Difficult intubation and extubation in adult anaesthesia

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Anaesth Crit Care Pain Med 37 (2018) 639–651

Guidelines

Difficult intubation and extubation in adult anaesthesia☆

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ARTICLE INFO

Article history:
Received 16 February 2018
Received in revised form 14 March 2018
Accepted 20 March 2018
Available online 23 May 2018

Keywords:
Difficult airway management
Updated guidelines
Difficult tracheal intubation
Difficult tracheal extubation
Strategy
Algorithms

ABSTRACT

Objective: To provide an update to French guidelines about "Difficult intubation and extubation in adult anaesthesia 2006".
Design: A consensus committee of 13 experts was convened. A formal conflict-of-interest (COI) policy was developed at the onset of the process and enforced throughout. The entire guidelines process was conducted independent of any industry funding. The authors were advised to follow the principles of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system to guide assessment of quality of evidence. The potential drawbacks of making strong recommendations in the presence of low-quality evidence were emphasized. Few recommendations were ungraded.
Methods: The panel focused on 6 questions: 1) Why must oxygen desaturation be avoided during intubation and what preoxygenation and oxygenation techniques should be used to prevent it? 2) Should videolaryngoscopes be used instead of standard laryngoscopy with or without a long stylet to achieve a better success rate of intubation after the first attempt during anticipated difficult intubation off fiberoptic intubation? 3) Should TCI or target controlled inhalation anaesthesia (TCIA) be used instead of bolus sedation for airway control in the event of suspected or proven difficulty in a patient spontaneously breathing? 4) What mode of anaesthesia should be performed in patients with difficult intubation criteria and potentially difficult mask ventilation? 5) In surgical patients, what criteria predict difficulties encountered during postoperative tracheal extubation? 6) Should decision trees and algorithms be employed to direct decision-making for the management of difficult intubation, whether foreseen or not? (based on the information from the preceding five issues). Population, intervention, comparison, and outcomes (PICO) questions were reviewed and updated as needed, and evidence profiles were generated. The analysis of the literature and the recommendations were then conducted according to the GRADE® methodology.
Results: The SFAR Guideline panel provided 13 statements on difficult intubation and extubation in adult anaesthesia. After two rounds of discussion and various amendments, a strong agreement was reached

☆ Updated guidelines from the French National Society of Anaesthesia and Intensive Care Medicine (Société française d'anesthésie et de réanimation – SFAR).

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https://doi.org/10.1016/j.accpm.2018.03.013

for 99% of recommendations. Of these recommendations, five have a high level of evidence (Grade 1±), 8 have a low level of evidence (Grade 2±). No recommendation was provided for one question.
Conclusions: Substantial agreement exists among experts regarding many strong recommendations for the best care of patients with difficult intubation and extubation in adult anaesthesia.

1. Introduction

Tracheal intubation and extubation are routine and inseparable techniques in anaesthesia and intensive care. Despite being commonly applied, their importance must not be underappreciated. In some cases, tracheal intubation and/or extubation are challenging and still represent an important cause of morbidity and mortality in anaesthesiology. In 2006, the French Society of Anaesthesia and Intensive Care Medicine (Société française d'anesthésie et de réanimation – SFAR) hosted a conference of experts on "difficult intubation" (CE/DI: Annales françaises d'anesthésie et de réanimation 27 (2008) 1–62), largely detailing assessment and risk management related to difficult intubation and prevention of hypoxemia essentially per procedure. Since then, the development of new techniques and research, such as videolaryngoscopes for example, has paved the way for changes in practice, supporting this guidelines updating.

2. Objectives

The following formalised recommendations are the result of the work by the SFAR to update the CE/DI of 2006.

The main focuses of this update are:

- Pre-oxygenation and the need to remind robust practices adapted to new techniques such as trans nasal humidified high-flow oxygen or high-flow nasal oxygen (HFNO);
- The positioning of videolaryngoscopes in the management of an anticipated or unanticipated difficult tracheal intubation depending on the predictable difficulty of facial mask ventilation;
- Depth of anaesthesia and muscle relaxation to facilitate mask ventilation and tracheal intubation with oxygenation techniques backup;
- The management of a difficult intubation (planned or not planned) with algorithms considering:
  - Assessment of the difficulty of facial mask ventilation;
  - The management of planned difficult tracheal intubation without mask ventilation and positioning of video laryngoscopes;
  - Management of planned difficult tracheal intubation with difficult mask ventilation and recall of oxygenation techniques;
  - The management of an unanticipated difficult tracheal intubation with or without ventilation mask difficulty;
  - Risk stratification of tracheal extubation in order to create a comprehensive preventive strategy.

3. Methods

3.1. Literature review

Relevant literature was collected data from the PubMed and Cochrane, with results limited to the 10 years following the CE/DI 2006. For each selected question, if at least one meta-analysis was available, the literature search was carried out on subsequent publications.

3.2. Methodology for developing recommendations

First, the organising committee defined the specific issues to be analysed. Second, experts were designated to the relevant issues. The questions were formulated in the PICO (Patients Intervention Comparison Outcome) format. The analysis of the literature and the recommendations were then conducted according to the GRADE® methodology (Grade of Recommendation Assessment, Development and Evaluation). This method enables, after a quantitative analysis of the literature, to separately determine the quality of evidence, an estimate of the confidence that one can have in the analysis of the effect of the quantitative intervention and a level of recommendation. The quality of evidence was stratified into four categories:

- High: future research will most likely not change the confidence in the estimation of the effect;
- Moderate: future research will likely change the confidence in the estimation of the effect and could modify the estimate of the effect itself;
- Low: future research will most likely have an impact on the confidence in the estimation of the effect and will probably modify the estimate of the effect itself;
- Very low: the estimate of the effect is very uncertain.

The quality of the evidence was analysed for each study then a global level proof was defined for a given question and criterion. The final formulation of the recommendations will always be binary: either positive or negative, and either strong or weak.

Strong: we strongly recommend (GRADE 1+) or not (1−).

Weak: We probably recommend (GRADE 2+) or probably not (2−).

The strength of the recommendation is determined based on four key factors and validated by experts after a vote, using GRADE® Grid method:

- Estimation of the effect;
- The overall level of evidence: the higher it is, the more likely recommendation will be strong;
- The balance between desirable and undesirable effects: the more it is favourable, the more likely the recommendation will be strong;
- Values and preferences: in case of uncertainty or large variability, the recommendation will more likely be weak; these values and preferences should ideally be obtained directly from the persons concerned (patient, doctor, decision maker).

In order to issue a recommendation on a criterion, at least 50% of the experts had to broadly agree and less than 20% had to express a contrary opinion. For a recommendation to be strong, at least 70% of the participants had to broadly agree. In the absence of strong agreement, the recommendations were redrafted and, again, subject to listing with the aim of achieving a better consensus.

After summarising the work of the experts and applying the GRADE® method, thirteen recommendations have been formalised and algorithms produced. These provide guidance for the management of difficult tracheal intubation (whether or not it

is planned), whether there is a possibility of ventilation with difficult facial mask, as well as for tracheal extubation.

