Update in
Anaesthesia

Extubation after Anaesthesia: A Systematic Review

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Summary

Almost all tracheal intubations are performed with the expectation of subsequent extubation. However there is a relative lack of guidance and research regarding this key aspect of anaesthetic care. Respiratory complications around extubation arise in 12% of elective cases, compared to 4.6% in the same patient group at induction.[1] If coughing is discounted as a complication, the incidence was still higher for the extubation period. The American Society of Anesthesiologists closed claims project shows that, in the management of the patient with a difficult airway, 12% of claims relate to extubation events.[2] We present a systematic review of the available evidence for management of extubation.

METHODOLOGY

The electronic database PubMed was searched up to June 2009. The search contained the following MeSH headings: extubation, cough, laryngospasm, post-operative residual paralysis and was limited to human studies in core clinical journals. All titles and abstracts were reviewed and papers focusing on all aspects of extubation relating to anaesthesia were chosen. Those concerned with extubation in intensive care were not included. Randomised controlled trials, cohort studies, case control studies, cross-sectional studies, case series and expert opinion were selected for analysis. Studies were then assessed using the method described by the Scottish Intercollegiate Guidelines Network (Table 1). Initially studies were assigned a level, dependent on their place in a hierarchy of study types. Next a quality rating was assigned to each study design with particular attention to the risk of bias within the methods used. A grade of recommendation was then made on the strength of evidence available.

Table 1. *Scottish Intercollegiate Guidelines Network grading for recommendations in evidence based guidelines. RCT – randomised controlled trial*

Levels of evidence	
1^{++}	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias.
1^{+}	Well conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias.
1^{-}	Meta-analyses, systematic reviews or RCTs, or RCTs with a high risk of bias.
2^{++}	High quality systematic reviews of case-control or cohort studies or high quality case control or cohort studies with a very low risk of confounding bias or chance, and a high probability that the relationship is causal.
2^{+}	Well conducted case-control or cohort studies with a low risk of confounding bias or chance, and a moderate probability that the relationship is causal.
2^{-}	Case-control or cohort studies with a high risk of confounding, bias, or chance and a significant risk that the relationship is not causal.
3	Non-analytic studies, e.g. case reports, case series.
4	Expert opinion.
Grade of recommendations	
A	At least one meta-analysis, systematic review, or RCT rated as 1^{++} and directly applicable to the target population or a systematic review of RCTs or a body of evidence consisting principally of studies rated as 1^{+} directly applicable to the target population and demonstrating overall consistency of results.
B	A body of evidence including studies rated as 2^{++} directly applicable to the target population and demonstrating overall consistency of results or extrapolated evidence from studies rated as 1^{++} or 1^{+}.
C	A body of evidence including studies rated as 2^{+} directly applicable to the target population and demonstrating overall consistency of results or extrapolated evidence from studies rated as 2^{++}.
D	Evidence level 3 or 4 or extrapolated evidence from studies rated as 2^{+}

RESULTS

The search produced a total of 6267 citations in PubMed. In addition papers were included from a process called snowballing (using cited references from original bibliographies to extend the search). In total, 46 studies were included in the systematic review.

Paralysis and reversal

Inadequate reversal of paralysis results in a greater likelihood of airway obstruction. Importantly inadequate reversal may still be present when there is adequate spontaneous ventilation.[3] Peripheral nerve stimulators (PNS) can be used to ensure adequate reversal, with the train-of four (TOF) ratio being the most widely used measure (see article in this edition of *Update*). The ratio that is judged adequate has increased with progressive evidence and some authors believe it may be as high as 0.9.[4] This can either be assessed subjectively (using visual or tactile assessment by the clinician), or objectively using an accelerometer. A review of over seven thousand elective adult patients found 51 significant respiratory events in the recovery ward. When 41 of these were matched with controls it was found that the incidence of TOF ratios of less than 0.7 was 73% in the patients with a respiratory

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event, whereas in the matched control group there was none with a TOF less than 0.9.[5]

