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Difficult intubation and extubation in adult anesthesia

Updated guidelines from the French National Society of Anesthesia and Intensive Care (Société Française d'Anesthésie et de Réanimation – SFAR)

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Abstract :

These updated guidelines from the SFAR about Difficult intubation and extubation in adult anesthesia focused on 6 questions 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).

1) *Why must oxygen desaturation be avoided during intubation and what preoxygenation and oxygenation techniques should be used to prevent it ?* Because arterial oxygen desaturation increases the risk of morbidity and mortality and then should be definitively prevented during tracheal intubation or supra-glottic device insertion manoeuvres (Grade 1+, strong agreement). To definitively prevent arterial desaturation during tracheal intubation or insertion of a supra-glottal device, it is necessary to perform a preoxygenation procedure (3 min / 8 Deep Inspirations), including for the management of emergencies (Grade 1+, strong agreement). In some cases, it is probably best to combine apneic oxygenation with specific techniques to prevent arterial oxygen desaturation. (Grade 2+, strong agreement).

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 ?* During scheduled surgery, videolaryngoscopes should definitively be used first in patients where mask ventilation is possible and there exist at least two criteria for difficult intubation. (Grade 1+, strong agreement). In the case of a rapid sequence induction for patients with a full stomach, the literature does not support the use of videolaryngoscopes (no recommendation). If difficult intubation is not foreseen, videolaryngoscopes should probably be employed 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). Videolaryngoscopes should be probably used, as alternative airway control technique instead of fiberscope, in spontaneous ventilation patients for anticipated difficult or impossible planned intubation and difficult mask ventilation. (Grade 2+, weak agreement).

3) *Should TCI or target controlled inhalation anesthesia (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) *What mode of anesthesia should be performed in patients with difficult intubation criteria and potentially difficult mask ventilation ?* A deep level of anesthesia must definitively be maintained by rapidly reversible agents in order to optimize conditions of mask ventilation and intubation. (Grade 1+, strong agreement). If difficult intubation is anticipated, a muscle relaxant should probably be used in order to improve the conditions of mask ventilation and intubation. A short acting muscle relaxant or one that can be rapidly inactivated during routine monitoring should be used. (Grade 2+, strong agreement).

5) *In surgical patients, what criteria predict difficulties encountered during postoperative tracheal extubation ?* Since reintubation is a source of morbidity and mortality, it is probably best to adapt the airway management to risk factors associated with extubation failure. (Grade 2+, strong agreement). Risk factors for failure should be probably explored prior to extubation. (Grade 2+, strong agreement). Extubating patients should probably follow a rigorous strategy. (Grade 2+, strong agreement). In the presence of extubation risk factors, preventive measures should probably be undertaken according decision algorithms. (Grade 2+, strong agreement).

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) Decision trees and algorithms should be definitively used to optimize the management of difficult airway control. (Grade 1+, strong agreement).

KEYWORDS :

**Difficult airway management,
Updated guidelines,
Difficult tracheal intubation,
Difficult tracheal extubation,
Strategy,
Algorithms**

Introduction

Tracheal intubation and extubation are routine and inseparable techniques in anesthesia and intensive care, despite being commonly applied their importance must not be underappreciated. In some cases, tracheal intubation and / or extubation is challenging and still represents an important cause of morbidity and mortality in anesthesiology. In 2006, the French Society of Anesthesia and Intensive Care (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.

1. 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 :

- preoxygenation and the need to remind robust practices adapted to new techniques such as transnasal 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:
 - 1) assessment of the difficulty of facial mask ventilation;
 - 2) the management of planned difficult tracheal intubation without mask ventilation and positioning of video laryngoscopes;
 - 3) management of planned difficult tracheal intubation with difficult mask ventilation and recall of oxygenation techniques;
 - 4) the management of an unanticipated difficult tracheal intubation with or without ventilation mask difficulty;

5) risk stratification of tracheal extubation in order to create a comprehensive preventive strategy

2. Methods

2.1. 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.