All of the recommendations were submitted to the expert group. After two rounds of discussion and various amendments, a strong agreement was reached for 99% of recommendations. Of these recommendations, five have a high level of evidence (Grade 1±), 8 have a low level of evidence (Grade 2±).

4. Questions and recommendations

4.1. Question 1. Why must oxygen desaturation be avoided during intubation and what pre-oxygenation and oxygenation techniques should be used to prevent it?

4.1.1. Rationale

Pre-oxygenation before performing a tracheal intubation (TI) or insertion of a supra-glottic device (SGD) helps increase patients' oxygen reserves to prevent or to postpone any arterial oxygen desaturation during apnoea. In healthy adults, the delay between the onset of apnoea and the occurrence of arterial oxygen desaturation ($SpO_2 \leq 90\%$) is limited to 1–2 minutes if the patient has breathed in ambient air before induction and can be extended to 6–8 min with pre-oxygenation in 100% inhaled oxygen [1]. The arterial oxygen desaturation (SpO_2) time is a better indicator of the oxygen reserves than PaO_2 and by its clinical relevance it represents the primary endpoint of pre-oxygenation studies. Pre-oxygenation performed before anaesthetic induction can delay the onset of desaturation during apnoea and while attempting intubation. The incidence of the occurrence of hypoxemia when performing anaesthetic induction is still a major cause of morbidity and anaesthetic mortality [2,3]. The fourth national audit (NAP4) in the UK revealed difficult or failed intubation represented 39% of incidents related to airway control [2]. Inability to adequately control of airways is frequently associated with arterial oxygen desaturation [4]. By increasing reserves in oxygen and prolonging the duration of tolerance to apnoea, pre-oxygenation can prevent hypoxemia during induction of anaesthesia with a higher PaO_2 [5]. In contrast, the absence of pre-oxygenation even in ASA I patients can lead to arterial oxygen desaturation ($SpO_2 < 90\%$) in 30 to 60% of cases [6].

R1.1 – We recommend preventing arterial oxygen desaturation during tracheal intubation or supra-glottic device insertion manoeuvres because of the risk of morbidity and mortality.
(Grade 1+) Strong Agreement

4.1.2. Rationale

The efficiency and/or the difficulty of pre-oxygenation depend on the technical conditions of pre-oxygenation with the facemask according to the absence or presence of leaks [7–9], and may also be related to the presence of risk factors for difficult mask ventilation [10]. In the event of a facial mask leak, $SpO_2 < 85\%$ was observed in ASA I or II patients [7,8]. It is accepted that when the end-tidal oxygen fraction (FeO_2) is greater than 90%, pre-oxygenation is considered effective. The reduction of the functional residual capacity (FRC) in the obese patient and pregnant women from the second trimester results in a reduction of the denitrogenation and pre-oxygenation times but, by decreasing the pulmonary volume of the oxygen stores, the delay of onset of arterial oxygen desaturation is shortened, thus exposing an increased risk of oxygen desaturation in relation to this decrease of the FRC itself related to weight gain [11–14]. During labour, the time to arterial oxygen desaturation ($SpO_2 < 90\%$) is significantly shorter than in women during pregnancy, with $SpO_2 < 90\%$ occurring on average at 98 seconds compared to 292 seconds respectively, largely due to the increased oxygen consumption during labour [15]. The FRC decreases from the second trimester. This decrease in FRC is aggravated by the supine position. The transition to a semi-sitting position with the head elevated at 30° allows a significant increase in FRC, with an estimated average gain of 188 mL, compared to the supine position [16]. However, despite possible increases in the FRC when pregnant women are positioned with their head raised to 30°, there is no evidence supporting an increase delay in arterial oxygen desaturation [14]. In obese patients, controlled trials have demonstrated the benefit of the sitting position [17] or having the head elevated at 25° [18] during pre-oxygenation compared with the supine position. The increased time to arterial oxygen desaturation ($SpO_2 < 90$–92%) is 30% on average, allowing a tolerance to apnoea beyond 3.5 minutes in proclive (head-raised) position compared to 2.5 minutes in the supine position [17,18]. Similarly, it has been shown that a proclive position of 20° significantly prolonged the delay in arterial oxygen desaturation ($SpO_2 < 95\%$) in patients who are neither pregnant nor obese. [19]. Thus, while pre-oxygenation in the proclive position is recommended in obese patients, the benefit of prolonging the time to arterial oxygen desaturation in pregnant women remains to be demonstrated, even if the increase in FRC with the proclive position appears to increase the effectiveness of the pre-oxygenation. Finally, even a moderate proclive position (20°) prolongs desaturation time in the general population.

Pre-oxygenation is based on several standard techniques. Two of the most important are:

- Spontaneous ventilation in pure oxygen for a time ranging from 2 to 5 minutes in a circuit filter with a fresh gas flow rate of 5 L/min;
- Spontaneous ventilation with manoeuvres of vital capacity, 4 to 8, made of pure oxygen for a short period of time, 30 and 60 seconds respectively. This last technique requires that the inspiratory flow of the circuit is equal to or greater than that of the patient, which can be facilitated by bypass valves [9,20].

Controlled primary studies on the topic show the superiority of spontaneous oxygen ventilation for 3 minutes and 8 vital capacity manoeuvres in 60 seconds compared to 4 vital capacity manoeuvres in 30 seconds [9,20–22]. The increase of the inspiratory flow of oxygen (up to 20 L/min) when manoeuvring the 4 vital capacity manoeuvres in 30 seconds does not improve the performance of this procedure [20,21]. In addition, vital capacity manoeuvres in pure oxygen require excellent patient cooperation since the outcome is improved if these vital capacity manoeuvres are initiated by forced expiration allowing a better pulmonary denitrogenation [9,23].

In an emergency context, it is essential to recall that in the description of rapid sequence induction (RSI), pre-oxygenation is one of the main constituent elements [24]. For obstetric emergencies, the manoeuvres of vital capacity do not represent a viable alternative as the spontaneous ventilation pre-oxygenation technique may be "shortened" at 2 minutes due to a decrease in FRC [13]. Similarly, the use of non-invasive ventilation (NIV) as an inspiratory aid with or without PEEP allows urgent shortening of the pre-oxygenation time with the goal of a $FeO_2 > 90\%$ [25].

Despite applying pre-oxygenation, only 20% of patients in vital distress requiring tracheal intubation demonstrate a significant response to this procedure with the use of a bag-valve mask ventilation [26]. Thus, in the hypoxemic patient requiring tracheal intubation, the use of non-invasive ventilation can prevent the occurrence of desaturation episodes during intubation [27]. In hypoxemic patients, data for high flow nasal oxygen is mostly

derived from a positive before/after study [28] and a randomised controlled trial that does not differentiate any pre-oxygenation benefit between high flow nasal oxygen and oxygen administration by conventional facial mask [29]. Non-invasive ventilation as a pre-oxygenation technique has also been demonstrated to provide some benefit in preventing the occurrence of oxygen desaturation during tracheal intubation in obese patients, when compared to conventional pre-oxygenation for 5 minutes [30].

