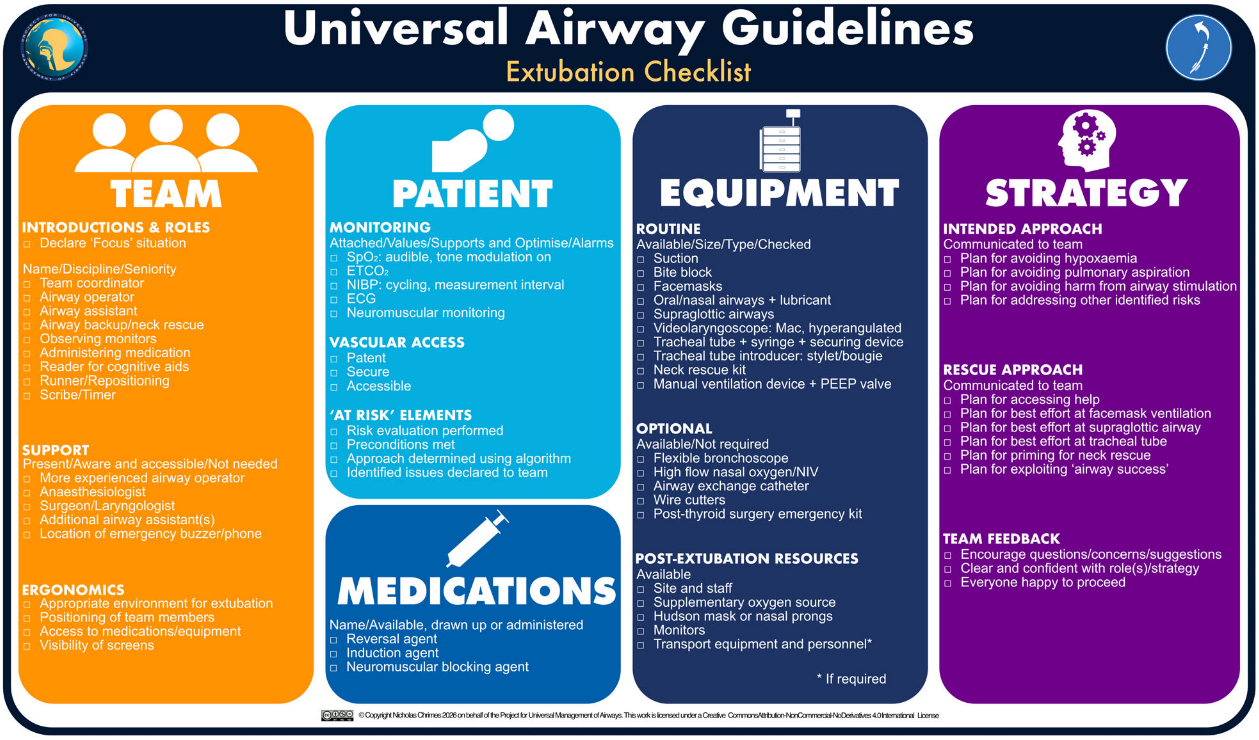

Figure 4 Tracheal extubation checklist. This has been designed to be used as an implementation tool. When extubation is anticipated to be challenging, use of the extubation checklist in a team setting to confirm completion of tasks, immediately before commencing the extubation sequence (Fig. 5), is encouraged. Optimal use during clinical practice requires prior familiarity with the checklist and guideline text. Instructions for use are provided at www.UniversalAirway.org/extubation/checklist. A high-resolution version is available for download at https://www.UniversalAirway.org/downloads. Printing and laminating at A3 size is recommended. SpO_2, pulse oximetry; $ETCO_2$, end-tidal carbon dioxide, NIBP, non-invasive blood pressure; ECG, electrocardiogram; PEEP, positive end-expiratory pressure; NIV, non-invasive ventilation; Mac, Macintosh blade.

high success rate [214, 215]. Significantly improved first attempt rates (87% vs. 14% when not using an airway exchange catheter) and overall tracheal re-intubation success rates of 92% have been reported when an airway exchange catheter is used [214, 216]. An airway exchange catheter should only be considered when it is judged that proceeding with extubation is appropriate [14, 30, 217, 218]. Airway exchange catheters should not be used to justify proceeding with extubation when a patient would benefit from deferral or tracheostomy [14, 30, 217, 218].

Where the extubation algorithm recommends awake extubation over an airway exchange catheter in a child, the safety and feasibility of this must be considered. In young children, a short trachea predisposes to endobronchial or supraglottic displacement. Other considerations include the child's ability to tolerate the catheter and the experience of the practitioner with airway exchange catheter use in this population. While evidence suggests airway exchange catheters can be used effectively even in young children, experience is limited [34, 219–221].

Choice of airway exchange catheter

The airway exchange catheter should be at least twice the length of the existing tracheal tube to minimise the risk of displacement during extubation [43]. It should also be sufficiently stiff to permit tracheal re-intubation; thus, wires are not recommended [14, 222]. Distance and radio-opaque markings are both essential [14, 23, 66, 222].

Insertion of the airway exchange catheter

Once the patient is awake and otherwise ready for extubation, the airway exchange catheter is inserted through the existing tracheal tube with the distance markings on the airway exchange catheter aligned with those of the tracheal tube [14, 15, 31]. Insertion of the airway exchange catheter to the same depth as the tracheal tube, measured at the patient's teeth or lips, assists with achieving ideal position of the airway exchange catheter tip, half-way between the larynx and carina [14, 15, 30, 217]. Secure four-point fixation of the airway exchange catheter in the midline (above and

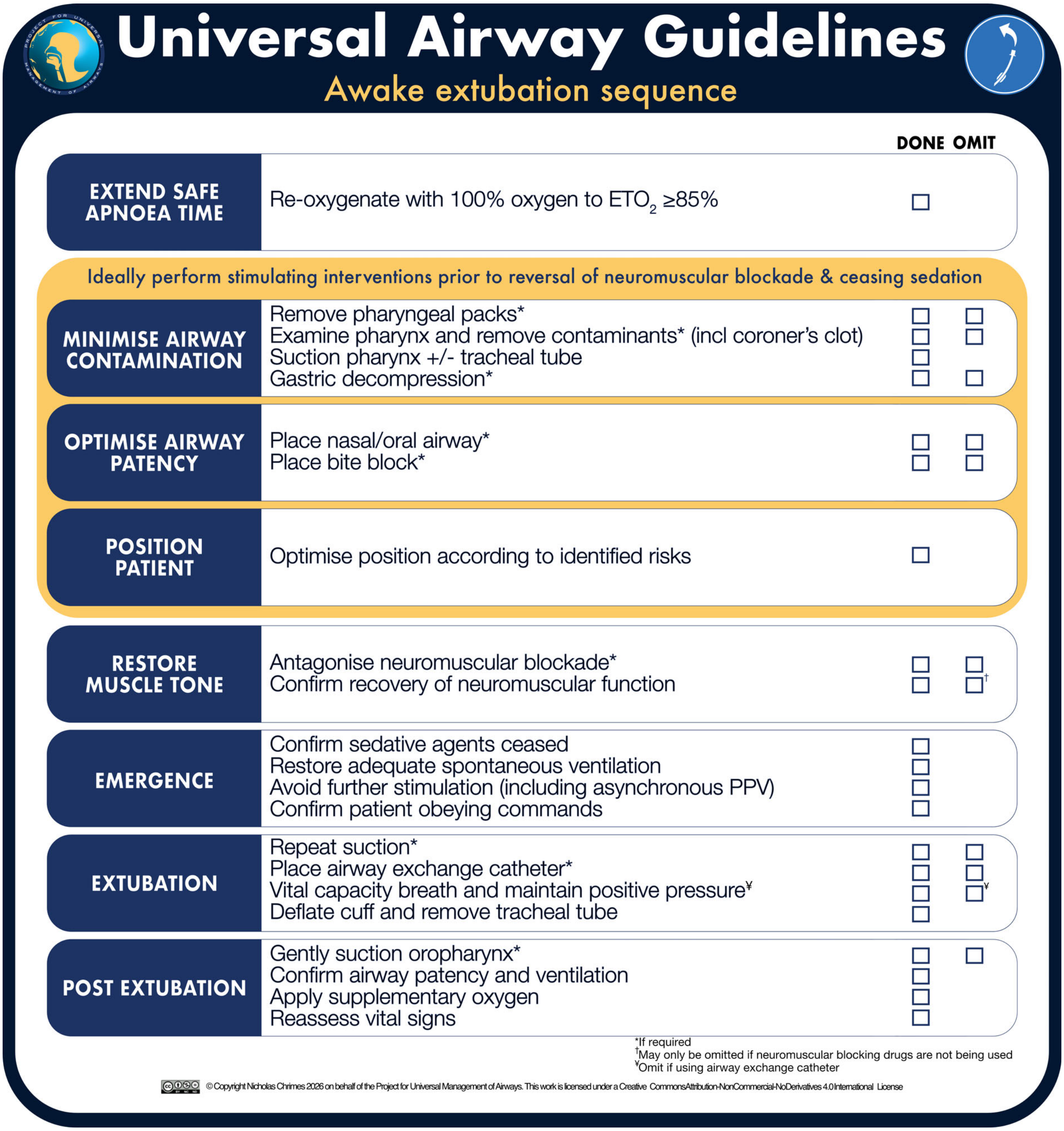

Figure 5 Tracheal extubation sequence. This may be used as a foundation tool or an implementation tool. When used as an implementation tool, it should be preceded by completion of the 'Extubation Checklist' (Fig. 4). When extubation is anticipated to be challenging, allocating a reader to verbalise each item is encouraged. Optimal use during clinical practice requires prior familiarity with the graphic and guideline text. Instructions for use are provided at www.UniversalAirway.org/extubation/checklist. A high-resolution version is available for download at https://www.UniversalAirway.org/downloads. Printing and laminating at A3 size is recommended. ETO_2, end-tidal oxygen; PPV, positive-pressure ventilation.

below the mouth) is suggested [23, 30, 43, 66, 213]. Images illustrating measurement of depth of insertion and four-point fixation of the airway exchange catheter are provided in online Supporting Information Figures S1 and S2 and at https://www.UniversalAirway.org/extubation/aec. For nasally-placed airway exchange catheters, avoidance of pressure on the nasal ala should be ensured [43]. Clear labelling of the airway exchange catheter as an airway device is essential to distinguish it from a gastric tube [30].

Supplemental oxygen via airway exchange catheters
Due to an unacceptable risk of barotrauma, oxygen should not be insufflated via an airway exchange catheter [14, 15, 31, 43, 223, 224]. Supplemental oxygen can be provided to the patient through a facemask or nasal prongs. If a patient with an airway exchange catheter in situ desaturates, and simple measures are unsuccessful (e.g. increased FiO_2 or airway support), urgent tracheal re-intubation should occur [15, 223].

Use and dwell time of the airway exchange catheter
Correct airway exchange catheter placement should be confirmed with waveform capnography, nasoendoscopy or videolaryngoscopy [23, 43, 66]. Neither sedation nor topical anaesthesia is usually required for tolerance of the airway exchange catheter, and patients should be able to talk, cough and breathe deeply around the device [23]. Patient tolerance is optimised by midtracheal depth of insertion and secure fixation [23, 214, 216]. Coughing or gagging should prompt re-evaluation of the midtracheal position of the airway exchange catheter using a chest X-ray [14, 23].