A recent study of 185 patients showed that of ninety patients assessed using visual assessment of PNS to be adequately reversed, 10 required some airway support and 19 had arterial desaturation to below 90%. Twelve of these patients had an objective TOF ratio less than 0.7 on arrival in the recovery ward. In contrast where an accelerometer was used neither of these complications occurred and the lowest TOF value was 0.84.[6]

Recommendation: Paralysis and reversal

Use of a peripheral nerve stimulator reduces the incidence of postoperative respiratory and airway complications. *(Grade B)*

Position for extubation

Traditional anaesthetic doctrine is for patients to be extubated in the left lateral, head-down position, to reduce the risk of aspiration. Mehta studied six techniques of extubation in a population of 90 general surgical patients to assess prevention of aspiration of 20ml contrast medium, instilled into the hypopharynx.[7] He found that 10 degree head-down tilt in left lateral position, with gentle suction via a catheter placed through the endotracheal tube, prevented any trace of contrast passing below the cords. Importantly the same study demonstrated that in 10/30 patients there was evidence of contamination of the lungs despite attempts being made to empty the mouth and pharynx by suction.

However, it has been suggested in an editorial and supported by a survey of UK consultant anaesthetists that this practice is becoming less prevalent.[8] The change in practice may be related to the increased prevalence of obesity and chronic smoking related lung disease with more patients extubated in the sitting position. Another explanation is that the increase in use of the Laryngeal Mask Airway (LMA), that is usually removed with the patient supine, has made removal of airway devices in the supine position seem to be more acceptable practice. There is no trial evidence to confirm that supine extubation is more or less safe than other techniques. Following emergency surgery, extubation in the left lateral position is still the most favoured position.

Recommendation: Position for extubation

Extubation in the left lateral, head-down position is the position least likely to be associated with aspiration and therefore is the position that should be used in unstarved patients undergoing emergency surgery. *(Grade B)*

For elective patients, particularly those who are obese or have pre-existing respiratory compromise, the sitting position may be considered. *(Grade D)*

Pre-oxygenation prior to extubation

There is some evidence to suggest that a mixture of oxygen and nitrogen may have benefit in avoiding absorption atelectasis. However pre-oxygenation with 100% oxygen prior to extubation is recommended to improve the margin of safety, given the potential for unpredictable airway problems.[9]

Recommendation: Pre-oxygenation prior to extubation

Prior to extubation patients should be administered 100% oxygen. *(Grade D)*

Conscious level

The risk of laryngospam is thought to be higher if the airway is stimulated during Guedel's excitatory plane of anaesthesia. Therefore extubation should either be performed with the patient in a deep plane of anaesthesia or fully awake. A survey of anaesthetists in the United States listed reactive airways disease and reduction in coughing and straining as reasons to favour deep extubation.[10] Despite work demonstrating the ability of volatile anaesthetics to obtund airway reactivity, there is no clinical trial evidence to support this practice. The potential risks of deep extubation include airway obstruction and aspiration of gastric contents.

A randomised controlled trial in paediatric ENT and strabismus surgery found no difference in the incidence of laryngospasm, coughing, sore throat, croup and arrhythmias in those extubated deep or awake.[11] It appears that the technique used should primarily be dictated by the preference of the anaesthetist. A further small study in 1 to 4-year-olds found a higher incidence of coughing and desaturation below 90% with deep (defined as a volatile concentration of more than 2 MAC) compared to awake extubation from isoflurane anaesthesia.[12] This has not been studied in adults. Another suggested approach is that of a 'no touch' technique, where, after suctioning blood and saliva from the pharynx following tonsillectomy, the patient was turned on their side and no further stimulation was permitted until the patient woke spontaneously.[13] This case series of 20 showed a zero incidence of laryngospasm.

Recommendation: Conscious level

Following paediatric surgery, the incidence of post-extubation cough and laryngospasm are similar using deep or awake extubation. *(Grade C)*

In adults, to reduce the incidence of post-extubation cough, deep extubation may be considered. *(Grade D)*

Phase of respiration

Laryngospasm is believed to be less likely during inspiration, since the firing threshold of neurones supplying the adductors of the vocal cords is increased during inspiration.[14] Therefore some recommend extubation at the end of inspiration, with an accompanying positive pressure breath delivered as the cuff is deflated. This technique also

elicits a cough which assists with clearing of secretions from the airway. A further finding of this study was that a higher arterial partial pressure of CO_2 correlated with less cord reactivity. There are no clinical studies investigating this phenomenon in relation to extubation.