R 1.2 – To definitively prevent arterial desaturation during tracheal intubation or insertion of a supra-glottal device, we recommend performing a pre-oxygenation procedure (3 min/8 deep inspirations), including for the management of emergencies.
(Grade 1+) Strong Agreement

4.1.3. Rationale

Combining apnoeic oxygenation during tracheal intubation manoeuvres with mandatory pre-oxygenation is potentially interesting in some cases to prevent arterial oxygen desaturation, especially in patients at risk of rapid arterial desaturation, for example obese patients or those in critical condition. This may even be beneficial in cases of anticipated or not difficult tracheal intubation including emergency intubation. Apnoeic oxygenation techniques essentially include nasopharyngeal insufflation with the aid of an oxygen cannula at a flow rate of 5 L/min or high flow nasal oxygen. In obese patients, these two techniques make it possible to prolong the arterial oxygen desaturation time, with a doubling of this time during a controlled trial comparing nasopharyngeal insufflation to apnoeic oxygenation after conventional pre-oxygenation in both cases [31]. A similar observational study demonstrated the prevention of the occurrence of arterial oxygen desaturation in difficult airway patients with high flow nasal oxygen, with a median apnoea time of 14 minutes [32]. In this same study, patients in whom a difficult intubation was anticipated could be supported for airway control without the occurrence of $SpO_2 < 90\%$ [32]. On the other hand, high flow nasal oxygen with a "low" flow at 15 L/min did not demonstrate benefit in preventing arterial oxygen desaturation in patients in vital distress requiring tracheal intubation in intensive care [33].

R 1.3 – In some cases, we recommend combining apnoeic oxygenation with specific techniques to prevent arterial oxygen desaturation.
(Grade 2+) Strong Agreement

4.2. Question 2. Should videolaryngoscopes be used instead of standard laryngoscopy with or without a long stylet to achieve a better success rate of intubation after the first attempt during anticipated difficult intubation off fiberoptic intubation?

4.2.1. Prerequisites

We do not recommend using a videolaryngoscope if one of the following cases is encountered:

- Patient mouth opening < 2.5 cm;
- Cervical spine fixed in flexion;
- Tumour of the upper aero-digestive tract with stridor;
- We recommend ensuring the possibility of introducing a videolaryngoscope in the mouth before the patient is asleep;
- A desaturation < 95% requires the cessation of intubation manoeuvres in favour of those allowing oxygenation. If there is a proven risk of hypoxemia, the videolaryngoscope cannot replace a supra-glottic device.

R 2.1 – During scheduled surgery, we recommend using videolaryngoscopes first in patients where mask ventilation is possible and who present at least two criteria for difficult intubation.
(Grade 1+) Strong Agreement

4.2.2. Rationale

In patients with at least two predictive factors of difficult intubation (especially a Mallampati III or IV score), videolaryngoscopes improve visualisation of the glottis and the success rate of first attempt tracheal intubation, compared to Macintosh blade [34–40]. The performance of videolaryngoscopes depends on the type of device, the expertise of the operator and the patient's characteristics. Today, it is conventional to describe devices with and without gutters, with characteristics such as manoeuvrability. Videolaryngoscopes should be used by practitioners trained in the use of these devices in patients who meet the criteria for difficult intubation [41]. The use of videolaryngoscopes in patients with at least one difficult intubation criterion could probably enable the learning and maintenance of the practitioner's expertise.

In most studies comparing direct laryngoscopy and videolaryngoscopy, patients with at least two criteria of difficult intubation benefit from the administration of a muscle relaxant [34,36–38]. Videolaryngoscopes with a screen enables visualisation of external laryngeal manoeuvres and can thus improve glottis exposure according adjustment manoeuvres provided by the operator or an assistant [35]. When using a videolaryngoscope without gutter, the use of a preformed guide may be useful for directing the tracheal tube. In cases of cervical spine pathology, a meta-analysis showed a higher rate of intubation success and better vision of the glottis as well as a lower complication rate with an Airtraq™ than with a laryngoscope equipped with a classic Macintosh blade [42]. In obese patients ($BMI > 30\ kg.m^{-2}$), videolaryngoscopes allow better visualisation of the glottis and improve the rate of intubation success [40,43]. In addition, a decrease in the risk of oxygen desaturation ($SpO_2 < 92\%$) has been reported for these patients [40].

In case of rapid sequence induction for patients with a full stomach, the literature does not support the use of videolaryngoscopes.
NO RECOMMENDATION

R2.2 – If difficult intubation is not foreseen, we recommend using videolaryngoscopes as a second attempt device in patients with a Cormack and Lehane grade III or IV, if mask ventilation is possible.
(Grade 2+) Strong Agreement

4.2.3. Rationale

The time required for endotracheal intubation with a videolaryngoscope may be shorter, equal to or longer than a laryngoscope equipped with a Macintosh blade [38,42,44,45]. As this parameter is random and depends on many factors (type of device, the expertise of operator and patient's characteristics), videolaryngoscopes cannot, at present, be offered systematically as first-line support of patients at risk of regurgitation and inhalation. The Sellick manoeuvre could alter the glottic vision with a videolaryngoscope and decrease the success rate of intubation in a patient with a full stomach [46,47].

R2.3 – We recommend using videolaryngoscopes as an alternative airway control technique, instead of the fiberscope, in spontaneous ventilation patients for anticipated difficult or impossible planned intubation and difficult mask ventilation.
(Grade 2+) Weak Agreement

4.2.4. Prerequisites

In patients with an unexpected difficult intubation, one or two attempts at laryngoscopy by an expert practitioner are performed in first, using all possible means of optimisation (repositioning the patient's head, use of gum elastic bougie as Eschmann stylet, BURP manoeuvre) to view the glottis and achieve tracheal intubation.

The gum elastic bougie is part of the first stage of optimising airway management in cases of unanticipated difficult intubation.

4.2.5. Rationale

Videolaryngoscopes reduce the incidence of Cormack and Lehane grade III and IV initially observed by direct laryngoscopy in patients with an unexpected difficult intubation [48,49]. In these situations, the risk of intubation failure with videolaryngoscopy technique is low for experienced practitioners. In a non-randomised multicentre retrospective study (7 centres) between 2004 and 2013, accounting in 1427 failures with direct laryngoscopy technique with a Macintosh blade, the videolaryngoscopy was reported as the most common backup method in first-line by anaesthetists. In this case, the success rate of intubation of the trachea is more important compared to other rescue devices used in the same context [50]. The use of videolaryngoscopes may be associated with trauma to the upper airways or larynx particularly when a stylet for the endotracheal tube is used during videolaryngoscopy [41].

4.2.6. Prerequisites

In cases where tracheal intubation is not possible, fiberoptic intubation is the method of reference. Tumours at the base of the tongue are prime indications of fiberoptic intubation. In cases of stridor associated with respiratory distress, tracheotomy should be first line management.

The failure rate of fiberoptic intubation is not zero and the indications of this technique diminish with the arrival of videolaryngoscopes [51].

Fiberoptic intubation, as in videolaryngoscopy, is operator-dependent and thus requires specific training [52].

If fiberoptic intubation fails, videolaryngoscopes probably have a place in patients with sufficient space in mouth opening (> 2.5 cm).