Although commonly practised, many airway exchange catheters are not licensed to be left in the airway for an extended period following extubation, making this an off-label application [14, 23, 225]. Patients with an airway exchange catheter in situ should remain in a high-acuity environment with resources to undertake tracheal re-intubation if required and clear instructions regarding who should be called if deterioration occurs [31]. Placement and removal of the airway exchange catheter are advanced procedures requiring an operator and team familiar with both the device and technique, including risks [31, 58, 222, 224, 226–230]. The airway exchange catheter should only be removed when the risk of tracheal re-intubation no longer remains, or there are no longer concerns about tracheal re-intubation being challenging [23, 66, 214]. Dwell times can be hours or up to several days [214, 231]. The patient must remain nil orally while the airway exchange catheter is in situ [23].

Tracheal re-intubation over the airway exchange catheter
In preparation for tracheal re-intubation over the airway exchange catheter, a team briefing outlining the intended and rescue components of the airway strategy should be undertaken using a checklist [31]. A tracheal tube with an internal diameter slightly greater than the external diameter of the airway exchange catheter should be selected [30, 31, 43, 222]. Positioning of the airway exchange catheter in the trachea should be reconfirmed before tracheal re-intubation [30, 66]. An airway assistant should be exclusively assigned to ensure that the airway exchange catheter depth does not change during tracheal re-intubation [66].

Induction of unconsciousness and neuromuscular blockade to facilitate tracheal re-intubation is recommended in most cases [87, 232]. However, in some patients, topicalisation and awake tracheal re-intubation over the airway exchange catheter may be possible [14]. Use of a videolaryngoscope is recommended, whether undertaking tracheal re-intubation awake or unconscious [43, 87, 232]. Blind tracheal re-intubation over an airway exchange catheter is discouraged [43, 87, 232]. Laryngoscopy retracts the tongue, allows monitoring of the airway exchange catheter during tracheal tube placement and may allow visualisation of the tracheal tube entering the glottis. If the airway exchange catheter dislodges during tracheal re-intubation, the rescue approach from the airway strategy should be implemented. The potential complications of airway exchange catheters and a guide for using an airway exchange catheter are provided in online Supporting Information Table S1 and Figure S3 and at https://www.Universal/Airway.org/extubation/aec [216, 222, 224, 228, 233].

Complications of extubation
Uneventful extubation involves executing the who, when, where and how elements of the intended approach to extubation. However, when upper airway obstruction or apnoea occurs, the rescue approach (`what is the plan if that plan fails?′) must be implemented (Fig. 1).

Upper airway obstruction in relation to extubation may occur due to loss of pharyngeal patency; airway soiling; laryngospasm; or the patient biting on a tracheal tube or supraglottic airway. Loss of pharyngeal patency may be acute or gradual. The cause of acute upper airway obstruction may not be easily delineated, and should be managed according to the standard principles for airway rescue. Particular issues contributing to airway obstruction during extubation are discussed below.

Biting on tracheal tube or supraglottic airway
Young, healthy adults are prone to biting down forcefully during waking, obstructing the tracheal tube or supraglottic airway if a bite block is not present. When such obstruction occurs in this patient group, strong respiratory muscles combined with limited chest wall compliance predispose to the development of negative-pressure pulmonary oedema when inspiratory efforts are made, although this complication has also been reported in children [1, 14, 234–239]. Removing the tracheal tube at this stage may not be possible or, if achieved, may precipitate subsequent laryngospasm during this excitatory phase of emergence.

Conversely, deflating the cuff of a tracheal tube or supraglottic airway that has been obstructed by biting may allow the patient to breathe around the tube and avoid the occurrence of negative-pressure pulmonary oedema [14, 236–238]. If this is contraindicated (e.g. patient `at risk´ of pulmonary aspiration) or unsuccessful, sedation should be deepened, followed by administration of a rapid-onset neuromuscular blocking drug if necessary.

If negative-pressure pulmonary oedema does occur, removal of oedema fluid from the airway is achieved by applying positive pressure to the lungs rather than by attempting to suction the fluid from the airway [236, 237]. Suction increases fluid loss and interrupts delivery of oxygen and application of positive pressure to the lungs, aggravating hypoxaemia [240, 241]. Suctioning of the airway is appropriate only as part of the management of negative-pressure pulmonary oedema when it is required to provide a view for tracheal intubation. When pulmonary oedema fluid is copious, keeping the heat and moisture exchange filter non-dependent helps avoid it becoming blocked [242]. Diuretics are not beneficial in negative-pressure pulmonary oedema and may aggravate hypovolaemia resulting from transfer of fluid to the lungs [236].

Laryngospasm

Laryngospasm may cause partial or complete upper airway obstruction. Partial upper airway obstruction is typically associated with stridor in the spontaneously breathing patient. Other causes of upper airway obstruction or increased airway pressure (foreign body; blood clot; gastric regurgitation; collapse of pharyngeal tissues; bronchospasm) may be difficult to distinguish from laryngospasm and should always be considered [101]. A stepwise approach to treatment of laryngospasm is outlined in Fig. 6 [14, 101, 243–245]. Upper airway obstruction that does not resolve with administration of an intubating dose of neuromuscular blocking drug is not due to laryngospasm, and other causes should be sought. If specific therapies for laryngospasm are unsuccessful, standard optimisations to restore upper airway patency by each of the lifelines should be implemented, with progression to neck rescue when required. Any persistent hypoxaemia, high airway pressure or inadequate end-tidal carbon dioxide should then be managed accordingly.

Gastric regurgitation or pulmonary aspiration

If gastric regurgitation occurs, the patient should be placed either on their side or in the head-down position [91, 246, 247]. Wide-bore suction is preferred over a standard Yankauer sucker for large volume, viscous or semi-solid regurgitated material [181]. Care should be taken to avoid stimulation of the gag reflex, which may trigger or worsen vomiting. If significant pulmonary aspiration has occurred, consider the need for bronchoscopy [145, 248–250].

Airway conversion

The substitution of one successfully established lifeline for another, or between a lifeline and a neck airway, can be classified as either conversion or replacement [178]. Airway conversion procedures are characterised by the continuous ability to maintain alveolar ventilation, or the presence of a guide that facilitates rapid restoration of alveolar ventilation (e.g. tracheal intubation via a supraglottic airway) [178]. Conversion techniques lie on a spectrum, with the most conservative techniques providing both (see online Supporting Information Appendix S4 or https://www.UniversalAirway.org/conversion). In contrast, airway replacement techniques inevitably interrupt alveolar ventilation via the initial lifeline until it can be restored via the subsequent lifeline, and do not employ a guide in the airway (e.g. removal of a supraglottic airway to attempt tracheal intubation) [178]. Replacement techniques are more accurately conceptualised as discontinuation of airway management coupled with planned immediate airway restoration using an alternative lifeline. When a tracheal tube or supraglottic airway is in situ, and substitution of lifelines is required, airway conversion is preferred over airway replacement procedures, particularly when the margin of safety from hypoxaemia is reduced [178, 251].

Airway conversion requires an equivalent level of evaluation, strategy formulation, preparation and vigilance to that necessary for tracheal intubation and extubation. This includes plans for airway rescue, as conversion does not eliminate the risk of airway obstruction [178]. Unless spontaneous respiration is required to maintain alveolar ventilation, deep neuromuscular blockade during conversion procedures typically improves safety by reducing the risk of airway loss due to coughing or laryngospasm and by facilitating airway rescue. When tracheal tube exchange is performed, an airway exchange catheter rather than a bougie should be used due to its greater length [43, 214].

Discussion

Planned extubation is always an elective procedure. Adverse events during extubation are common, highlighting the importance of performing a structured risk

Figure 6 Stepwise treatment of laryngospasm [14, 101, 243–245]. This has been designed to be used as an implementation tool. A high-resolution version is available for download at https://www.UniversalAirway.org/downloads. Printing and laminating at A3 size is recommended. CPAP, continuous positive airway pressure; NMBD, neuromuscular blocking drug; IV, intravenous; IM, intramuscular; IO, intra-osseous.

assessment and linking this assessment to a comprehensive extubation strategy. Extubation warrants the same level of evaluation, strategy formulation, preparation and vigilance as are required for tracheal intubation. When substitution of an existing tracheal tube or supraglottic airway device is required, airway conversion procedures are typically preferred to airway replacement procedures.

The principles outlined in this guideline are applicable across geographical boundaries, patient populations and clinical contexts. This includes adults and children in the operating theatre, emergency department and intensive care unit. While extubation is a less common procedure in emergency medicine, it may be performed following short-term tracheal intubation for decreased conscious state (intoxication or overdose); to facilitate imaging in patients who are unable to cooperate; or to provide airway protection during procedures requiring sedation. These guidelines apply equally to these situations. Although every effort was made to address common principles relating to discontinuation of airway support across all airway lifelines and patient types, more nuanced aspects of these specific contexts had to be omitted in the interests of the length and clarity of the document. It is recognised that, in some settings, system constraints may make immediate implementation of some recommendations infeasible. In the interim, these recommendations should be viewed as aspirational.

As infrequent, unanticipated, life-threatening events do not lend themselves to experimental research, the level of evidence for most recommendations is necessarily expert opinion. These guidelines may have benefited from seeking feedback from patients and policy makers.

Effective translation of these guidelines into clinical practice requires practitioners to be trained in their use. Free educator and learner resources will progressively be made available at https://www.UniversalAirway.org/training.

Review of these guidelines, ideally by a group including representatives from the major international airway societies, is intended to be undertaken within 10 years of publication. Until then, it is hoped that these guidelines improve the safety of tracheal extubation globally.

Author affiliations

Louise Ellard,[1,2] Andy Higgs,[3] Richard M. Cooper,[4] Carin A. Hagberg,[5] Paul A. Baker,[6,7] Robert Greif,[8,9] George Kovacs,[10] J. Adam Law,[11] Sheila N. Myatra,[12] Ellen P. O'Sullivan,[13] William H. Rosenblatt,[14] Christopher H. Ross,[15,16] John C. Sakles,[17] Massimiliano Sorbello,[18] and Nicholas C. Chrimes[19,20]

1 Consultant, Department of Anaesthesia, Austin Health, Melbourne, VIC, Australia
2 Honorary Clinical Senior Fellow, Department of Critical Care, University of Melbourne, Melbourne, VIC, Australia
3 Consultant, Department of Anaesthesia and Intensive Care, Warrington Teaching Hospitals NHS Foundation Trust, Cheshire, UK
4 Professor Emeritus, Department of Anesthesiology and Pain Medicine, University of Toronto, Toronto, ON, Canada
5 Chief Academic Officer, Division Head, Anesthesiology, Critical Care and Pain Medicine, Bud Johnson Clinical Distinguished Chair, Department of Anaesthesiology and Perioperative Medicine, University of Texas MD Anderson Cancer Center, Houston, TX, USA
6 Associate Professor, Department of Anaesthesiology, University of Auckland, Auckland, New Zealand
7 Consultant, Department of Anaesthesiology, Starship Children's Hospital, Auckland, New Zealand
8 Professor, Department of Anesthesiology and Pain Medicine, Bern University Hospital, University of Bern, Bern, Switzerland
9 Professor of Medical Education, Sigmund Freud University, Vienna, Austria
10 Professor, Departments of Emergency Medicine, Anesthesia, Medical Neurosciences and Division of Medical Education, Dalhousie University, Halifax, NS, Canada
11 Professor, Department of Anesthesia, Pain Management and Perioperative Medicine, Dalhousie University, Halifax, NS, Canada
12 Professor, Department of Anaesthesiology, Critical Care and Pain, Tata Memorial Hospital, Homi Bhabha National Institute, Mumbai, India
13 Consultant, Department of Anaesthesiology, St James's Hospital, Dublin, Ireland
14 Professor, Department of Anesthesia, Yale School of Medicine, New Haven, CT, USA
15 Attending, Department of Emergency Medicine, Mercy Health, Javon Bea Hospital, Rockton and Riverside Campuses, Rockford, IL, USA
16 Visiting Professor, Department of Surgery, University of Illinois College of Medicine, Chicago, IL, USA
17 Professor, Department of Emergency Medicine, University of Arizona College of Medicine, Tucson, AZ, USA
18 Associate Professor, Kore University, Enna, Italy; Head of Department, Anesthesia and Intensive Care, Giovanni Paolo II Hospital, Ragusa, Italy
19 Consultant, Department of Anaesthesia and Pain Management, Gosford Hospital, Gosford, NSW, Australia
20 Consultant, Sydney Clinical Skills and Simulation Centre, Royal North Shore Hospital, Sydney, NSW, Australia