2.2. 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 confidence in estimation of the effect and could modify the estimate of the effect itself
- Low : future research will most likely have an impact on 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: It should definitively be undertaken (GRADE 1+) or not (1-)
- Weak: It should probably be undertaken (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.

1. Estimation of the effect
2. The overall level of evidence: the higher it is, the more likely recommendation will be strong
3. The balance between desirable and undesirable effects: the more it is favourable, the more likely the recommendation will be strong.
4. 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 broadly agree and less than 20% 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 summarizing the work of the experts and applying the GRADE[®] method, thirteen recommendations have been formalized 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 +/-).

Questions and recommendations

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

R1.1 - Arterial oxygen desaturation should be definitively prevented during tracheal intubation or supra-glottic device insertion manoeuvres because of the risk of morbidity and mortality

(Grade 1+) Strong Agreement

Rationale : Preoxygenation 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 preoxygenation 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 preoxygenation studies. Preoxygenation performed before anesthetic 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 anesthetic 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, preoxygenation can prevent hypoxemia during induction of anesthesia with PaO_2 higher [5]. In contrast, the absence of preoxygenation even in ASA I patients can lead to arterial oxygen desaturation ($SpO_2 < 90\%$) in 30 to 60% of cases [6].

R 1.2 - To definitively prevent arterial desaturation during tracheal intubation or insertion of a supra-glottal device, it is necessary to perform a preoxygenation procedure (3 min / 8 Deep Inspirations), including for the management of emergencies
(Grade 1+) Strong Agreement

Rationale : The efficiency and / or the difficulty of preoxygenation depend on the technical conditions of preoxygenation with the face mask according absence or presence of leaks [7-9], and may also be related to presence of risk factors for difficult mask ventilation [10]. In the event of a facial mask leak, SpO₂ <85% was observed in ASA I or II patients [7,8]. It is accepted that when the end-tidal oxygen fraction (FeO₂) is greater than 90%, preoxygenation 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 preoxygenation 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 (SpO₂ <90%) is significantly shorter than in women during pregnancy with SpO₂ <90% occurring on average at 98 seconds compared 292 seconds respectively, largely due to the increased of oxygen consumption during labour [15]. The FRC decreases from the second trimester. This decrease in FRC is aggravated by 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 preoxygenation compared with supine position. The increase time to arterial oxygen desaturation (SpO₂ <90-92%) is 30% on average, allowing a tolerance to apnea 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 (SpO₂ < 95%) in patients who are neither pregnant nor obese. [19]. Thus, while preoxygenation 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 preoxygenation. Finally, even a moderate proclive position (20°) prolongs desaturation time in the general population.

Preoxygenation 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 manoeuvre 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 the context of the emergency it is essential to recall that in the description of rapid sequence induction (RSI), preoxygenation 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 preoxygenation 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 preoxygenation time with the goal of a $FeO_2 > 90\%$ [25].

Despite applying preoxygenation, 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 randomized controlled trial that does not differentiate any preoxygenation benefit between high flow nasal oxygen and oxygen administration by conventional facial mask [29]. Non-invasive ventilation as a preoxygenation 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 preoxygenation for 5 minutes [30].

R 1.3 - In some cases, it is probably best to combine apneic oxygenation with specific techniques to prevent arterial oxygen desaturation.

(Grade 2+) Strong Agreement

Rationale: Combining apneic oxygenation during tracheal intubation manoeuvres with mandatory preoxygenation is potentially interesting in some cases to prevent arterial oxygen desaturation, especially in patients at risk of rapid arterial desaturation, for example the obese or those in critical condition. This may even be beneficial in cases of anticipated or not difficult tracheal intubation including emergency intubation. Apneic 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 apneic oxygenation after conventional preoxygenation 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 apnea 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 SpO₂ <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].

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 ?

Prerequisites

- A videolaryngoscope should not be used if one of the following cases is encountered in the case of:

1. patient mouth opening < 2.5 cm;
2. cervical spine fixed in flexion;
3. a tumour of the upper aero-digestive tract with stridor

- It is necessary to ensure 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, videolaryngoscopes should definitively be used first in patients where mask ventilation is possible and there exist at least two criteria for difficult intubation.