Regardless of the technique chosen to control the airway during difficult intubation and difficult mask ventilation, sedated patients should maintain spontaneous ventilation.

4.2.7. Rationale

Few studies are available on this subject. It is possible to perform oral or nasal intubation under videolaryngoscopy in spontaneously breathing patients with trained operators combining topical anaesthesia and sedation with target-controlled infusion (TCI) using remifentanil similar to that recommended for fiberoptic intubation. In this case, oxygenation with or without high flow nasal oxygen therapy should be considered. The use of videolaryngoscopes for anticipated difficult intubation is an acceptable alternative technique to the fiberoptic intubation, either with a nasal or oral route for tracheal intubation with tracheal tube visualisation possible during the progress between the vocal cords [52–54]. Most relevant studies were carried out on patients without tumours (normal larynx) and with experienced operators in patients with for mouth openings > 2.5 cm.

4.3. Question 3. Should TCI or target controlled inhalation anaesthesia (TCIA) be used instead of bolus sedation for airway control in the event of suspected or proven difficulty in a patient spontaneously breathing?

NO RECOMMENDATION

4.3.1. Rationale

The 2006 CE/DI already specifies that the use of propofol and remifentanil in TCI is associated with a low risk of desaturation, improves intubating conditions for the operator and the patient comfort [55]. Remifentanil allows better patient cooperation [56–58]. Recent literature data do not propose changes to this.

4.4. Question 4. What mode of anaesthesia should be performed in patients with difficult intubation criteria and potentially difficult mask ventilation?

4.4.1. Prerequisites

It is essential to ensure the availability of oxygenation techniques before considering general anaesthesia.

R4.1 – We recommend maintaining a deep level of anaesthesia using rapidly reversible agents in order to optimise conditions of mask ventilation and intubation.
(Grade 1+) Strong Agreement

4.4.2. Rationale

The decision to maintain spontaneous ventilation or not must consider the possibility of mask ventilation or the use of alternative oxygenation techniques. The depth of anaesthesia [59] must be sufficient to optimise the conditions for mask ventilation and intubation. The action of anaesthetic agents should be rapidly reversible to allow the return of spontaneous ventilation in the case of failure. Propofol [60,61] and sevoflurane [62] are the hypnotics of choice. The addition of a short acting opioid improves intubating conditions but involves a higher risk of prolonging apnoea [63].

R4.2 – If difficult intubation is anticipated, we recommend administering a muscle relaxant in order to improve the conditions of mask ventilation and intubation. We recommend using a short acting muscle relaxant or one that can be rapidly inactivated during routine monitoring.
(Grade 2+) Agreement

4.4.3. Rationale

The use of muscle relaxant improves conditions for mask ventilation [64–66] and intubation [67,68]. If difficult intubation is expected, it is recommended to use a muscle relaxant to increase the chances of success [69]. The level of neuromuscular blockade must be quantitatively assessed using a neuromuscular blockade monitor. There is no published data supporting the testing of mask ventilation before the injection of neuromuscular blocking agent. Instead, the administration of a neuromuscular blocking agent during anaesthesia in patients with upper airway obstruction is considered as a standard in adults [70], including in situations where a rescue tracheotomy is decided [71]. The short or rapidly inactivated muscle relaxant action allows the return to effective spontaneous ventilation (respiratory rate between 10 and 25 per minute, capnogram satisfactory) in case of failure of airway control.

Two neuromuscular blocking agents meet these criteria:

- Succinylcholine at a dose of 1 $mg.kg^{-1}$ (real weight);

- Rocuronium at a dose of 0.6 mg.kg^{-1} or 1.0 mg.kg^{-1} in case of rapid induction sequence. It can be inactivated using a dose of 8–16 mg.kg^{-1} of sugammadex [72–74], even if there is deep block, according to the dose of rocuronium administered and the time period between the administrations of rocuronium and sugammadex. In cases where rocuronium is administered for anticipated difficult intubation, the required dose of sugammadex should be immediately available.

4.5. Question 5. In surgical patients, what criteria predict difficulties encountered during postoperative tracheal extubation?

4.5.1. Prerequisites

Tracheal extubation should be performed when the reversibility of the anaesthetic is sufficient and the physiological parameters are stable and satisfactory.

Conditions for tracheal extubation are:

- Quantitative Train of Four (TOF) is $>$ 90% [75]. The lack of a reliable signal (calibration error, patient movements, defective sensors [76]) should prompt consideration of a systematic antagonising;
- Regular, spontaneous breathing ensuring adequate gas exchange;
- Satisfactory haemodynamic conditions;
- Awake patient (eye opening/response to orders/no agitation) unless decision to extubate a patient under anaesthesia (to prevent coughing for example);
- The lack of immediate risk of surgical complications.

These criteria can be a checklist; the last condition is discussed with operators as part of the HAS (Haute Autorité de santé, France) checklist. The literature does not specify the core temperature threshold where a patient should not be extubated.

R5.1 – Since reintubation is a source of morbidity and mortality, we recommend adapting the airway management to risk factors associated with extubation failure.
(Grade 2+) Strong Agreement

4.5.2. Rationale

The problems associated with extubation (tracheal tube or supraglottic device) have serious consequences with significant sequelae rate as evidenced by the study of patient complaints in the US [77] and the UK [78]. The use of algorithms can limit the incidence of these complications [79]. Re-intubation procedures and management of extubation failures are not well known in the medical community. Yet, the 2006 CE/DI defined the criteria for appropriate tracheal extubation and proposed to manage risk situations by applying an extubation algorithm with criteria including those for difficult extubation [79]. In the NAP4 study, considering incidents related to airway management, 38 incidents occurred in the recovery period after extubation (20 in the operating room, 2 during transport and 16 in the recovery room) [2]. Four causal factors were reported: laryngospasm, biting of the tube causing anoxia or negative pressure oedema, obstructive clot and cervical oedema after prolonged positioning in the Trendelenburg position. Sixteen cases out of thirty-eight occurred in a context of ENT surgery. This type of survey focused on airway regardless of the medical context (or respiratory failure especially cardiac). Epidemiological studies on postoperative reintubation revealed this is often due to limited cardiorespiratory reserves not allowing tracheal extubation.

R5.2 – We recommend exploring risk factors for failure prior to extubation.
(Grade 2+) Strong Agreement

4.5.3. Rationale

The epidemiology of postoperative reintubation recognised as risk factors:

- Residual paralysis [80];
- Avoidable human factors (inexperience, lack of procedures);
- Medical factors that limit the reserves of the body (cardiac or respiratory);
- Obstruction of the airway [81].

Recent studies have quantified these risk factors [82–84]. These studies are mono-centric and several risk factors strongly depend on the patient base of each institution and the type of surgery performed. Overall, the general risk factors are dominated by cardiac failure and/or COPD. Malnutrition also plays a role. The existence of a previous difficult intubation is not noted in these studies but must be taken into account.

High risk surgeries include:

- Major surgery: vascular surgery, transplantation, neurosurgery, thoracic surgery, cardiac surgery;
- Head and neck surgery: airway, face and neck surgeries;
- Long duration surgery ($>$ 4 hours) in a Trendelenburg or declive position with ongoing fluid maintenance without monitoring, and a large diameter tracheal tube (size of endotracheal tube $>$ 7.5 mm).