Acknowledgements

The authors wish to thank A. Rehak for his assistance in developing the components of an airway strategy. We would like to thank J. Graham, B. Ingram, B. Ots and the following members of our international multidisciplinary advisory group (https://www.UniversalAirway.org/advisorygroup) and airway society representatives for completing expert surveys, providing targeted expert input and/or reviewing drafts of the manuscript: A. Alberts; M. Aziz; A. Barrow; D. Braude; A. Chan-Dominy; K. Chrimes; M. Clifford; J.C. Flores-Carrillo; T. Do; K. Fraser; J. Gatward; T. Heidegger; R. Hofmeyr; H. Huitink; P. Jones; M. Kristensen; O. Langer; J. Mosier; M. Mushabi; C. Nickson; M. Parotto; S. Sabato; C. Sandoval; T. Saracoglu; F. Urdaneta; R. Venkateswaran, and G. Zhou. LE is President of the Safe Airway Society and co-author of UpToDate chapter `Extubation following Anaesthesia´. NC is the creator of the Vortex Approach but has no financial interest in this material which is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International Licence. NC is a co-founder and clinical council member of the Safe Airway Society and an executive member of the Australian and New Zealand College of Anaesthetists, Australian Society of Anaesthetists and New Zealand Society of Anaesthetists Tripartite Airway Management Special Interest Group. NC is a director of the healthcare education provider Simpact Pty Ltd. AH is immediate past Treasurer of the Difficult Airway Society. CAH has received research support from Ambu, Fisher and Paykel Health Limited, Karl Storz Endoscopy, Teleflex and Vyaire Medical. CAH has received honoraria from UpToDate and Elsevier. PAB is the owner of Airway Simulation Ltd which manufactures the ORSIM® bronchoscopy simulator. RG is treasurer of the European Airway Management Society and has received research support from Karl Storz Endoscopy. GK and JAL are Co-Directors of Airway Interventions and Management in Emergencies Educational Programs. CR is an independent contractor for Teleflex Inc. and also assists in the development and teaching of procedural skills labs. JS is faculty on The Difficult Airway Course, Associate Editor of Walls Manual of Emergency Airway Management, Author UpToDate Chapter: RSI for Adults Outside the Operating Room and Author UpToDate Chapter: Emergency Cricothyrotomy. MS is the past president of the European Airway Management Society. He has received paid consultancy from DEAS Italia; he is a patent co-owner (no royalties – DNA®) and a patent co-owner (royalties – Cricospeed®) of DEAS Italia; he has a paid consultancy agreement with Flexicare, UK, NDA with Flexicare Italy and AI Endoscopic, Zurich. No data or statistical code were generated. No external funding or other competing interests declared.

References

1. Cook T, Woodall N, Frerk C. 4th National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Major complications of airway management in the United Kingdom. Report and findings. 2011. https://www.nationalauditprojects.org.uk/downloads/NAP4%20Full%20Report.pdf (accessed 24/06/2023).
2. Asai T, Koga K, Vaughan RS. Respiratory complications associated with tracheal intubation and extubation. *Br J Anaesth* 1998; **80**: 767–75. https://doi.org/10.1093/bja/80.6.767.
3. Crosby ET, Duggan LV, Finestone PJ, Liu R, De Gorter R, Calder LA. Anesthesiology airway-related medicolegal cases from the Canadian Medical Protection Association. *Can J Anaesth* 2021; **68**: 183–95. https://doi.org/10.1007/s12630-020-01846-7.
4. Apfelbaum JL, Hagberg CA, Connis RT, et al. 2022 American Society of Anesthesiologists Practice Guidelines for management of the difficult airway. *Anesthesiology* 2022; **136**: 31–81. https://doi.org/10.1097/ALN.0000000000004002.
5. Law JA, Duggan LV, Asselin M, et al. Canadian Airway Focus Group updated consensus-based recommendations for management of the difficult airway: part 1. Difficult airway management encountered in an unconscious patient. *Can J Anaesth* 2021; **68**: 1373–404. https://doi.org/10.1007/s12630-021-02007-0.
6. Ahmad I, El-Boghdadly K, Iliff H, et al. Difficult Airway Society 2025 guidelines for management of unanticipated difficult tracheal intubation in adults. *Br J Anaesth* 2026; **136**: 283–307. https://doi.org/10.1016/j.bja.2025.10.006.
7. Myatra SN, Shah AP, Ramkumar V, et al. All India Difficult Airway Association 2025 Guidelines for the management of unanticipated difficult airway in adults under general anaesthesia. *Indian J Anaesth* 2025; **69**: 1117–41. https://doi.org/10.4103/ija.ija_1210_25.
8. Ahmad I, El-Boghdadly K, Bhagrath R, et al. Difficult Airway Society guidelines for awake tracheal intubation (ATI) in adults. *Anaesthesia* 2020; **75**: 509–28. https://doi.org/10.1111/anae.14904.
9. Japanese Society of Anesthesiologists. JSA airway management guideline 2014: To improve the safety of induction of anesthesia. *J Anesth* 2014; **28**: 482–93. https://doi.org/10.1007/s00540-014-1844-4.
10. Higgs A, McGrath BA, Goddard C, Rangasami J, Suntharalingam G, Gale R, Cook TM. Guidelines for the management of tracheal intubation in critically ill adults. *Br J Anaesth* 2018; **120**: 323–52. https://doi.org/10.1016/j.bja.2017.10.021.
11. Ramkumar V, Jain K, Shah AP, et al. All India Difficult Airway Association 2025 guidelines for the management of unanticipated difficult airway in obstetrics under general anaesthesia. *Indian J Anaesth* 2025; **69**: 1142–66. https://doi.org/10.4103/ija.ija_1082_25.
12. Doctor JR, Shah AP, Kundra P, et al. All India Difficult Airway Association 2025 guidelines for the management of unanticipated difficult airway in paediatrics under general anaesthesia. *Indian J Anaesth* 2025; **69**: 1167–86. https://doi.org/10.4103/ija.ija_1096_25.
13. Mushambi MC, Kinsella SM, Popat M, et al. Obstetric Anaesthetists' Association and Difficult Airway Society