Recommendation: Phase of respiration

Extubation should be performed at the end of inspiration. *(Grade D)*

Laryngospasm

This is a relatively common complication in the post-extubation period. The reflex is mediated by the vagus nerves, with the afferent loop conducted via the superior laryngeal nerve to the cricothyroid muscle, causing prolonged adduction of the vocal cords.[15] Patients in an excitatory plane of anaesthesia are particularly at risk, although this phase is often more transient with the rapid onset and offset of today's inhalational and intravenous anaesthetic agents. Glottic stimulation is the most common precipitant, but it can be mediated by other stimuli such as movement and surgical stimulation.

Intravenous (IV) lidocaine 2mg.kg^{-1}, given at induction, dampens laryngeal and pharyngeal reflexes.[16] This is only effective if the injection is given within about 60 to 90 seconds of extubation.[9] This effect is thought to be mediated centrally and there may be a role in treatment of laryngospasm.

Visvanathan et al have designed an algorithm to guide treatment of patients who develop laryngospasm (Figure 1). The authors suggest that 31 out of 189 incidences of laryngospasm reported to the Australian Incident Monitoring Study (AIMS) would have been detected and managed more quickly using this guideline.[17]

As well as intravenous anaesthetic agents and suxamethonium (as described in Figure 1), doxapram 1.5mg.kg^{-1} has been used successfully in the management of laryngospasm.[18] A manual technique, Larson's manoeuvre, has been described in conjunction with jaw thrust. Firm pressure is applied in the space between the ascending ramus of the mandible and the mastoid process - the 'laryngospasm notch'[19] (Figure 2). The mechanism of this technique is unclear.

Recommendation: Laryngospasm

The administration of lidocaine immediately prior to extubation reduced the incidence of post-extubation laryngospasm (however in the authors' experience this not common clinical practice). *(Grade B)*

Adjuncts to the airway – the laryngeal mask

Replacing the endotracheal tube (ETT) with an intermediate airway (such as an LMA) prior to emergence from anaesthesia is safe and effectively reduces coughing, bucking, post anaesthesia sore throat and the cardiovascular response.[20,21,22] This skill is technically unchallenging and superior to use of an oropharyngeal airway.[23,24]