The risk of airway obstruction is taken into account. The leak test is not recognised as reliable in anaesthesia, contrary to intensive care recommendations.

R5.3 – We recommend extubating patients following a rigorous strategy.
(Grade 2+) Strong Agreement

4.5.4. Rationale

A rigorous technique to perform tracheal extubation consists of [85]:

- Using an algorithm to identify high-risk situations;
- Extubating in half-sitting position (obese/obstructive sleep apnoea) or lateral decubitus if stomach emptiness is in doubt;
- Deflating the balloon using a syringe [86];
- Aspirating in the mouth to avoid endo-tracheal suctioning during withdrawal of the tracheal tube (to prevent lung derecruitment);
- Preventing biting of the endotracheal tube or laryngeal mask, prior to extubation, including during transportation from the operating room to the recovery room [87];
- Administering an $FiO_2 = 1$ and remove the tracheal tube by positive pressure at the end of inspiration to limit the risk of atelectasis. Protective ventilation can prevent the formation of atelectasis after abdominal and thoracic surgery [88], but this is not demonstrated in cardiac surgery [89]. Additionally, a recruitment manoeuvre performed 30 minutes before extubation followed by CPAP does not improve oxygenation after extubation [90];

- Oxygenate and immediately. The presence of two healthcare professionals, with an anaesthetist readily available, avoids serious incidents during extubation: death and coma cardiac arrest [91].

R5.4 – In the presence of extubation risk factors, we recommend implementing preventive measures.
(Grade 2+) Strong Agreement

4.5.5. Rationale

Preventive measures include:

- Organising leadership to enable quick and coordinated progress of the extubation algorithm;
- Only considering extubation if the oxygen and/or reintubation equipment is available and in the presence of two persons, one of whom being an anaesthetist [91];
- Carefully evaluating the indication of extubation and achieving consensus between all care providers (Item No. 9 of the HAS checklist is often insufficiently understood [92]):
  - Extubation delayed to ensure it is achievable (the leak test is not valid in anaesthesia but supported in intensive care, visualisation of the glottis): monitoring until extubation (SpO_2, capnography, spirometry, neuromuscular monitoring),
  - Tracheotomy: this indication depends upon the risk of airway obstruction and cardiopulmonary reserves of the individual patient. This decision is shared between the surgeon and the anaesthesiologist, especially during neck surgery;
  - Extubation with airway exchange catheter or dedicated hardware guide (tracheal extubation kit) showed their effectiveness for reintubation occurring within 10 hours after the surgery [90]. This technique may be complicated by injuries and the presence of the guide should not exceed 24 hours. This recognises technical failures of the order of 7 to 14% [93,94]. These failures occur mostly with small diameter guides and reintubation is facilitated by classic or videolaryngoscopy [95]. Oxygenation through the guide can be dangerous in cases where of jet ventilation in manual mode without following simple rules: small tidal volumes, lower respiratory frequency, and optimizing the expiration to prevent the risk of barotrauma; it should be recommended in cases of extreme emergency [96]. This was further emphasised recently [97];
- Determine a suitable location for monitoring risk: intensive care unit, high-dependency unit or surgical ward if the risk is considered low;
- Written documentation of risk factors and plan [92];
- The risk of post-extubation aspiration postoperatively is rare [3];
- Maintain oxygenation:
  - Seated,
  - Oxygen therapy;
  - Or non invasive ventilation (NIV).

The patient should be informed, including subsequently in written form, the circumstances and reasons for the difficult extubation.

Recommendations R5.1, R5.2, R5.3, R5.4 are summarised in Fig. 1 describing the extubation algorithm according the patient's and surgery's risk factors, and Fig. 2 with the extubation procedure algorithm and process of decision making (Figs. 3–6)

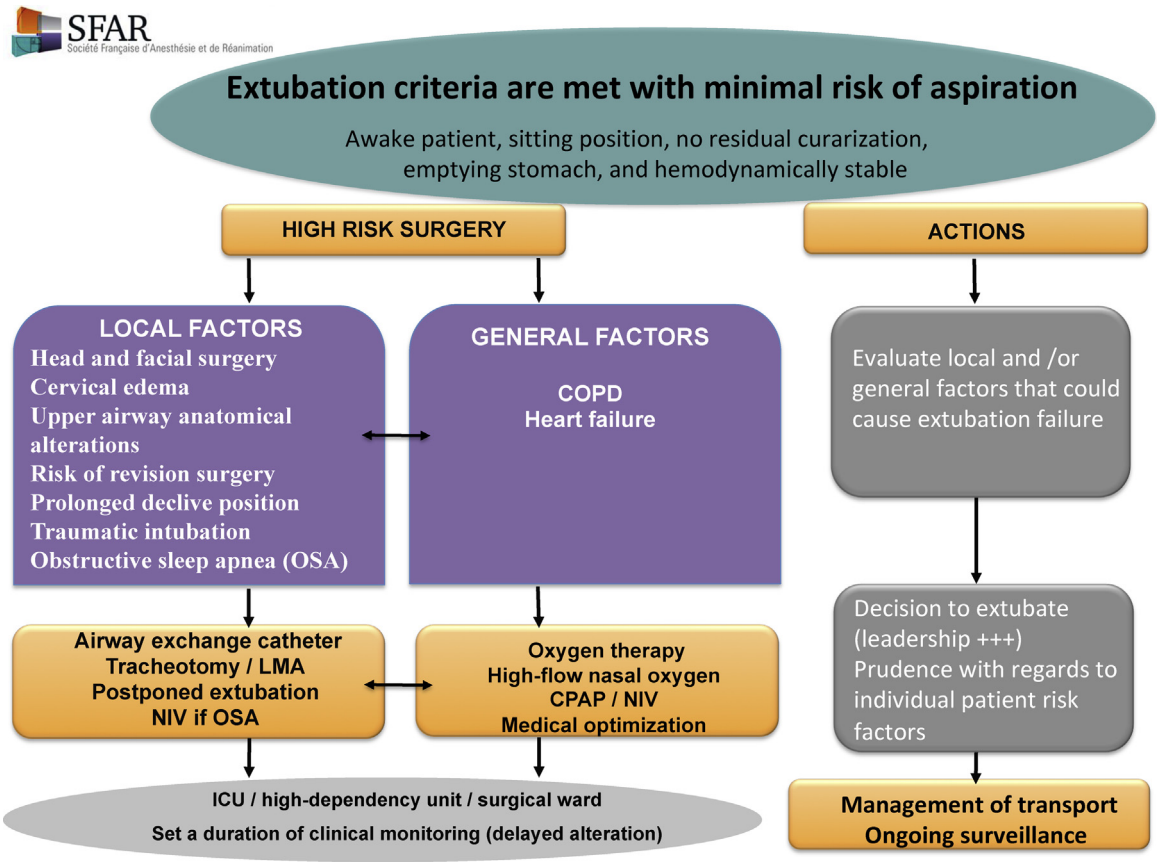

Fig. 1. Extubation algorithm according to the patient's and surgery's risk factors.