(Grade 1+) Strong Agreement

Rationale: In patients with at least two predictive factors of difficult intubation (especially a Mallampati III or IV score), videolaryngoscopes improve visualization 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 maneuverability. Videolaryngoscopes should be used by practitioners trained in the use of these devices in patients who meet 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 administration of muscle relaxant [34, 36-38]. The videolaryngoscope with a screen enables visualization of external laryngeal maneuvers and can thus improve glottis exposure according adjustment maneuvers provided by the operator or an assistant [35]. In the case of 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 $> 30 \text{ kg.m}^{-2}$), videolaryngoscopes allow better visualization of the glottis and improve the rate of intubation success [40, 43]. In addition, a decrease in the risk of oxygen desaturation (SpO₂ $< 92\%$) has been reported for these patients [40].

In the case of a rapid sequence induction for patients with a full stomach, the literature does not support the use of videolaryngoscopes.

NO RECOMMENDATION

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 dependent 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 maneuver could alter the glottic vision with a videolaryngoscope and decrease the success rate of intubation in a patient with a full stomach [46, 47].

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 optimization (repositioning the patient's head, use of gum elastic bougie as Eschmann stylet, BURP maneuver) to view the glottis and achieve tracheal intubation.
- The gum elastic bougie is part of the first stage of optimizing airway management in cases of unanticipated difficult intubation.

R2.2 - If difficult intubation is not foreseen, videolaryngoscopes should probably be employed 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

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-randomized multicenter retrospective study (7 centers) 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 anesthetists. 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].

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 keep maintain spontaneous ventilation.

R2.3 – Videolaryngoscopes should be probably used, as alternative airway control technique instead of fiberscope, in spontaneous ventilation patients for anticipated difficult or impossible planned intubation and difficult mask ventilation.

(Grade 2+) Weak Agreement

Rationale: Few studies are available on this subject. It is possible to perform oral or nasal intubation under videolaryngoscopy in breathing spontaneously 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 visualization 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.

3. Should TCI or target controlled inhalation anesthesia (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

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

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

Prerequisites

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

R4.1 – A deep level of anesthesia must definitively be maintained by rapidly reversible agents in order to optimize conditions of mask ventilation and intubation.

(Grade 1+) Strong Agreement

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 anesthesia [59] must be sufficient to optimize the conditions for mask ventilation and intubation. The action of anesthetic 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 hypnotic of choice. The addition of a short acting opioid improves intubating conditions but involves a higher risk of prolonging apnea [63].

R4.2 - If difficult intubation is anticipated, a muscle relaxant should probably be used in order to improve the conditions of mask ventilation and intubation. A short acting muscle relaxant or one that can be rapidly inactivated during routine monitoring should be used.

(Grade 2+) Strong Agreement

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 anesthesia 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 even if there is deep block by sugammadex at a dose of $8\text{-}16 \text{ mg.kg}^{-1}$ [72-74] according to the dose of rocuronium administered and the time period between rocuronium and sugammadex administration. In cases where rocuronium is administered for anticipated difficult intubation, the required dose of sugammadex should be immediately available.

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

Prerequisites

- Tracheal extubation should be performed when the reversibility of the anesthetic 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 antagonizing.
 - Regular, spontaneous breathing ensuring adequate gas exchange.
 - Satisfactory hemodynamic conditions.
 - Awake patient (eye opening / response to orders / no agitation) unless decision to extubate of a patient under anesthesia (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 checklist HAS (Haute Autorité de Santé, France). 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, it is probably best to adapt the airway management to risk factors associated with extubation failure.

(Grade 2+) Strong Agreement

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 algorithm 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 NAP4 study, considering incidents in connection with airway management, 38 incidents occurred in the recovery period after extubation (20 in the operating room, 2 during transport and 16 in 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 – Risk factors for failure should be probably explored prior to extubation.

(Grade 2+) Strong Agreement

Rationale: The epidemiology of postoperative reintubations recognized 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 recognized as reliable in anesthesia, contrary to intensive care recommendations.