guidelines for the management of difficult and failed tracheal intubation in obstetrics. *Anaesthesia* 2015; **70**: 1286–306. https://doi.org/10.1111/anae.13260.
14. Difficult Airway Society Extubation Guidelines Group, Popat M, Mitchell V, et al. Difficult Airway Society Guidelines for the management of tracheal extubation. *Anaesthesia* 2012; **67**: 318–40. https://doi.org/10.1111/j.1365-2044.2012.07075.x.
15. Kundra P, Shah AP, Ahmed SM, et al. All India Difficult Airway Association 2025 guidelines for extubation of the "at-risk" airway. *Indian J Anaesth* 2025; **69**: 1187–207. https://doi.org/10.4103/ija.ija_766_25.
16. Petrini F, Accorsi A, Adrario E, et al. Recommendations for airway control and difficult airway management. *Minerva Anestesiol* 2005; **71**: 617–57.
17. Woodall N, Frerk C, Cook TM. Can we make airway management (even) safer? – lessons from national audit. *Anaesthesia* 2011; **66**(Suppl 2): 27–33. https://doi.org/10.1111/j.1365-2044.2011.06931.x.
18. Peterson GN, Domino KB, Caplan RA, Posner KL, Lee LA, Cheney FW. Management of the difficult airway: a closed claims analysis. *Anesthesiology* 2005; **103**: 33–9. https://doi.org/10.1097/00000542-200507000-00009.
19. Thille AW, Harrois A, Schortgen F, Brun-Buisson C, Brochard L. Outcomes of extubation failure in medical intensive care unit patients. *Crit Care Med* 2011; **39**: 2612–8. https://doi.org/10.1097/CCM.0b013e3182282a5a.
20. Joffe AM, Aziz MF, Posner KL, Duggan LV, Mincer SL, Domino KB. Management of difficult tracheal intubation: a closed claims analysis. *Anesthesiology* 2019; **131**: 818–29. https://doi.org/10.1097/ALN.0000000000002815.
21. Schroeder RA, Pollard R, Dhakal I, et al. Temporal trends in difficult and failed tracheal intubation in a regional community anesthetic practice. *Anesthesiology* 2018; **128**: 502–10. https://doi.org/10.1097/ALN.0000000000001974.
22. Sorbello M, Frova G. When the end is really the end? The extubation in the difficult airway patient. *Minerva Anestesiol* 2013; **79**: 194–9.
23. Parotto M, Cooper RM, Behringer EC. Extubation of the challenging or difficult airway. *Curr Anesthesiol Rep* 2020; **10**: 334–40. https://doi.org/10.1007/s40140-020-00416-3.
24. Chrimes N, Higgs A, Law JA, et al. Project for universal management of airways - part 1: concept and methods. *Anaesthesia* 2020; **75**: 1671–82. https://doi.org/10.1111/anae.15269.
25. Halperin JL, Levine GN, Al-Khatib SM, et al. Further evolution of the ACC/AHA clinical practice guideline recommendation classification system: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol* 2016; **67**: 1572–4. https://doi.org/10.1016/j.jacc.2015.09.001.
26. Cook TM, MacDougall-Davis SR. Complications and failure of airway management. *Br J Anaesth* 2012; **109**(Suppl 1): i68–85. https://doi.org/10.1093/bja/aes393.
27. Grillo-Ardila CF, Triana-Moreno LC, Laverde-Sabogal CE, Mora-Arteaga JA, Aguilar-Schotborgh MA, Ramirez-Mosquera JJ. Diagnostic accuracy of tests for assessing readiness for liberation from mechanical ventilation in adults: an overview of reviews. *J Intensive Care* 2026; **14**: 14. https://doi.org/10.1186/s40560-026-00848-9.
28. Taboada M, Rey R, Martinez S, et al. Reintubation in the ICU following cardiac surgery: is it more difficult than first-time intubation in the operating room?: a prospective observational study. *Eur J Anaesthesiol* 2020; **37**: 25–30. https://doi.org/10.1097/EJA.0000000000001019.
29. Heisenberg D, Stieger A, Oberle F, Parotto M, Heidegger T. Challenge of tracheal extubation and tube exchange of a difficult airway: a narrative review. *J Anesth* 2025; **39**: 465–75. https://doi.org/10.1007/s00540-025-03510-0.
30. Hagberg CA, Artime CA. Extubation of the perioperative patient with a difficult airway. *Colomb J Anesthesiol* 2014; **42**: 295–301. https://doi.org/10.1016/j.rcae.2014.06.003.
31. Sturgess DJ, Greenland KB, Senthuran S, Ajvadi FA, van Zundert A, Irwin MG. Tracheal extubation of the adult intensive care patient with a predicted difficult airway - a narrative review. *Anaesthesia* 2017; **72**: 248–61. https://doi.org/10.1111/anae.13668.
32. Salam A, Tilluckdharry L, Amoateng-Adjepong Y, Manthous CA. Neurologic status, cough, secretions and extubation outcomes. *Intensive Care Med* 2004; **30**: 1334–9. https://doi.org/10.1007/s00134-004-2231-7.
33. Tracy E, Crandall C, Grajales A, Plunkett A. The perioperative implications of the patient with Obstructive Sleep Apnea (OSA) - a narrative review. *Future Sci OA* 2025; **11**: 2540744. https://doi.org/10.1080/20565623.2025.2540744.
34. Weatherall AD, Burton RD, Cooper MG, Humphreys SR. Developing an Extubation strategy for the difficult pediatric airway - who, when, why, where, and how? *Paediatr Anaesth* 2022; **32**: 592–9. https://doi.org/10.1111/pan.14411.
35. Joffe A, Barnes CR. Extubation of the potentially difficult airway in the intensive care unit. *Curr Opin Anaesthesiol* 2022; **35**: 122–9. https://doi.org/10.1097/ACO.0000000000001119.
36. Engidaw MS, Tekeba B, Amare HT, Belay KA, Ayana Y, Liyew B. Incidence and predictors of extubation failure among adult intensive care unit patients in Northwest Amhara comprehensive specialized hospitals. *Sci Rep* 2025; **15**: 20957. https://doi.org/10.1038/s41598-025-05625-6.
37. Marchioni A, Moretti A, Tabbi L, et al. The forgotten airway: central airway pathology in the ICU. *Front Med (Lausanne)* 2025; **12**: 1712110. https://doi.org/10.3389/fmed.2025.1712110.
38. Sorbello M, La Via L, Paterno DS, et al. Artificial intelligence in airway management: a narrative review. *Br J Anaesth* 2026; **136**: 1606–15. https://doi.org/10.1016/j.bja.2025.12.052.
39. Chaverra Kornerup S, Parotto M. Extubation-related complications. *Int Anesthesiol Clin* 2024; **62**: 82–90. https://doi.org/10.1097/AIA.0000000000000454.
40. Athanassoglou V, Patel A, McGuire B, et al. Systematic review of benefits or harms of routine anaesthetist-inserted throat packs in adults: practice recommendations for inserting and counting throat packs: an evidence-based consensus statement by the Difficult Airway Society (DAS), the British Association of Oral and Maxillofacial Surgery (BAOMS) and the British Association of Otorhinolaryngology, Head and Neck Surgery (ENT-UK). *Anaesthesia* 2018; **73**: 612–8. https://doi.org/10.1111/anae.14197.
41. Zeng X, Chen XJ, Lai P, Chen J, Chen Z, Qi X. Risk prediction models for extubation failure in critically ill patients on mechanical ventilation: a systematic review. *Front Med (Lausanne)* 2025; **12**: 1695394. https://doi.org/10.3389/fmed.2025.1695394.
42. Cheung AWW, Cheng LCM. Emergence and extubation. *Anaesth Intensive Care Med* 2024; **25**: 544–9. https://doi.org/10.1016/j.mpaic.2024.06.017.
43. Parotto M, Ellard L. Extubation and reintubation of the difficult airway. In: Hagberg CA, ed. *Hagberg and Benumof's airway management*. Philadelphia: Elsevier, 2026 (in press).
44. Reddall RE, Yeow D. Extubation techniques in anaesthesia – a narrative review. *J Oral Maxillofac Anesth* 2023; **2**. https://dx.doi.org/10.21037/joma-23-2.
45. De Bast Y, De Backer D, Moraine JJ, Lemaire M, Vandenborght C, Vincent JL. The cuff leak test to predict failure of tracheal extubation for laryngeal edema. *Intensive Care Med* 2002; **28**: 1267–72. https://doi.org/10.1007/s00134-002-1422-3.
46. Ochoa ME, Marin MC, 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. *Intensive Care Med* 2009; **35**: 1171–9. https://doi.org/10.1007/s00134-009-1501-9.
47. Zhou T, Zhang HP, Chen WW, et al. Cuff-leak test for predicting postextubation airway complications: a systematic review. *J Evid Based Med* 2011; **4**: 242–54. https://doi.org/10.1111/j.1756-5391.2011.01160.x.
48. Kuriyama A, Jackson JL, Kamei J. Performance of the cuff leak test in adults in predicting post-extubation airway complications: a systematic review and meta-analysis. *Crit Care* 2020; **24**: 640. https://doi.org/10.1186/s13054-020-03358-8.
49. Jaber S, Chanques G, Matecki S, et al. Post-extubation stridor in intensive care unit patients. Risk factors evaluation and importance of the cuff-leak test. *Intensive Care Med* 2003; **29**: 69–74. https://doi.org/10.1007/s00134-002-1563-4.
50. Kallet RH, Matsushima A, Yoo S, Lipnick MS. Utilization of a risk stratification tool and volume-based cuff leak test to assess postextubation stridor. *Respir Care* 2023; **68**: 309–19. https://doi.org/10.4187/respcare.10285.
51. Bhargava T, Kumar A, Bharti A, Khuba S. Comparison of laryngeal ultrasound and cuff leak test to predict post-extubation stridor in total thyroidectomy. *Turk J Anaesthesiol Reanim* 2021; **49**: 238–43. https://doi.org/10.5152/TJAR.2020.176.
52. Shin SH, Heath K, Reed S, Collins J, Weireter LJ, Britt LD. The cuff leak test is not predictive of successful extubation. *Am Surg* 2008; **74**: 1182–5. https://doi.org/10.1177/000313480807401210.
53. El Amrousy D, Elkashlan M, Elshmaa N, Ragab A. Ultrasound-guided laryngeal air column width difference as a new predictor for postextubation stridor in children. *Crit Care Med* 2018; **46**: e496–501. https://doi.org/10.1097/CCM.0000000000003068.
54. El-Baradey GF, El-Shmaa NS, Elsharawy F. Ultrasound-guided laryngeal air column width difference and the cuff leak volume in predicting the effectiveness of steroid therapy on postextubation stridor in adult. Are they useful? *J Crit Care* 2016; **36**: 272–6. https://doi.org/10.1016/j.jcrc.2016.07.007.
55. Tsai WW, Hung KC, Huang YT, Yu CH, Lin CH, Chen IW, Sun CK. Diagnostic efficacy of sonographic measurement of laryngeal air column width difference for predicting the risk of post-extubation stridor: a meta-analysis of observational studies. *Front Med (Lausanne)* 2023; **10**: 1109681. https://doi.org/10.3389/fmed.2023.1109681.
56. Caranza R, Nandwani N, Tring JP, Thompson JP, Smith G. Upper airway reflex sensitivity following general anaesthesia for day-case surgery. *Anaesthesia* 2000; **55**: 367–70. https://doi.org/10.1046/j.1365-2044.2000.00806.x.
57. Borders JC, Fink D, Levitt JE, et al. Relationship between laryngeal sensation, length of intubation, and aspiration in patients with acute respiratory failure. *Dysphagia* 2019; **34**: 521–8. https://doi.org/10.1007/s00455-019-09980-1.
58. Cavallone LF, Vannucci A. Review article: Extubation of the difficult airway and extubation failure. *Anesth Analg* 2013; **116**: 368–83. https://doi.org/10.1213/ANE.0b013e31827ab572.
59. Kane AD, Armstrong RA, Kursumovic E, et al. Methods of the 7th National Audit Project (NAP7) of the Royal College of Anaesthetists: peri-operative cardiac arrest. *Anaesthesia* 2022; **77**: 1376–85. https://doi.org/10.1111/anae.15856.
60. Denipah N, Dominguez CM, Kraai EP, Kraai TL, Leos P, Braude D. Acute management of paradoxical vocal fold motion (vocal cord dysfunction). *Ann Emerg Med* 2017; **69**: 18–23. https://doi.org/10.1016/j.annemergmed.2016.06.045.
61. Larsen B, Caruso LJ, Villariet DB. Paradoxical vocal cord motion: an often misdiagnosed cause of postoperative stridor. *J Clin Anesth* 2004; **16**: 230–4. https://doi.org/10.1016/j.jclinane.2003.08.010.
62. Berkow L, Kanowitz A. Unplanned extubation in the perioperative environment. *APSF Newslett* 2022; **37**: 14–6.
63. Lundstrom LH, Moller AM, Rosenstock C, et al. A documented previous difficult tracheal intubation as a prognostic test for a subsequent difficult tracheal intubation in adults. *Anaesthesia* 2009; **64**: 1081–8. https://doi.org/10.1111/j.1365-2044.2009.06057.x.
64. Iliff HA, El-Boghdadly K, Ahmad I, et al. Management of haematoma after thyroid surgery: systematic review and multidisciplinary consensus guidelines from the Difficult Airway Society, the British Association of Endocrine and Thyroid Surgeons and the British Association of Otorhinolaryngology, Head and Neck Surgery. *Anaesthesia* 2022; **77**: 82–95. https://doi.org/10.1111/anae.15585.
65. Russotto V, Laffey JG, Tassistro E, et al. Peri-intubation complications in critically ill obese patients: a secondary analysis of the international INTUBE cohort. *Crit Care* 2025; **29**: 192. https://doi.org/10.1186/s13054-025-05419-2.
66. Cooper RM, Parotto M. Extubation and reintubation of the difficult airway. In: Hagberg CA, Artime CA, Aziz MF, eds. *Hagberg and Benumof's airway management*. Philadelphia: Elsevier, 2018; 853–75.
67. Kwon B, Yoo JU, Furey CG, Rowbottom J, Emery SE. Risk factors for delayed extubation after single-stage, multi-level anterior cervical decompression and posterior fusion. *J Spinal Disord Tech* 2006; **19**: 389–93. https://doi.org/10.1097/00024720-200608000-00002.
68. Langeron O, Bourgain JL, Francon D, et al. Difficult intubation and extubation in adult anaesthesia. *Anaesth Crit Care Pain Med* 2018; **37**: 639–51. https://doi.org/10.1016/j.accpm.2018.03.013.
69. Brodsky MB, Akst LM, Jedlanek E, et al. Laryngeal injury and upper airway symptoms after endotracheal intubation during surgery: a systematic review and meta-analysis. *Anesth Analg* 2021; **132**: 1023–32. https://doi.org/10.1213/ANE.0000000000005276.
70. Ellard L, Brown DH, Wong DT. Extubation of a difficult airway after thyroidectomy: use of a flexible bronchoscope via the LMA-classic. *Can J Anaesth* 2012; **59**: 53–7. https://doi.org/10.1007/s12630-011-9619-y.
71. Lam AM, Vavilala MS. Macroglossia: compartment syndrome of the tongue? *Anesthesiology* 2000; **92**: 1832–5. https://doi.org/10.1097/00000542-200006000-00046.
72. Cooper RM. Complications associated with the use of the GlideScope videolaryngoscope. *Can J Anaesth* 2007; **54**: 54–7. https://doi.org/10.1007/BF03021900.
73. Oppenheimer AG, Gulati V, Kirsch J, Alemar GO. Case 223: arytenoid dislocation. *Radiology* 2015; **277**: 607–11. https://doi.org/10.1148/radiol.2015140145.
74. Kharasch ED, Sivarajan M. Gastroesophageal perforation after intraoperative transesophageal echocardiography. *Anesthesiology* 1996; **85**: 426–8. https://doi.org/10.1097/00000542-199608000-00027.
75. Gruen R, Cade R, Vellar D. Perforation during nasogastric and orogastric tube insertion. *Aust N Z J Surg* 1998; **68**: 809–11. https://doi.org/10.1111/j.1445-2197.1998.tb04687.x.
76. Lacoste L, Gineste D, Karayan J, et al. Airway complications in thyroid surgery. *Ann Otol Rhinol Laryngol* 1993; **102**: 441–6. https://doi.org/10.1177/000348949310200607.
77. Venna RP, Rowbottom JR. A nine-year retrospective review of postoperative airway-related problems in patients following multilevel anterior cervical corpectomy. *Anesthesiology* 2001; **95**: B14.
78. Greenland KB, Acott C, Segal R, Riley RH, Merry AF. Delayed airway compromise following extubation of adult patients who