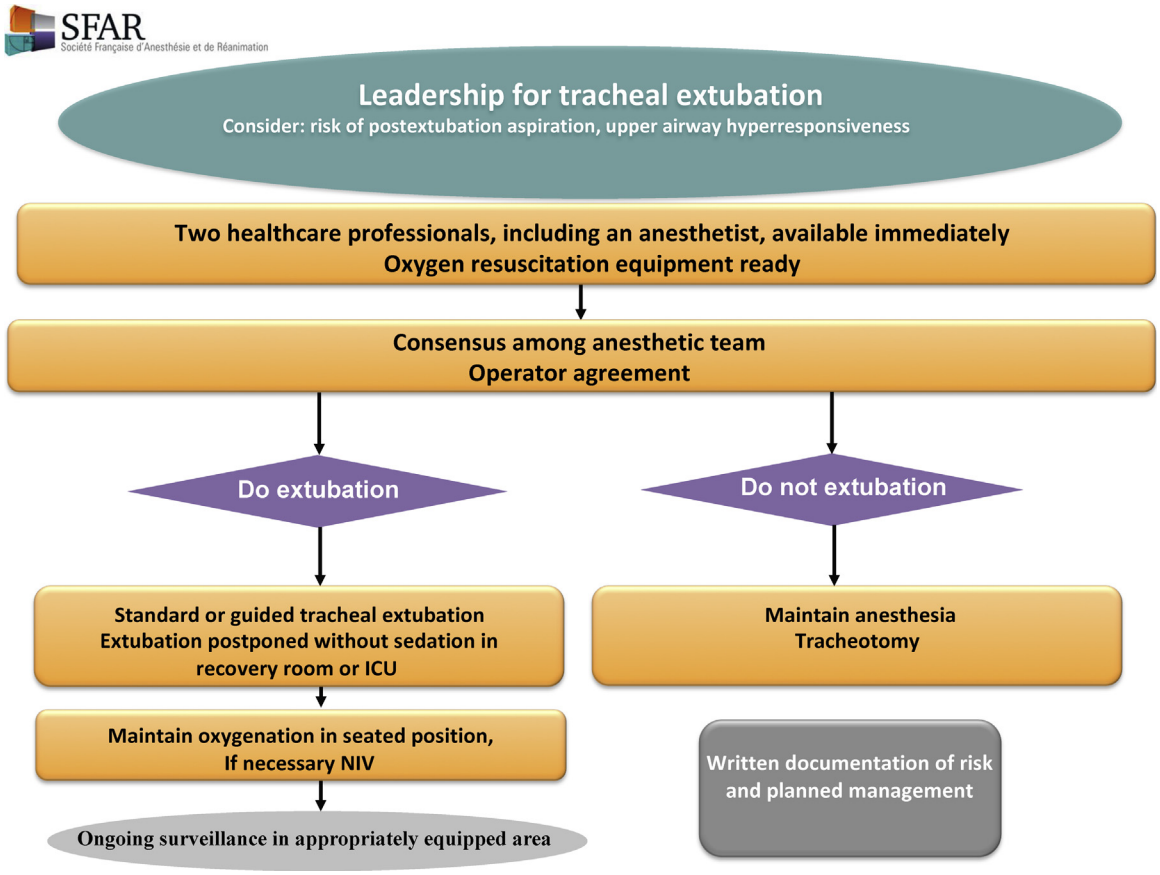

Fig. 2. Extubation procedure algorithm and decision-making process.

4.6. Question 6. Should decision trees and algorithms be employed to direct decision-making for the management of difficult intubation, whether foreseen or not? (based on the information from the preceding five issues)

4.6.1. Rationale

Airway control-related difficulties still represent the major causes of morbidity and mortality related to anaesthesia [2,3,77]. In order to reduce this risk, benchmarks and recommendations of relevant societies were established to guide management of difficult airway control and predict such difficulties. Additionally, decision trees and algorithms were developed to optimise management of risk during anaesthetic induction [98–102]. The established algorithms represent an educational and practical tool for optimal upper airway management in the operating room by providing robust guidance for techniques and airway control devices [98–102]. The absolute priority of these recommendations is maintaining the oxygenation of the patient at all times. This point has not changed over time and remains the ultimate goal of these algorithms regardless of the origin or the development of the recommendation [98–102]. Preventing these risks is based on their prediction when assessing preoperatively for both difficulty of the facemask ventilation and tracheal intubation. This preoperative assessment is fully integrated in the early management of a difficult-to-control airway in the operating room. The prediction of difficult airways can be refined by sophisticated models taking into account the individual interaction between difficult intubation risk factors [103]. Finally, better prediction of risk is no longer based on a binary yes/no, but rather an intermediate-risk or "grey" zone [103]. This grey or inconclusive zone does not classify an individual as risky or not and thus does not prescribe a specific treatment strategy for a patient. Rather it promotes early using anticipated appropriate algorithms. To formalise this strategy of airway control, decision-making algorithms were established on the recommendations made by various scientific societies [98–102]. This promoted personal and team reflection and in order to anticipate critical situations. The development of predefined algorithms that involve different devices for difficult airway control enabled demonstration of the effectiveness of using multiple devices by ensuring patient oxygenation, and in most of the cases tracheal intubation with several successive lines of treatment: gum elastic bougie, videolaryngoscope and intubating laryngeal mask [104]. The algorithms first focus on achieving patient oxygenation by first choosing face mask ventilation and secondly management of anticipated or not difficulty for tracheal intubation [98]. Appropriate techniques are based on these two scenarios. In algorithms, the following components of airway control are considered: the patient (oxygenation and/or tracheal intubation difficulties) the operator (expertise for a range of techniques and effective reasoning) as well as various oxygenation and tracheal intubation techniques. The last but equally important element to be taken account is anaesthesia; its depth and quality criteria: maintaining spontaneous ventilation or the possibility of apnoea, deepening of anaesthesia and/or maintenance of adequate depth not to impede mask ventilation and/or tracheal intubation. Similarly, one should accept failure of tracheal intubation (limited to two attempts) and calling using assistance (technical and/or that a senior anaesthetist) before the occurrence of any unforeseen difficulties in oxygenation and/or tracheal intubation [100]. Finally, we do not recommend considering laryngoscopy to assess the difficulty of the airway control when the difficulty is planned or predictable, as this procedure is unreliable due to the depth of anaesthesia as minimum, often leading to a critical situation or extreme tracheal