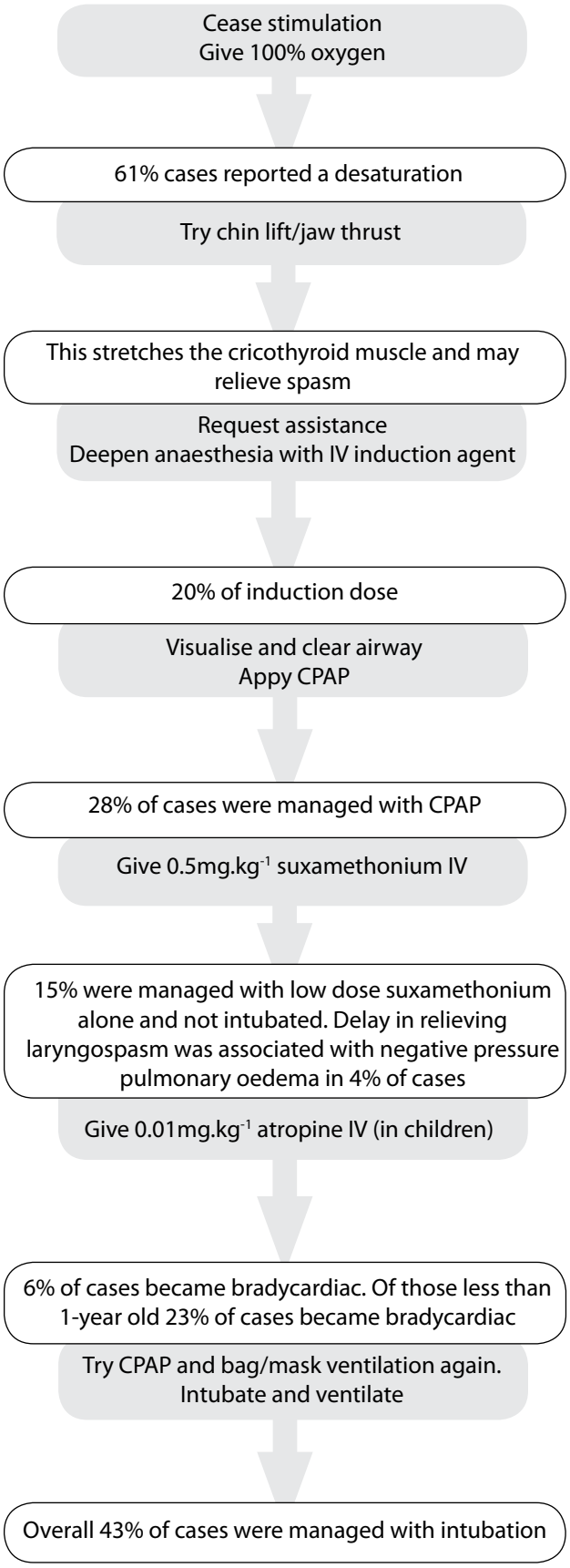

Figure 1. *Algorithm as proposed by Visvanathan et al for management of laryngospasm*[17]

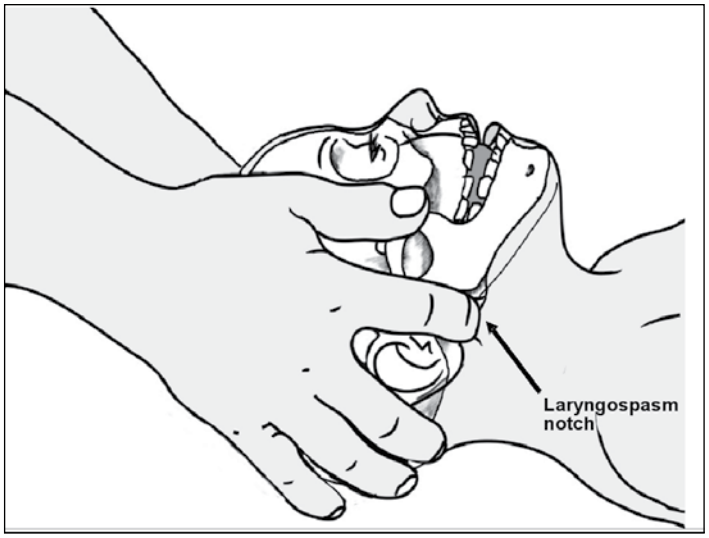

Figure 2. *Larson's manoeuvre involves firm bilateral, medial and cephalad pressure with either the index or middle finger in the 'laryngospasm notch'*

Recommendation: Adjuncts to the airway – the laryngeal mask

Following elective surgery replacing an endotracheal tube with an LMA will reduce the incidence of post-extubation airway adverse sequelae and obtund the cardiovascular response. *(Grade B)*

Pharmacological intervention: cough suppression and haemodynamic stabilisation

Cough is a common response during emergence from anaesthesia and may be considered a normal airway protective mechanism. In some situations this response may be detrimental, for example in neurosurgery or eye surgery. There is also a significant haemodynamic response to extubation which is of relevance for patients who may not tolerate extremes of cardiovascular response (eg. ischaemic heart disease, heart failure).[25]

β-agonists

Beta adrenergic agonists (e.g. albuterol) do not reduce the incidence of coughing at extubation.[26]

Lidocaine

The effects of intravenous, topical (larygotracheal topicalisation or instilled down the ETT) and intra-cuff lidocaine on cough and haemodynamic responsiveness have been studied.