required surgical drainage of Ludwig's angina: comment on three coronial cases. *Anaesth Intensive Care* 2011; **39**: 506–8.
79. Nicholson JJ, Bradley WPL, Stefanutto T, Downey GO, Berkow L. Airway management after cervical spine surgery: a review of the literature. *Australas Anaesth* 2017; 13–20.
80. Teo EY, Kelley BS, Black IH. Observational study of Mallampati changes after prone spinal surgery. *J Clin Anesth* 2014; **26**: 606–10. https://doi.org/10.1016/j.jclinane.2014.04.010.
81. Singha D, Kattimani MM, Kanwar M, Bhandari S, Singh J. Evaluation of changes in Mallampati class in patients undergoing lumbar spine surgeries in the prone position: a prospective observational study. *Saudi J Anaesth* 2023; **17**: 163–7. https://doi.org/10.4103/sja.sja_438_22.
82. Jain M, Lal J, Aggrawal D, Sharma J, Singh AK, Bansal T. A study to evaluate changes in modified Mallampati class in patients undergoing spine surgery in prone position. *Cureus* 2022; **14**: e25767. https://doi.org/10.7759/cureus.25767.
83. Li H, Huang Y, Shen B, Ba Z, Wu D. Multivariate analysis of airway obstruction and reintubation after anterior cervical surgery: a retrospective cohort study of 774 patients. *Int J Surg* 2017; **41**: 28–33. https://doi.org/10.1016/j.ijsu.2017.03.014.
84. Shah AH, Clementi EA, Limage K, Harley EH. Airway compromise in adults following anterior cervical discectomy and fusion: a systematic review and meta-analysis. *Laryngoscope Investig Otolaryngol* 2025; **10**: e70215. https://doi.org/10.1002/lio2.70215.
85. Wiles MD, Iliff HA, Brooks K, et al. Airway management in patients with suspected or confirmed cervical spine injury: Guidelines from the Difficult Airway Society (DAS), Association of Anaesthetists (AoA), British Society of Orthopaedic Anaesthetists (BSOA), Intensive Care Society (ICS), Neuro Anaesthesia and Critical Care Society (NACCS), Faculty of Prehospital Care and Royal College of Emergency Medicine (RCEM). *Anaesthesia* 2024; **79**: 856–68. https://doi.org/10.1111/anae.16290.
86. Saunders TG, Gibbins ML, Seller CA, Kelly FE, Cook TM. Videolaryngoscope-assisted flexible intubation tracheal tube exchange in a patient with a difficult airway. *Anaesth Rep* 2019; **7**: 22–5. https://doi.org/10.1002/anr3.12007.
87. Mort TC, Braffett BH. Conventional versus video laryngoscopy for tracheal tube exchange: Glottic visualization, success rates, complications, and rescue alternatives in the high-risk difficult airway patient. *Anesth Analg* 2015; **121**: 440–8. https://doi.org/10.1213/ANE.0000000000000825.
88. Tanaka A, Uchiyama A, Horiguchi Y, et al. Predictors of post-extubation stridor in patients on mechanical ventilation: a prospective observational study. *Sci Rep* 2021; **11**: 19993. https://doi.org/10.1038/s41598-021-99501-8.
89. Perri D, Piraino T. To leak, or not to leak: is that really the question? *Chest* 2025; **168**: 4–5. https://doi.org/10.1016/j.chest.2025.02.039.
90. Rewers M, Chrimes N. Human factors in airway management. In: Cook TM, Kristensen MS, eds. *Core topics in airway management*. Cambridge, UK: Cambridge University Press, 2021; 305–15.
91. Kluger MT, Short TG. Aspiration during anaesthesia: a review of 133 cases from the Australian Anaesthetic Incident Monitoring Study (AIMS). *Anaesthesia* 1999; **54**: 19–26. https://doi.org/10.1046/j.1365-2044.1999.00642.x.
92. Bangera A. Anaesthesia for adenotonsillectomy: an update. *Indian J Anaesth* 2017; **61**: 103–9. https://doi.org/10.4103/0019-5049.199855.
93. Thilen SR, Weigel WA, Todd MM, et al. 2023 American Society of Anesthesiologists Practice Guidelines for monitoring and antagonism of neuromuscular blockade: a report by the American Society of Anesthesiologists Task Force on Neuromuscular Blockade. *Anesthesiology* 2023; **138**: 13–41. https://doi.org/10.1097/ALN.0000000000004379.
94. Elia S, Liu P, Chrusciel C, Hilgenberg A, Skourtis C, Lappas D. Effects of tracheal extubation on coronary blood flow, myocardial metabolism and systemic haemodynamic responses. *Can J Anaesth* 1989; **36**: 2–8. https://doi.org/10.1007/BF03010879.
95. Kulkarni A, Price G, Saxena M, Skowronski G. Difficult extubation: calming the sympathetic storm. *Anaesth Intensive Care* 2004; **32**: 413–6. https://doi.org/10.1177/0310057X0403200319.
96. Barham NJ, Boomers OW, Sherry KM, Locke TJ. Myocardial ischaemia during tracheal extubation in patients after cardiac surgery: an observational study. *Br J Anaesth* 1998; **80**: 832–3. https://doi.org/10.1093/bja/80.6.832.
97. Rose DK, Cohen MM, DeBoer DP. Cardiovascular events in the postanesthesia care unit: contribution of risk factors. *Anesthesiology* 1996; **84**: 772–81. https://doi.org/10.1097/00000542-199604000-00003.
98. Conti J, Smith D. Haemodynamic responses to extubation after cardiac surgery with and without continued sedation. *Br J Anaesth* 1998; **80**: 834–6. https://doi.org/10.1093/bja/80.6.834.
99. Wellwood M, Aylmer A, Teasdale S, et al. Extubation and myocardial ischaemia. *Anesthesiology* 1984; **61**: A132.
100. Chrimes N. Correction. *Anaesthesia* 2017; **72**: 274. https://doi.org/10.1111/anae.13732.
101. Visvanathan T, Kluger MT, Webb RK, Westhorpe RN. Crisis management during anaesthesia: laryngospasm. *Qual Saf Health Care* 2005; **14**: e3. https://doi.org/10.1136/qshc.2002.004275.
102. Ghofaily LA, Simmons C, Chen L, Liu R. Negative pressure pulmonary edema after laryngospasm: a revisit with a case report. *J Anesth Clin Res* 2013; **3**: 252. https://doi.org/10.4172/2155-6148.1000252.
103. Cheng JZ, Wang J. Negative pressure pulmonary edema related to laryngospasm and upper airway obstruction in a patient with Treacher Collins syndrome. *Cureus* 2021; **13**: e14426. https://doi.org/10.7759/cureus.14426.
104. Lang SA, Duncan PG, Shephard DA, Ha HC. Pulmonary oedema associated with airway obstruction. *Can J Anaesth* 1990; **37**: 210–8. https://doi.org/10.1007/BF03005472.
105. Scarbrough FE, Wittenberg JM, Smith BR, Adcock DK. Pulmonary edema following postoperative laryngospasm: case reports and review of the literature. *Anesth Prog* 1997; **44**: 110–6.
106. Disma N, Asai T, Cools E, et al. Airway management in neonates and infants: European Society of Anaesthesiology and Intensive Care and British Journal of Anaesthesia joint guidelines. *Br J Anaesth* 2024; **132**: 124–44. https://doi.org/10.1016/j.bja.2023.08.040.
107. Brewster DJ, Chrimes N, Do TB, et al. Consensus statement: safe Airway Society principles of airway management and tracheal intubation specific to the COVID-19 adult patient group. *Med J Aust* 2020; **212**: 472–81. https://doi.org/10.5694/mja2.50598.
108. Cook TM, El-Boghdadly K, McGuire B, McNarry AF, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: guidelines from the Difficult Airway Society, the Association of Anaesthetists the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. *Anaesthesia* 2020; **75**: 785–99. https://doi.org/10.1111/anae.15054.
109. Burian BK, Clebone A, Dismukes K, Ruskin KJ. More than a tick box: medical checklist development, design, and use. *Anesth Analg* 2018; **126**: 223–32. https://doi.org/10.1213/ANE.0000000000002286.
110. McKechnie A, Iliff HA, Black R, et al. Airway management in patients living with obesity: best practice recommendations from the Society for Obesity and Bariatric Anaesthesia:

Endorsed by the All Wales Airway Group, Scottish Airway Group and Difficult Airway Society. *Anaesthesia* 2025; **80**: 1103–14. https://doi.org/10.1111/anae.16647.