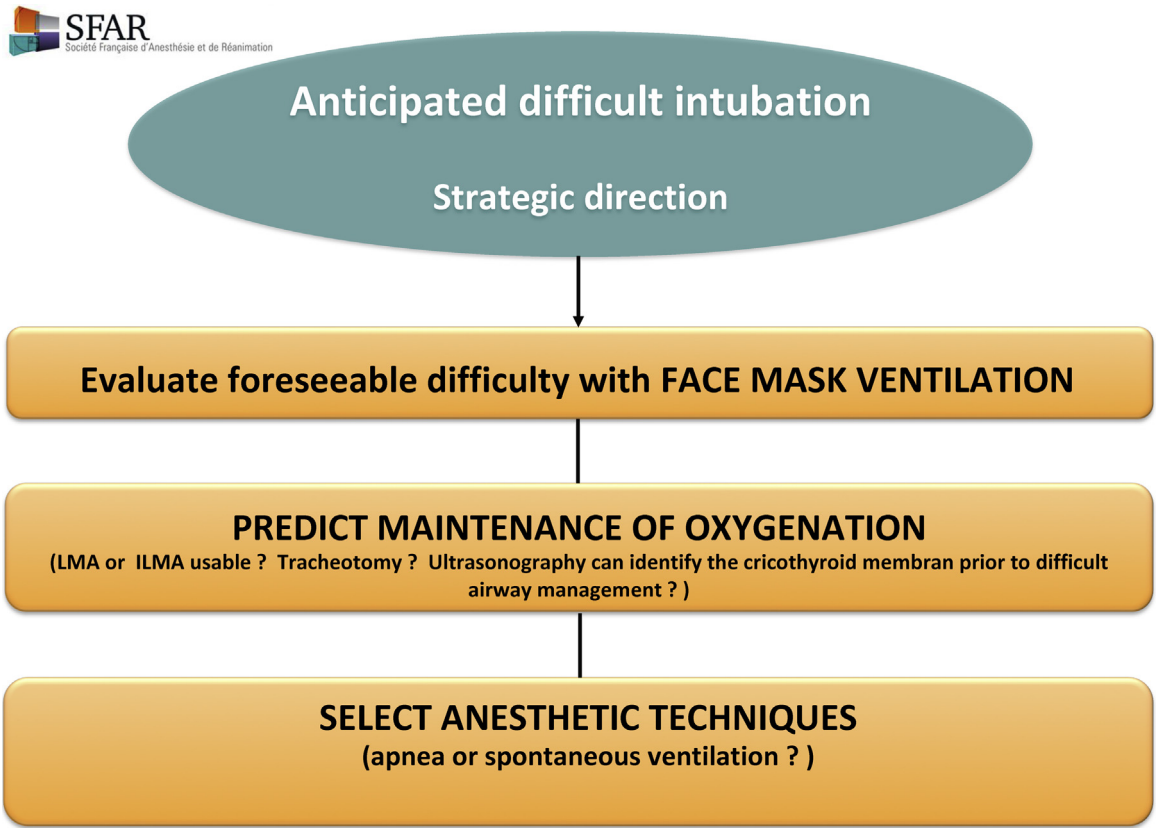

Fig. 3. Strategic direction when difficult intubation is anticipated.

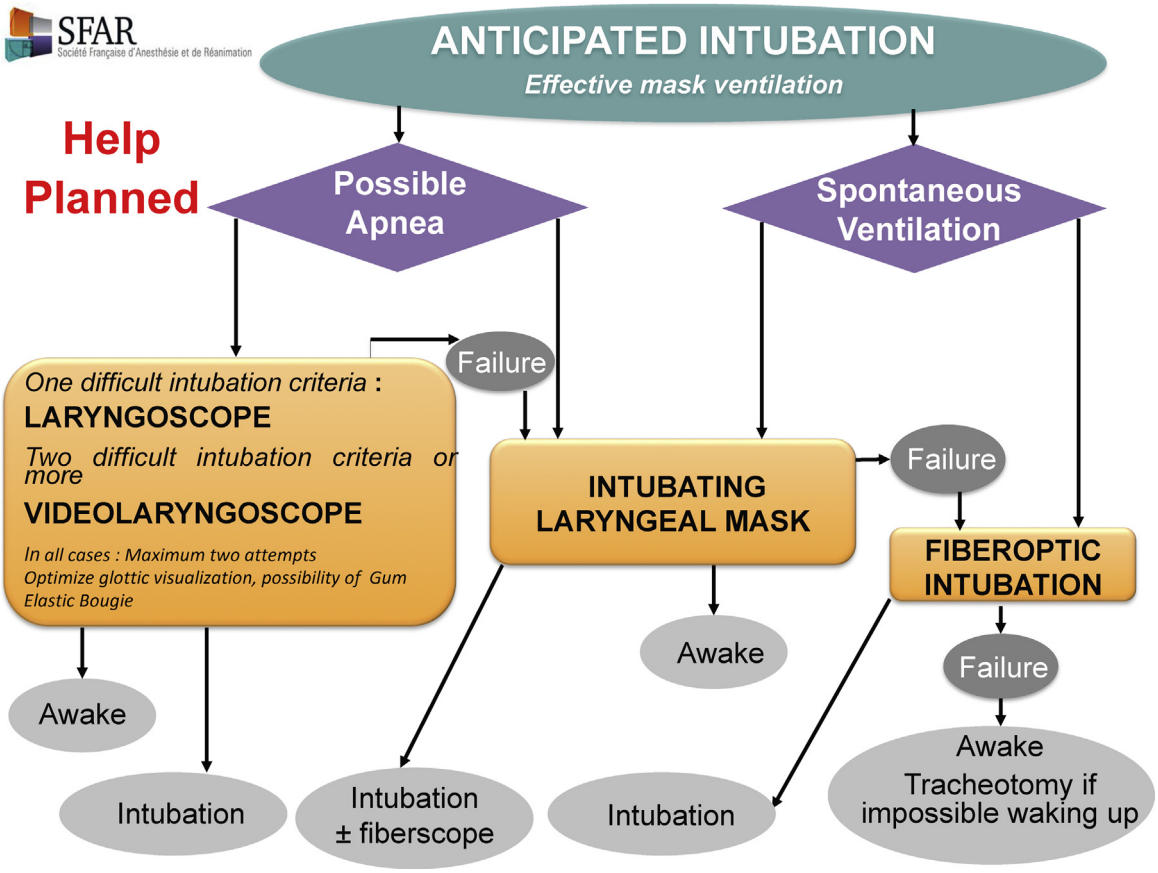

Fig. 4. Anticipated difficult intubation with effective mask ventilation algorithm.