Early studies showed that lidocaine topical spray (five minutes before and during extubation) and lidocaine 1mg.kg^{-1} IV (two minutes prior to extubation) reduce coughing and the haemodynamic response to extubation.[27,28] However more recent studies have shown that coughing and haemodynamic responsiveness are reduced when lidocaine is instilled topically down the ETT five minutes prior to extubation, but not when it was given intravenously.[29] Lidocaine applied topically prior to intubation has also been shown to be more effective when compared with the same dose intravenously.[30] The extubation benefits of topical lidocaine, administered prior to intubation, are seen in procedures of less than two hours duration.[31] In addition the serum concentration of lidocaine required to suppress the cough reflex has been recorded as >3mcg.ml^{-1} whilst cough suppression has been achieved at recorded levels <1.63mcg.ml^{-1} when the lidocaine is applied topically.[32,33]

Lidocaine instilled into the ETT cuff reduces the incidence of cough but has no effects on haemodynamic responsiveness.[34] These effects are also seen with alkalinised intra-cuff lidocaine; the ETT cuff was inflated with 2ml 2% lidocaine in 1.4% or 8.4% sodium bicarbonate, which may improve the diffusion of lidocaine across the cuff membrane. The incidence of post-extubation sore throat and cough were reduced.[35]

Opioids

Opioids have been shown to be effective in reducing the airway and circulatory reflexes at extubation. Low dose remifentanil reduced coughing and haemodynamic responsiveness to extubation in a trial of 60 elective adult ENT patients, with an incidence of coughing of 40% compared to 80% when a low dose infusion (0.014mcg.kg^{-1}.min^{-1}) was administered throughout the extubation period.[36] Alfentanil, 15mcg.kg^{-1} prior to extubation, has also been shown to be effective in a study of 34 elective adult oral surgical patients, with some attenuation of the haemodynamic response.[37] In both studies there was no significant delay in emergence. In a recent small randomised control trial, an anaesthetic using propofol-remifentanil was compared with one using sevoflurane-remifentanil. The total intravenous anaesthetic was associated with a statistically significant lower incidence of cough compared with the volatile-based anaesthetic at extubation, with a cough incidence of only 6%.[38]

Calcium antagonists

Verapamil 0.1mg.kg^{-1} alone and in combination with 1mg.kg^{-1} intravenous lidocaine was studied in 100 healthy patients undergoing elective minor surgery. As a sole agent, verapamil was more effective than placebo and intravenous lidocaine in blunting the haemodynamic response to extubation. The combination of verapamil and lidocaine had the greatest effects.[39] Verapamil 0.1mg.kg^{-1} has been shown to be more effective than diltiazem 0.2mg.kg^{-1}.[40]

β-blockers

Esmolol or labetolol were equally effective in controlling the systolic blood pressure at emergence following intra-cranial surgery and in the recovery room.[41] The effects of beta-blockade on the haemodynamic response to extubation appears to be greater than with short acting opiates.[42]

Recommendation: Cough suppression and cardiovascular response to extubation

Topical lidocaine can be used to reduce cough and the cardiovascular response to extubation where the benefits outweigh the risk of impaired airway protective reflexes. When administered at intubation, the effects last for two hours. Intravenous and intra-cuff alkalinised lidocaine are alternatives but may be less effective. *(Grade B)*

The difficult airway

The algorithms for difficult airway management recommended by the Difficult Airway Society (UK) do not mention extubation. The updated ASA (US) guidelines published in 2003 provide some guidance.[43] They advise that the anaesthetist consider the relative merits of awake versus deep extubation, as well as an evaluation for factors that impact adversely on ventilation and therefore mitigate against immediate extubation. They also recommend formation of a 'plan B' in the event of failed extubation, due to airway obstruction or respiratory failure, suggesting use of an airway exchange catheter (AEC, Figure 3). This is a long semi-rigid hollow tube that is used to facilitate the removal of an endotracheal tube whilst still maintaining access to the airway. Following extubation the AEC can be used as a conduit for the provision of oxygen via jet ventilation or oxygen insufflation. In the case of a failed extubation, an ETT can be 'rail-roaded' over the AEC, which acts as a bougie. Use of an AEC is straightforward and the procedure for use is described in Table 2. There are three main types available - the Sheridan TTX, Tracheal Tube Exchanger (Hudson Respiratory Care inc.), the Cook Exchange Catheter (Cook Medical) and the Endotracheal Ventilation Catheter (Cardiomed supplies inc.)