111. Myatra SN, Kornerup SC, Parotto M. Extubation in head and neck surgery. *Curr Opin Anaesthesiol* 2025; **38**: 869–76. https://doi.org/10.1097/ACO.0000000000001579.
112. Crimmins D, Crilly H, van Nieuwenhuysen C, et al. Sugammadex hypersensitivity: a multicentre retrospective analysis of a large Australian cohort. *Br J Anaesth* 2025; **134**: 72–9. https://doi.org/10.1016/j.bja.2024.07.042.
113. Harper NJN, Cook TM, Garcez T, et al. Anaesthesia, surgery, and life-threatening allergic reactions: epidemiology and clinical features of perioperative anaphylaxis in the 6th National Audit Project (NAP6). *Br J Anaesth* 2018; **121**: 159–71. https://doi.org/10.1016/j.bja.2018.04.014.
114. Anastasian ZH, Kim M, Heyer EJ, Wang S, Berman MF. Attending handoff is correlated with the decision to delay extubation after surgery. *Anesth Analg* 2016; **122**: 758–64. https://doi.org/10.1213/ANE.0000000000001069.
115. ANZCA. ANZCA position statement on the post-anaesthesia care unit 2020. 2020. https://www.anzca.edu.au/getattachment/7045495a-0f12-4464-852c-b93c0453e1ed/PS04(A)-Position-statement-on-the-post-anaesthesia-care-unit-2020#page (accessed 12/09/2024).
116. Balas MC, Tate J, Tan A, Pinion B, Exline M. Evaluation of the perceived barriers and facilitators to timely extubation of critically ill adults: an interprofessional survey. *Worldviews Evid-Based Nurs* 2021; **18**: 201–9. https://doi.org/10.1111/wvn.12493.
117. Semple J. Preparing for extubation and multidisciplinary rounds. *J Int Res Rev* 2025; **1**. https://doi.org/10.61148/JIRR/002.
118. Wallace S, McGrath BA. Laryngeal complications after tracheal intubation and tracheostomy. *BJA Educ* 2021; **21**: 250–7. https://doi.org/10.1016/j.bjae.2021.02.005.
119. Kumalasari RI, Kosasih CE, Priambodo AP. A scoping review of factors associated with delayed extubation in post cardiac surgery patients. *Vasc Health Risk Manag* 2025; **21**: 1–15. https://doi.org/10.2147/VHRM.S479352.
120. Batuwitage B, Charters P. Postoperative management of the difficult airway. *BJA Education* 2017; **17**: 235–41. https://doi.org/10.1093/bjaed/mkw077.
121. Wang L, Zhang Q, Guo D, et al. Construction of an extubation protocol for adult tracheal intubation patients in the intensive care unit: a Delphi study. *Aust Crit Care* 2025; **38**: 101111. https://doi.org/10.1016/j.aucc.2024.08.007.
122. Hyzy RC. Extubation management in the adult intensive care unit. 2025. https://www.uptodate.com/contents/extubation-management-in-the-adult-intensive-care-unit (accessed 05/06/2026).
123. Girard TD, Alhazzani W, Kress JP, et al. An Official American Thoracic Society/American College of Chest Physicians Clinical Practice Guideline: liberation from mechanical ventilation in critically ill adults. Rehabilitation protocols, ventilator liberation protocols, and cuff leak tests. *Am J Respir Crit Care Med* 2017; **195**: 120–33. https://doi.org/10.1164/rccm.201610-2075ST.
124. Park KJ, Oh YJ, Chang HJ, et al. Acute hemodynamic effects of recruitment maneuvers in patients with acute respiratory distress syndrome. *J Intensive Care Med* 2009; **24**: 376–82. https://doi.org/10.1177/0885066609344952.
125. Arnal JM, Paquet J, Wysocki M, et al. Optimal duration of a sustained inflation recruitment maneuver in ARDS patients. *Intensive Care Med* 2011; **37**: 1588–94. https://doi.org/10.1007/s00134-011-2323-0.
126. Benham-Hermetz J, Mitchell V. Safe tracheal extubation after general anaesthesia. *BJA Educ* 2021; **21**: 446–54. https://doi.org/10.1016/j.bjae.2021.07.003.
127. Guglielminotti J, Constant I, Murat I. Evaluation of routine tracheal extubation in children: inflating or suctioning technique? *Br J Anaesth* 1998; **81**: 692–5. https://doi.org/10.1093/bja/81.5.692.
128. Prazak J, Schenk NV, Schefold JC, Bachmann KF, Berger D. Effects of preoxygenation with intratracheal suctioning during extubation: an alternating cluster-controlled trial (intratracheal suctioning and oxygenation at extubation [innovate]). *Crit Care Med* 2025; **53**: e2179–90. https://doi.org/10.1097/ccm.0000000000006819.
129. Knepil GJ, Blackburn CW. Retained throat packs: results of a national survey and the application of an organisational accident model. *Br J Oral Maxillofac Surg* 2008; **46**: 473–6. https://doi.org/10.1016/j.bjoms.2008.02.005.
130. Bailey CR, Nouraie R, Huitink JM. Have we reached the end for throat packs inserted by anaesthetists? *Anaesthesia* 2018; **73**: 535–8. https://doi.org/10.1111/anae.14168.
131. Baranger V, Bon Mardion N, Dureuil B, Compere V. Human error in throat pack management: report of two cases. *A A Case Rep* 2016; **6**: 397–8. https://doi.org/10.1213/XAA.0000000000000348.
132. Curran J, Ward M, Knepil G. *Reducing the risk of retained throat packs after surgery*. UK: National Patient Safety Agency, 2009.
133. Lee JH, Jung H, Kim EH, Song IK, Kim HS, Kim JT. Optimal inspiratory pressure for face mask ventilation in paralyzed and unparalyzed children to prevent gastric insufflation: a prospective, randomized, non-blinded study. *Can J Anaesth* 2018; **65**: 1288–95. https://doi.org/10.1007/s12630-018-1183-2.
134. Liu EH, Yih PS. Negative pressure pulmonary oedema caused by biting and endotracheal tube occlusion – a case for oropharyngeal airways. *Singapore Med J* 1999; **40**: 174–5.
135. Dicpinigaitis PV, Mehta DC. Postobstructive pulmonary edema induced by endotracheal tube occlusion. *Intensive Care Med* 1995; **21**: 1048–50. https://doi.org/10.1007/BF01700672.
136. Falzon D, Foye R, Jefferson P, Ball DR. Extubation guidelines: Guedel oropharyngeal airways should not be used as bite blocks. *Anaesthesia* 2012; **67**: 919; author reply 21-2. https://doi.org/10.1111/j.1365-2044.2012.07255.x.
137. Yasny JS. Perioperative dental considerations for the anesthesiologist. *Anesth Analg* 2009; **108**: 1564–73. https://doi.org/10.1213/ane.0b013e31819d1db5.
138. Rassam S, Sandbythomas M, Vaughan RS, Hall JE. Airway management before, during and after extubation: a survey of practice in the United Kingdom and Ireland. *Anaesthesia* 2005; **60**: 995–1001. https://doi.org/10.1111/j.1365-2044.2005.04235.x.
139. Dixon BJ, Dixon JB, Carden JR, et al. Preoxygenation is more effective in the 25 degrees head-up position than in the supine position in severely obese patients: a randomized controlled study. *Anesthesiology* 2005; **102**: 1110–5; discussion 5A. https://doi.org/10.1097/00000542-200506000-00009.
140. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, Gattinoni L. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. *Anesth Analg* 1998; **87**: 654–60. https://doi.org/10.1097/00000539-199809000-00031.
141. Altermatt FR, Munoz HR, Delfino AE, Cortinez LI. Pre-oxygenation in the obese patient: effects of position on tolerance to apnoea. *Br J Anaesth* 2005; **95**: 706–9. https://doi.org/10.1093/bja/aei231.
142. Valenza F, Vagginelli F, Tiby A, et al. Effects of the beach chair position, positive end-expiratory pressure, and pneumoperitoneum on respiratory function in morbidly obese patients during anesthesia and paralysis.

Anesthesiology 2007; **107**: 725–32. https://doi.org/10.1097/01.anes.0000287026.61782.a6.
143. Jubb A, Ford P. Extubation after anaesthesia: a systematic review. *Update Anaesth* 2009; **25**: 30–6.
144. Roberts RB, Shirley MA. Reducing the risk of acid aspiration during cesarean section. *Anesth Analg* 1974; **53**: 859–68. https://doi.org/10.1213/00000539-197453060-00010.
145. Warner MA, Meyerhoff KL, Warner ME, Posner KL, Stephens L, Domino KB. Pulmonary aspiration of gastric contents: a closed claims analysis. *Anesthesiology* 2021; **135**: 284–91. https://doi.org/10.1097/ALN.0000000000003831.
146. Fuchs-Buder T, Romero CS, Lewald H, et al. Peri-operative management of neuromuscular blockade: a guideline from the European Society of Anaesthesiology and Intensive Care. *Eur J Anaesthesiol* 2023; **40**: 82–94. https://doi.org/10.1097/EJA.0000000000001769.
147. Cammu G, Schepens T, De Neve N, Wildemeersch D, Foubert L, Jorens PG. Diaphragmatic and intercostal electromyographic activity during neostigmine, sugammadex and neostigmine-sugammadex-enhanced recovery after neuromuscular blockade: a randomised controlled volunteer study. *Eur J Anaesthesiol* 2017; **34**: 8–15. https://doi.org/10.1097/EJA.0000000000000543.
148. Carvalho H, Verdonck M, Cools W, Geerts L, Forget P, Poelaert J. Forty years of neuromuscular monitoring and postoperative residual curarisation: a meta-analysis and evaluation of confidence in network meta-analysis. *Br J Anaesth* 2020; **125**: 466–82. https://doi.org/10.1016/j.bja.2020.05.063.
149. Fuchs A, Disma N, Engelhardt T, et al. Ventilation strategies and risk factors for intraoperative respiratory critical events and postoperative pulmonary complications in neonates and small infants: a secondary analysis of the nectarine cohort*. *Br J Anaesth* 2025; **135**: 1528–36. https://doi.org/10.1016/j.bja.2024.12.038.
150. Donati F. Residual paralysis: a real problem or did we invent a new disease? *Can J Anaesth* 2013; **60**: 714–29. https://doi.org/10.1007/s12630-013-9932-8.
151. Raval AD, Anupindi VR, Ferrufino CP, Arper DL, Bash LD, Brull SJ. Epidemiology and outcomes of residual neuromuscular blockade: a systematic review of observational studies. *J Clin Anesth* 2020; **66**: 109962. https://doi.org/10.1016/j.jclinane.2020.109962.
152. Ravindranath S, Backfish-White K, Wolfe J, Ranganath YS. Sugammadex for neuromuscular blockade reversal: a narrative review. *J Clin Med* 2025; **14**: 4128. https://doi.org/10.3390/jcm14124128.
153. Dubovoy TZ, Saager L, Shah NJ, et al. Utilization patterns of perioperative neuromuscular blockade reversal in the United States: a retrospective observational study from the multicenter perioperative outcomes group. *Anesth Analg* 2020; **131**: 1510–9. https://doi.org/10.1213/ANE.0000000000005080.
154. Hristovska AM, Duch P, Allingstrup M, Afshari A. Efficacy and safety of sugammadex versus neostigmine in reversing neuromuscular blockade in adults. *Cochrane Database Syst Rev* 2017; **8**: CD012763. https://doi.org/10.1002/14651858.CD012763.
155. Miyazaki Y, Sunaga H, Kida K, Hobo S, Inoue N, Muto M, Uezono S. Incidence of anaphylaxis associated with sugammadex. *Anesth Analg* 2018; **126**: 1505–8. https://doi.org/10.1213/ANE.0000000000002562.
156. Savic L, Savic S, Hopkins PM. Anaphylaxis to sugammadex: should we be concerned by the Japanese experience? *Br J Anaesth* 2020; **124**: 370–2. https://doi.org/10.1016/j.bja.2020.01.003.
157. Zecic F, Smart MH, Abbey TC, Pazhempallil A, Korban C. Sugammadex-induced anaphylactic reaction: a systematic review. *J Anaesthesiol Clin Pharmacol* 2022; **38**: 360–70. https://doi.org/10.4103/joacp.JOACP_573_20.
158. Seed MJ, Ewan PW. Anaphylaxis caused by neostigmine. *Anaesthesia* 2000; **55**: 574–5. https://doi.org/10.1046/j.1365-2044.2000.01125.x.
159. Orihara M, Takazawa T, Horiuchi T, et al. Comparison of incidence of anaphylaxis between sugammadex and neostigmine: a retrospective multicentre observational study. *Br J Anaesth* 2020; **124**: 154–63. https://doi.org/10.1016/j.bja.2019.10.016.
160. de Boer HD, Hunter JM. Sugammadex or neostigmine: should potential anaphylaxis be the overriding factor in the choice of a reversal drug? Comment on Br J Anaesth 2020; 124: 154-63. *Br J Anaesth* 2020; **125**: e220–1. https://doi.org/10.1016/j.bja.2020.03.017.
161. Tsai YF, Hung KC, Hsu CY, Lin HT, Lai YC, Wu SC. Sugammadex vs. neostigmine and the risk of postoperative pulmonary complications after upper gastrointestinal endoscopic procedures: a propensity score matched analysis of 15,730 patients. *Anaesthesia* 2026. https://doi.org/10.1111/anae.70263.
162. Hagberg CA, Asai T, Heidegger T, Myatra SN, Pandit JJ, Jiang Y. Era of sugammadex: a paradigm shift in airway management. *Anesthesiology* 2026; **144**: 978–97. https://doi.org/10.1097/ALN.0000000000005828.
163. Easdown LJ, Tessler MJ, Minuk J. Upper airway involvement in parkinson's disease resulting in postoperative respiratory failure. *Can J Anaesth* 1995; **42**: 344–7. https://doi.org/10.1007/BF03010713.
164. Liu EH, Choy J, Dhara SS. Persistent perioperative laryngospasm in a patient with Parkinson's disease. *Can J Anaesth* 1998; **45**: 495. https://doi.org/10.1007/BF03012589.
165. Fitzpatrick AJ. Upper airway obstruction in Parkinson's disease. *Anaesth Intensive Care* 1995; **23**: 367–9. https://doi.org/10.1177/0310057X9502300320.
166. Daley MD, Norman PH, Coveler LA. Tracheal extubation of adult surgical patients while deeply anesthetized: a survey of United States anesthesiologists. *J Clin Anesth* 1999; **11**: 445–52. https://doi.org/10.1016/s0952-8180(99)00043-4.
167. Juang J, Cordoba M, Ciaramella A, Xiao M, Goldfarb J, Bayter JE, Macias AA. Incidence of airway complications associated with deep extubation in adults. *BMC Anesthesiol* 2020; **20**: 274. https://doi.org/10.1186/s12871-020-01191-8.
168. Kim MK, Baek CW, Kang H, et al. Comparison of emergence after deep extubation using desflurane or desflurane with remifentanil in patients undergoing general anesthesia: a randomized trial. *J Clin Anesth* 2016; **28**: 19–25. https://doi.org/10.1016/j.jclinane.2015.08.013.
169. Egbuta C, Evans F. Extubation of children in the operating theatre. *BJA Educ* 2022; **22**: 75–81. https://doi.org/10.1016/j.bjae.2021.10.003.
170. Leone M, Einav S, Chiumello D, et al. Noninvasive respiratory support in the hypoxaemic peri-operative/periprocedural patient: a joint esa/esicm guideline. *Eur J Anaesthesiol* 2020; **37**: 265–79. https://doi.org/10.1097/EJA.0000000000001166.
171. Renda T, Corrado A, Iskandar G, Pelaia G, Abdalla K, Navalesi P. High-flow nasal oxygen therapy in intensive care and anaesthesia. *Br J Anaesth* 2018; **120**: 18–27. https://doi.org/10.1016/j.bja.2017.11.010.
172. Ishihara A, Okada H, Mori T, et al. Effectiveness of early high-flow nasal oxygen therapy after extubation of patients in the intensive care unit. *J Crit Care* 2024; **83**: 154840. https://doi.org/10.1016/j.jcrc.2024.154840.
173. Thille AW, Chamblet L, Ragot S, et al. Prophylactic noninvasive ventilation after extubation in high-risk patients without hypercapnia. *Intensive Care Med* 2026; **52**: 1012–22. https://doi.org/10.1007/s00134-026-08396-4.