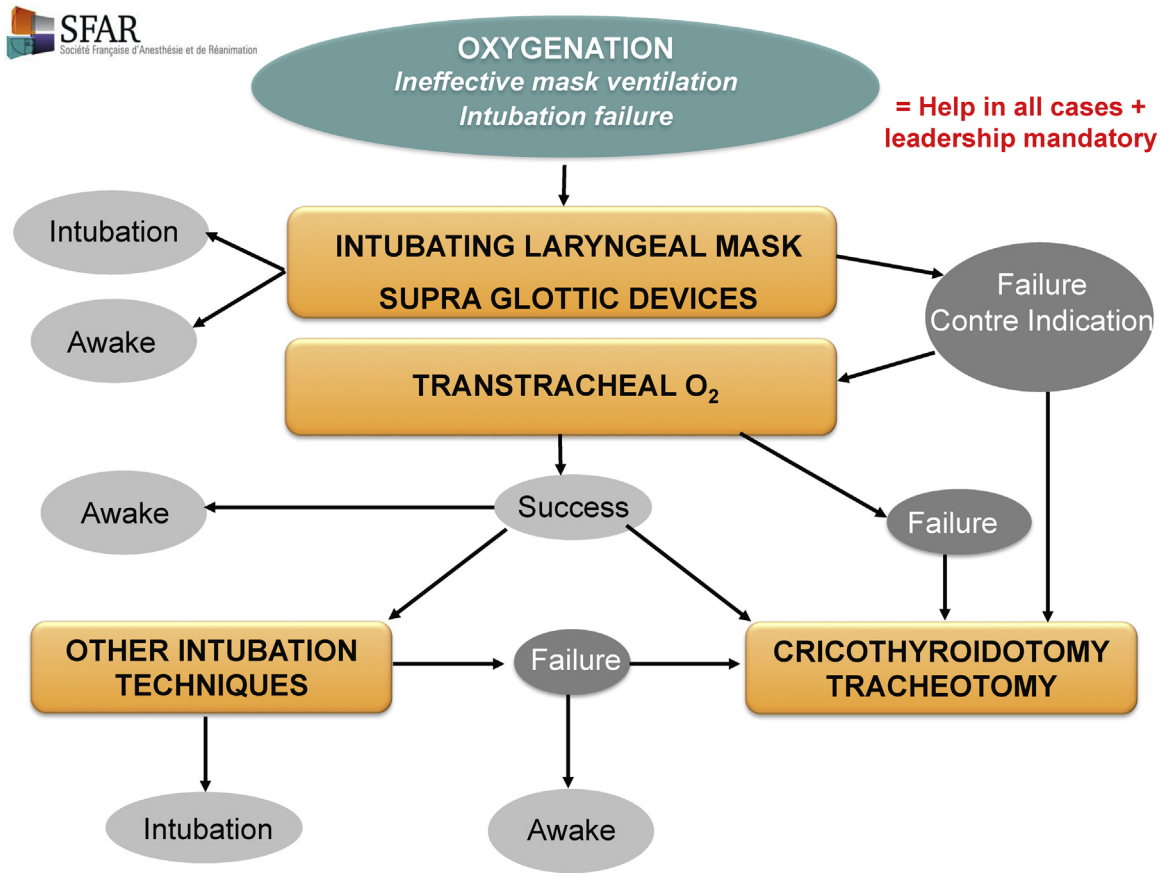

Fig. 5. Oxygenation algorithm with ineffective mask ventilation and intubation failure.

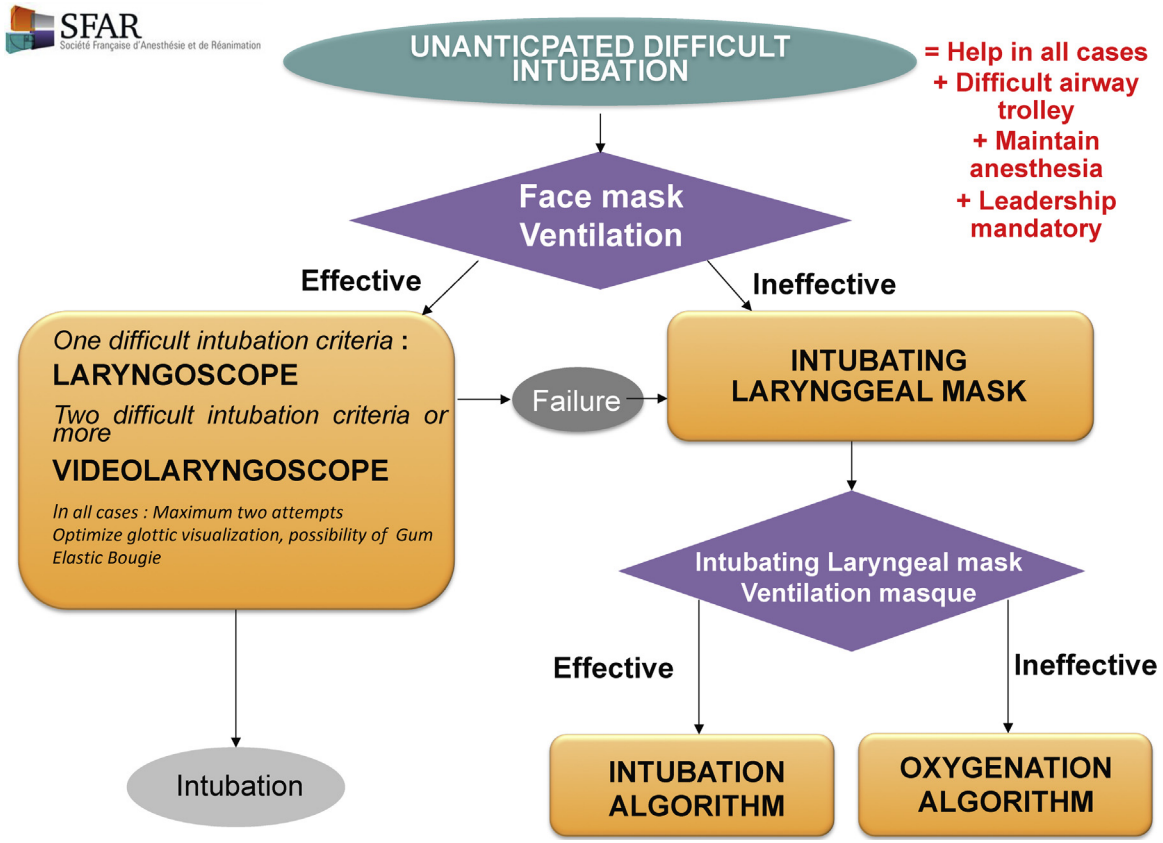

Fig. 6. Unanticipated difficult intubation algorithm.

intubation and difficult oxygenation. These algorithms cannot exhaustively consider all the difficulties, foreseeable or not, encountered during airway management. This upstream reflection provides insight into the difficulty when it occurs, and is clearly in a risk control approach, limiting risky improvisation that would occur otherwise. The expertise of each professional must be tied to the corresponding algorithm in a given clinical scenario. Recommendation R6.1 is summarised in Fig. 3 describing strategic direction when difficult intubation is anticipated, in Fig. 4 describing anticipated difficult intubation with effective mask ventilation algorithm, in Fig. 5 providing oxygenation algorithm with ineffective mask ventilation and intubation failure, and lastly in Fig. 6 with the unanticipated difficult intubation algorithm. The common denominator of these timeless recommendations is to maintain the patient's oxygenationwith technical suggestions to achieve this according the clinical context.

R6.1 – We recommend using decision trees and algorithms to optimise the management of difficult airway control.
(Grade 1+) Strong Agreement

Disclosure of interest

Olivier Langeron reports receiving lecture fees from Cook Medical and Teleflex, and consulting fees from Medtronic. Benoit Plaud is paid consultant and lecturer for MSD™. Patrick Schoettker received consulting honorarium fees and travel grants from the following companies: VBM, Medtronic, Prodol Medical. Patrick Schoettker was involved in the idea, conception and design of the S-Guide intubating bougie produced by VBM

Acknowledgements

The authors thank Manu Juneja (Melbourne Medical School, university of Melbourne) for his helpful assistance in reviewing the manuscript.

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