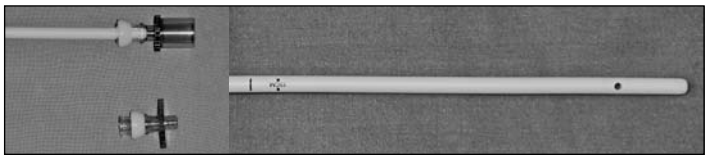

Figure 3. *A Cook Airway Exchange Catheter (Cook Medical) with the option of using either a 15mm adaptor or a Luer lock adaptor for use with jet ventilation*

Table 2. *Procedure for use of an airway exchange catheter*

- Patient sedated
- Administer 200mcg glycopyrolate to reduce oral secretions
- Administer 100% oxygen
- Suction ETT and pharynx
- Note length of ETT to nostril
- Deflate cuff
- Insert lubricated AEC to predetermined length - aim for 3cm above carina. In adults use a 14F AEC – this has an OD (outside diameter) of 4.7mm, which allows an ETT of ID (internal diameter) 5.5mm to be passed over it.
- Extubate patient
- Check position using capnography
- If applicable, oxygen can then be applied via the AEC
- AEC can be left in situ for several hours.

Benumof has written in support of the use of the AEC as part of a stepwise approach to extubation where the airway is difficult and failure of extubation is considered a possibility.[44] Airway exchange catheters tend to be used on intensive care patients and in this population they

Summary of recommendations (with grade)

1	Use of a peripheral nerve stimulator reduces the incidence of postoperative respiratory and airway complications.	**B**
2a	Extubation in the left lateral head down position is the position least likely to be associated with aspiration and therefore is the position that should be used in un-starved patients undergoing emergency surgery.	**B**
2b	For elective patients, particularly those who are obese or have pre-existing respiratory compromise the upright position may be considered.	**D**
3	Prior to extubation patients should be given 100% oxygen.	**D**
4a	Following paediatric surgery, to reduce the incidence of post extubation cough and laryngospasm, a technique of either extubation deep or awake can be considered.	**C**
4b	In adults, to reduce the incidence of post extubation cough, deep extubation can be considered.	**D**
5	Extubation should be performed at the end of the inspiration.	**D**
6	The administration of lidocaine immediately prior to to extubation will reduce the incidence of laryngospasm post-extubation.	**C**
7	Following elective surgery replacing an endotracheal tube with an LMA will reduce the incidence of post extubation airway adverse sequelae and cardiovascular response.	**B**
8a	Topical lidocaine can be used to reduce cough and the cardiovascular response to extubation where the risk of impaired airway protective reflexes is not outweighed by the benefits. IV and alakalinised intra-cuff lidocaine is an alternative but may be less effective.	**B**
8b	Where cough reduction is important consider small doses of short acting opiates and total intravenous anaesthesia.	**B**
8c	Where a cardiovascular response to extubation would be potentially detrimental a bolus dose of intravenous verapamil, esmolol or labetalol prior to extubation should be considered.	**B**
9	When the airway is considered difficult there should be consideration for a staged extubation using an Airway Exchange Catheter.	**B**

have been found to be well tolerated. Five out of 202 complained of a cough in one Canadian study - this was attributed to deep placement of the catheter.[45] In the same study AECs were shown to be effective with 20 out of 22 re-intubations being successful. In a second study there were 47 out of 51 successful re-intubations, with failures attributed to inadvertent displacement of the catheter (n=3) and significant laryngeal oedema.[46] Some potential risks of these devices include deep placement, trauma, high inflation pressures with jet ventilation and subsequent pneumothorax.

Recommendation: The difficult airway
When the airway is considered difficult consider a staged extubation using an airway exchange catheter. *(Grade B)*

SUMMARY

Despite a relative paucity of good quality evidence from large randomised trials, there are some areas where research data can be used to guide practice, improve safety and prevent undesirable complications related to extubation.

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