174. Litton E, Parke RL, McGuinness SP, et al. High-flow nasal oxygen therapy after cardiac surgery: a randomized clinical trial. *JAMA Netw Open* 2026; **9**: e265447. https://doi.org/10.1001/jamanetworkopen.2026.5447.
175. Cameron M, Corner A, Diba A, Hankins M. Development of a tracheostomy scoring system to guide airway management after major head and neck surgery. *Int J Oral Maxillofac Surg* 2009; **38**: 846–9. https://doi.org/10.1016/j.ijom.2009.03.713.
176. Myatra SN, Gupta S, D'Cruz AK, Rajanala V, Dhar H, Sharma S, Divatia JV. Identification of patients for a delayed extubation strategy versus elective tracheostomy for postoperative airway management in major oral cancer surgery: a prospective observational study in seven hundred and twenty patients. *Oral Oncol* 2021; **121**: 105502. https://doi.org/10.1016/j.oraloncology.2021.105502.
177. Chrimes N, Higgs A, Rehak A. Lost in transition: the challenges of getting airway clinicians to move from the upper airway to the neck during an airway crisis. *Br J Anaesth* 2020; **125**: e38–46. https://doi.org/10.1016/j.bja.2020.04.052.
178. Chrimes N. The Vortex: a universal `high-acuity implementation tool´ for emergency airway management. *Br J Anaesth* 2016; **117**(Suppl 1): i20–7. https://doi.org/10.1093/bja/aew175.
179. Higgs A, Mosier JM. Airway management in intensive care medicine. In: Hagberg CA, Artime CA, Aziz MF, eds. *Hagberg and Benumof's airway management*. Philadelphia, USA: Elsevier, 2023; 759–86.
180. Kuo PJ, Lin PC, Hsieh CH. Airway management following head and neck microvascular reconstruction: when is a tracheostomy necessary? *Risk Manag Healthc Policy* 2025; **18**: 2551–63. https://doi.org/10.2147/RMHP.S538063.
181. Finke SR, Schroeder DC, Ecker H, Bottiger BW, Herff H, Wetsch WA. Comparing suction rates of novel ducanto catheter against yankauer and standard suction catheter using liquids of different viscosity-a technical simulation. *BMC Anesthesiol* 2022; **22**: 285. https://doi.org/10.1186/s12871-022-01830-2.
182. Collins J, O'Sullivan EP. Rapid sequence induction and intubation. *BJA Educ* 2022; **22**: 484–90. https://doi.org/10.1016/j.bjae.2022.09.001.
183. Qiu J, Xie M, Chen J, et al. Tracheal extubation under deep anesthesia using transnasal humidified rapid insufflation ventilatory exchange vs. awake extubation: an open-labeled randomized controlled trial. *Front Med (Lausanne)* 2022; **9**: 810366. https://doi.org/10.3389/fmed.2022.810366.
184. Vitale L, Rodriguez B, Baetzel A, Christensen R, Haydar B. Complications associated with removal of airway devices under deep anesthesia in children: an analysis of the wake up safe database. *BMC Anesthesiol* 2022; **22**: 223. https://doi.org/10.1186/s12871-022-01767-6.
185. Veyckemans F. Tracheal extubation in children: planning, technique, and complications. *Paediatr Anaesth* 2020; **30**: 331–8. https://doi.org/10.1111/pan.13774.
186. Sorbello M, Cortese G, Gaconnet C, Skinner M. A modified Bailey's manoeuvre for supraglottic airway continuum using LMA protector. *Indian J Anaesth* 2019; **63**: 78–80. https://doi.org/10.4103/ija.IJA_502_18.
187. Nair I, Bailey PM. Use of the laryngeal mask for airway maintenance following tracheal extubation. *Anaesthesia* 1995; **50**: 174–5. https://doi.org/10.1111/j.1365-2044.1995.tb15104.x.
188. Asai T. Use of the laryngeal mask after tracheal extubation. *Can J Anaesth* 1999; **46**: 997–8. https://doi.org/10.1007/BF03013141.
189. Wei CF, Chung YT. Laryngeal mask airway facilitates a safe and smooth emergence from anesthesia in patients undergoing craniotomy: a prospective randomized controlled study. *BMC Anesthesiol* 2023; **23**: 29. https://doi.org/10.1186/s12871-023-01972-x.
190. Gulhas N, Durmus M, Demirbilek S, Togal T, Ozturk E, Ersoy MO. The use of magnesium to prevent laryngospasm after tonsillectomy and adenoidectomy: a preliminary study. *Paediatr Anaesth* 2003; **13**: 43–7. https://doi.org/10.1046/j.1460-9592.2003.00927.x.
191. Zalunardo MP, Zollinger A, Spahn DR, Seifert B, Pasch T. Preoperative clonidine attenuates stress response during emergence from anesthesia. *J Clin Anesth* 2000; **12**: 343–9. https://doi.org/10.1016/s0952-8180(00)00167-7.
192. Prajwal Patel HS, Shashank MR, Shivaramu BT. Attenuation of hemodynamic response to tracheal extubation: a comparative study between esmolol and labetalol. *Anesth Essays Res* 2018; **12**: 180–5. https://doi.org/10.4103/aer.AER_130_17.
193. Shetabi H, Nazemroaya B, Mahjobipoor H, Majidi S. Comparative study of the effect of two different doses of intravenous labetalol on the cardiovascular response to endotracheal extubation. *J Cardiovasc Thorac Res* 2023; **15**: 98–105. https://doi.org/10.34172/jcvtr.2023.31623.
194. Shetabi H, Karimian S. Efficacy of two doses of dexmedetomidine on attenuating cardiovascular response and safety of respiratory tract to extubation. *J Cardiovasc Thorac Res* 2023; **15**: 73–9. https://doi.org/10.34172/jcvtr.2023.31647.
195. Alkaya MA, Saracoglu KT, Pehlivan G, Eti Z, Gogus FY. Effects of esmolol on the prevention of haemodynamic responses to tracheal extubation after craniotomy operations. *Turk J Anaesthesiol Reanim* 2014; **42**: 86–90. https://doi.org/10.5152/TJAR.2013.57.
196. Mendon AF, Barreto Filho JH, Hungria M, Magalh Es TC. Efficacy of a single dose of esmolol to prevent extubation-related complications during emergence from anesthesia: a randomized, double-blind, placebo-controlled trial. *Braz J Anesthesiol* 2023; **73**: 426–33. https://doi.org/10.1016/j.bjane.2021.08.012.
197. Zhao G, Yin X, Li Y, Shao J. Continuous postoperative infusion of remifentanil inhibits the stress responses to tracheal extubation of patients under general anesthesia. *J Pain Res* 2017; **10**: 933–9. https://doi.org/10.2147/JPR.S123423.
198. Nho JS, Lee SY, Kang JM, et al. Effects of maintaining a remifentanil infusion on the recovery profiles during emergence from anaesthesia and tracheal extubation. *Br J Anaesth* 2009; **103**: 817–21. https://doi.org/10.1093/bja/aep307.
199. Chen ZX, Shi Z, Wang B, Zhang Y. Intracuff alkalinized lidocaine to prevent postoperative airway complications: a meta-analysis. *World J Clin Cases* 2021; **9**: 10626–37. https://doi.org/10.12998/wjcc.v9.i34.10626.
200. Estebe JP, Gentili M, Le Corre P, Dollo G, Chevanne F, Ecoffey C. Alkalinization of intracuff lidocaine: efficacy and safety. *Anesth Analg* 2005; **101**: 1536–41. https://doi.org/10.1213/01.ANE.0000180995.24211.89.
201. Staffel JG, Weissler MC, Tyler EP, Drake AF. The prevention of postoperative stridor and laryngospasm with topical lidocaine. *Arch Otolaryngol Head Neck Surg* 1991; **117**: 1123–8. https://doi.org/10.1001/archotol.1991.01870220071012.
202. Nath P, Williams S, Herrera Mendez LF, Massicotte N, Girard F, Ruel M. Alkalinized lidocaine preloaded endotracheal tube cuffs reduce emergence cough after brief surgery: a prospective randomized trial. *Anesth Analg* 2018; **126**: 615–20. https://doi.org/10.1213/ANE.0000000000002647.
203. Souissi H, Frechette Y, Murza A, et al. Intracuff 160 mg alkalinized lidocaine reduces cough upon emergence from N_2O-free general anesthesia: a randomized controlled trial. *Can J Anaesth* 2016; **63**: 862–70. https://doi.org/10.1007/s12630-016-0652-8.

204. Gladston DV, Padmam S, Amma RO, et al. A randomized controlled trial to study the effect of intratracheal and intravenous lignocaine on airway and hemodynamic response during emergence and extubation following general anesthesia. *North Clin Istanb* 2022; **9**: 323–30. https://doi.org/10.14744/nci.2021.33407.
205. Assefa B, Samuel H, Fentie F, Daniel T, Hika A, Aberra B, Alemu B. Effect of tracheal tube cuff inflation with alkalinized lidocaine versus air on hemodynamic responses during extubation and post-operative airway morbidities in children: prospective observational cohort study, Ethiopia. *BMC Anesthesiol* 2022; **22**: 337. https://doi.org/10.1186/s12871-022-01868-2.
206. Luthra A, Prabhakar H, Rath GP. Alleviating stress response to tracheal extubation in neurosurgical patients: a comparative study of two infusion doses of dexmedetomidine. *J Neurosci Rural Pract* 2017; **8**: S49–56. https://doi.org/10.4103/jnrp.jnrp_91_17.
207. Tung A, Fergusson NA, Ng N, Hu V, Dormuth C, Griesdale DEG. Medications to reduce emergence coughing after general anaesthesia with tracheal intubation: a systematic review and network meta-analysis. *Br J Anaesth* 2020; **124**: 480–95. https://doi.org/10.1016/j.bja.2019.12.041.
208. Alfred M, Barg-Walkow LH, Keebler JR, Chaparro A. Checking all the boxes: a checklist for when and how to use checklists effectively. *BMJ Qual Saf* 2024; **33**: 673–81. https://doi.org/10.1136/bmjqs-2023-016934.
209. Liaqat T, Amjad MA, Cherian SV. Difficult airway management in the intensive care unit: a narrative review of algorithms and strategies. *J Clin Med* 2025; **14**: 4930. https://doi.org/10.3390/jcm14144930.
210. Nejatian A, Forsberg IM, Thoro U, Sjoblom A, Kahlin J. Impact of checklist implementation on endotracheal intubation-related complications in critically ill adults - a retrospective before and after study. *Acta Anaesthesiol Scand* 2025; **69**: e70103. https://doi.org/10.1111/aas.70103.
211. Turkelson C, Keiser M, Sculli G, Capoccia D. Checklist design and implementation: critical considerations to improve patient safety for low-frequency, high-risk patient events. *BMJ Simul Technol Enhanc Learn* 2020; **6**: 148–57. https://doi.org/10.1136/bmjstel-2018-000353.
212. Law JA, Duggan LV, Asselin M, et al. Canadian airway focus group updated consensus-based recommendations for management of the difficult airway: part 2. Planning and implementing safe management of the patient with an anticipated difficult airway. *Can J Anaesth* 2021; **68**: 1405–36. https://doi.org/10.1007/s12630-021-02008-z.
213. Parotto M, Ellard L. Extubation following anesthesia. 2024. https://www.uptodate.com/contents/extubation-following-anesthesia (accessed 05/06/2026).
214. Mort TC. Continuous airway access for the difficult extubation: the efficacy of the airway exchange catheter. *Anesth Analg* 2007; **105**: 1357–62, table of contents. https://doi.org/10.1213/01.ane.0000282826.68646.a1.
215. Roten FM, Steffen R, Kleine-Brueggeney M, et al. Dislocation rates of postoperative airway exchange catheters - a prospective case series of 200 patients. *BMC Anesthesiol* 2019; **19**: 52. https://doi.org/10.1186/s12871-019-0723-9.
216. McLean S, Lanam CR, Benedict W, Kirkpatrick N, Kheterpal S, Ramachandran SK. Airway exchange failure and complications with the use of the cook airway exchange catheter®: a single center cohort study of 1177 patients. *Anesth Analg* 2013; **117**: 1325–7. https://doi.org/10.1213/ANE.0b013e3182a7cd3d.
217. Heidegger T. Extubation of the difficult airway – an important but neglected topic. *Anaesthesia* 2012; **67**: 213–5. https://doi.org/10.1111/j.1365-2044.2011.07043.x.
218. Loudermilk EP, Hartmannsgruber M, Stoltzfus DP, Langevin PB. A prospective study of the safety of tracheal extubation using a pediatric airway exchange catheter for patients with a known difficult airway. *Chest* 1997; **111**: 1660–5. https://doi.org/10.1378/chest.111.6.1660.
219. Stein ML, Bunten E, Butler CG, et al. Practice guidelines for difficult airway management: comment. *Anesthesiology* 2022; **137**: 514. https://doi.org/10.1097/ALN.0000000000004315.
220. Jagannathan N, Shivazad A, Kolan M. Tracheal extubation in children with difficult airways: a descriptive cohort analysis. *Paediatr Anaesth* 2016; **26**: 372–7. https://doi.org/10.1111/pan.12837.
221. Wise-Faberowski L, Nargozian C. Utility of airway exchange catheters in pediatric patients with a known difficult airway. *Pediatr Crit Care Med* 2005; **6**: 454–6. https://doi.org/10.1097/01.PCC.0000163739.82584.C6.
222. Benumof JL. Airway exchange catheters: simple concept, potentially great danger. *Anesthesiology* 1999; **91**: 342–4. https://doi.org/10.1097/00000542-199908000-00005.
223. Duggan LV, Law JA, Murphy MF. Brief review: supplementing oxygen through an airway exchange catheter: efficacy, complications, and recommendations. *Can J Anaesth* 2011; **58**: 560–8. https://doi.org/10.1007/s12630-011-9488-4.
224. Ruxton L. Determination of sherriff linda margaret ruxton in fatal accident inquiry into the death of gordon ewing. 2010. http://www.scotcourts.gov.uk/opinions/2010FAI15 (accessed 07/01/2023).
225. Popat M, Mitchell V, Dravid R, Patel A, Swampillai C, Higgs A. A reply. *Anaesthesia* 2012; **67**: 921–2. https://doi.org/10.1111/j.1365-2044.2012.07253.x.
226. deLima LG, Bishop MJ. Lung laceration after tracheal extubation over a plastic tube changer. *Anesth Analg* 1991; **73**: 350–1. https://doi.org/10.1213/00000539-199109000-00022.
227. Seitz PA, Gravenstein N. Endobronchial rupture from endotracheal reintubation with an endotracheal tube guide. *J Clin Anesth* 1989; **1**: 214–7. https://doi.org/10.1016/0952-8180(89)90044-5.
228. Baraka AS. Tension pneumothorax complicating jet ventilation via a cook airway exchange catheter. *Anesthesiology* 1999; **91**: 557–8. https://doi.org/10.1097/00000542-199908000-00031.
229. Benumof JL, Gaughan SD. Concerns regarding barotrauma during jet ventilation. *Anesthesiology* 1992; **76**: 1072–3. https://doi.org/10.1097/00000542-199206000-00053.
230. Heininger A, Krueger WA, Dieterich HJ, Konigsrainer I, Schroeder TH. Complications using a hollow fiber airway exchange catheter for tracheal tube exchange in critically ill patients. *Acta Anaesthesiol Scand* 2008; **52**: 1031. https://doi.org/10.1111/j.1399-6576.2008.01686.x.
231. Cooper RM. The use of an endotracheal ventilation catheter in the management of difficult extubations. *Can J Anaesth* 1996; **43**: 90–3. https://doi.org/10.1007/BF03015965.
232. Mort TC. Tracheal tube exchange: feasibility of continuous glottic viewing with advanced laryngoscopy assistance. *Anesth Analg* 2009; **108**: 1228–31. https://doi.org/10.1213/ane.0b013e3181990a82.
233. Fetterman D, Dubovoy A, Reay M. Unforeseen esophageal misplacement of airway exchange catheter leading to gastric perforation. *Anesthesiology* 2006; **104**: 1111–2. https://doi.org/10.1097/00000542-200605000-00041.
234. Bajwa SS, Kulshrestha A. Diagnosis, prevention and management of postoperative pulmonary edema. *Ann Med Health Sci Res* 2012; **2**: 180–5. https://doi.org/10.4103/2141-9248.105668.
235. Patton WC, Baker CL Jr. Prevalence of negative-pressure pulmonary edema at an orthopaedic hospital. *J South Orthop Assoc* 2000; **9**: 248–53.

236. Lemyze M, Mallat J. Understanding negative pressure pulmonary edema. *Intensive Care Med* 2014; **40**: 1140–3. https://doi.org/10.1007/s00134-014-3307-7.
237. Bhattacharya M, Kallet RH, Ware LB, Matthay MA. Negative-pressure pulmonary edema. *Chest* 2016; **150**: 927–33. https://doi.org/10.1016/j.chest.2016.03.043.
238. Deepika K, Kenaan CA, Barrocas AM, Fonseca JJ, Bikazi GB. Negative pressure pulmonary edema after acute upper airway obstruction. *J Clin Anesth* 1997; **9**: 403–8. https://doi.org/10.1016/s0952-8180(97)00070-6.
239. Ben-David Y, Bentur L, Gur M, et al. Pediatric negative pressure pulmonary edema: case series and review of the literature. *Pediatr Pulmonol* 2023; **58**: 3596–9. https://doi.org/10.1002/ppul.26700.
240. Pang WW, Chang DP, Lin CH, Huang MH. Negative pressure pulmonary oedema induced by direct suctioning of endotracheal tube adapter. *Can J Anaesth* 1998; **45**: 785–8. https://doi.org/10.1007/BF03012150.
241. Bhalotra AR, Thakur P. Suction, no suction or passive drainage for pulmonary oedema. *Turk J Anaesthesiol Reanim* 2018; **46**: 480–1. https://doi.org/10.5152/TJAR.2018.43179.
242. Wilkes AR. Heat and moisture exchangers and breathing system filters: their use in anaesthesia and intensive care. Part 2 - practical use, including problems, and their use with paediatric patients. *Anaesthesia* 2011; **66**: 40–51. https://doi.org/10.1111/j.1365-2044.2010.06564.x.
243. Larson CP Jr. Laryngospasm – the best treatment. *Anesthesiology* 1998; **89**: 1293–4. https://doi.org/10.1097/00000542-199811000-00056.
244. Alalami AA, Ayoub CM, Baraka AS. Laryngospasm: review of different prevention and treatment modalities. *Paediatr Anaesth* 2008; **18**: 281–8. https://doi.org/10.1111/j.1460-9592.2008.02448.x.
245. Higgs A, Littley N, Chrimes N. Bradycardia during hypoxaemic airway crises. Does atropine treat the patient or the anaesthetist? *Anaesthesia* 2019; **74**: 1482–3. https://doi.org/10.1111/anae.14823.
246. St Pierre M, Krischke F, Luetcke B, Schmidt J. The influence of different patient positions during rapid induction with severe regurgitation on the volume of aspirate and time to intubation: a prospective randomised manikin simulation study. *BMC Anesthesiol* 2019; **19**: 16. https://doi.org/10.1186/s12871-019-0686-x.
247. Takenaka I, Aoyama K, Iwagaki T. Combining head-neck position and head-down tilt to prevent pulmonary aspiration of gastric contents during induction of anaesthesia: a volunteer and manikin study. *Eur J Anaesthesiol* 2012; **29**: 380–5. https://doi.org/10.1097/EJA.0b013e328354a51a.
248. Sorbello M, Paterno DS, Zdravkovic I, La Via L. Pharmacological approach to rapid sequence induction/intubation: a contemporary perspective. *Curr Opin Anaesthesiol* 2025; **38**: 369–74. https://doi.org/10.1097/ACO.0000000000001528.
249. Olsson GL, Hallen B, Hambraeus-Jonzon K. Aspiration during anaesthesia: a computer-aided study of 185,358 anaesthetics. *Acta Anaesthesiol Scand* 1986; **30**: 84–92. https://doi.org/10.1111/j.1399-6576.1986.tb02373.x.
250. Warner MA, Warner ME, Weber JG. Clinical significance of pulmonary aspiration during the perioperative period. *Anesthesiology* 1993; **78**: 56–62. https://doi.org/10.1097/00000542-199301000-00010.
251. Chrimes N. The Vortex Approach to airway management - green zone. 2016. http://vortexapproach.org/greenzone/ (accessed 08/02/2026).

Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Class of recommendation and levels of evidence.

Appendix S2. Clinical practice implications.

Appendix S3. Instructions for using the extubation algorithm.

Appendix S4. Instructions for using the extubation checklist and awake extubation sequence.

Figure S1. Distance markings on airway exchange catheter and tracheal tube.

Figure S2. Four-point fixation of airway exchange catheter.

Figure S3. Airway exchange catheter user guide.

Figure S4. Spectrum of safety of airway conversion techniques.

Table S1. Potential complications of airway exchange catheters.