R5.3 – Extubating patients should probably follow a rigorous strategy.

(Grade 2+) Strong Agreement

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 apnea) 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 maneuver performed 30 minutes before extubation followed by CPAP does not improve oxygenation after extubation [90].

- Oxygenate and immediately control spontaneous efficient ventilation after extubation, in particular by capnography. The presence of two healthcare professionals, with an anesthetist readily available, avoids serious incidents during extubation: death and coma cardiac arrest [91].

R5.4 – In the presence of extubation risk factors, preventive measures should probably be undertaken.

(Grade 2+) Strong Agreement

Rationale: Preventive measures include:

- Organizing 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 is an anesthetist [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 anesthesia but supported in intensive care, visualization of the glottis) : monitoring until extubation (SpO₂, 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 anesthesiologist, especially during neck surgery
 - Extubation with airway exchange catheter or dedicated hardware guide (tracheal extubation kit) showed their effectiveness for reintubations 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 recognizes 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 emphasized 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 summarized in figure 1 describing the extubation algorithm according the patient's and surgery's risk factors, and figure 2 with the extubation procedure algorithm and process of decision making.

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)

R6.1 - Decision trees and algorithms should be definitively used to optimize the management of difficult airway control

(Grade 1+) Strong Agreement

Rationale: Airway control-related difficulties still represent major causes of morbidity and mortality related to anesthesia [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 optimize management of risk during anesthetic 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 face mask 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 formalize 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 anesthesia; its depth and quality criteria: maintaining spontaneous ventilation or the possibility of apnea, deepening of anesthesia 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 anesthetist) before the occurrence of any unforeseen difficulties in oxygenation and / or tracheal intubation [100]. Finally, it is not advisable to consider 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 anesthesia as minimum often leading to a critical situation or extreme tracheal 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. The common denominator of these timeless recommendations is to maintain the patient's oxygenation with technical suggestions to achieve this according the clinical context.

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Figures legends :

Figure 1 : Extubation algorithm according the patient's and surgery's risk factors.

Figure 2 : Extubation procedure algorithm and process of decision making.

Figure 3 : Strategic direction when difficult intubation is anticipated

Figure 4 : Anticipated difficult intubation with effective mask ventilation algorithm

Figure 5 : Oxygenation algorithm with ineffective mask ventilation and intubation failure

Figure 6 : Unanticipated difficult intubation algorithm

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Extubation criteria are met with minimal risk of aspiration

Awake patient, sitting position, no residual curarization, emptying stomach, and hemodynamically stable

HIGH RISK SURGERY

ACTIONS

LOCAL FACTORS

Head and facial surgery
Cervical edema
Upper airway anatomical alterations
Risk of revision surgery
Prolonged declive position
Traumatic intubation
Obstructive sleep apnea (OSA)

GENERAL FACTORS

COPD
Heart failure

Evaluate local and /or general factors that could cause extubation failure

Airway exchange catheter
Tracheotomy / LMA
Postponed extubation
NIV if OSA

Oxygen therapy
High-flow nasal oxygen
CPAP / NIV
Medical optimization

Decision to extubate (leadership +++)
Prudence with regards to individual patient risk factors

ICU / high-dependency unit / surgical ward
Set a duration of clinical monitoring (delayed alteration)

Management of transport
Ongoing surveillance

Leadership for tracheal extubation

Consider: risk of postextubation aspiration, upper airway hyperresponsiveness

Two healthcare professionals, including an anesthetist, available immediately
Oxygen resuscitation equipment ready

Consensus among anesthetic team
Operator agreement

Do extubation

Standard or guided tracheal extubation
Extubation postponed without sedation in
recovery room or ICU

Maintain oxygenation in seated position,
If necessary NIV

Ongoing surveillance in appropriately equipped area

Do not extubation

Maintain anesthesia
Tracheotomy

Written documentation of risk
and planned management

Anticipated difficult intubation

Strategic direction

Evaluate foreseeable difficulty with FACE MASK VENTILATION

PREDICT MAINTENANCE OF OXYGENATION

(LMA or ILMA usable ? Tracheotomy ? Ultrasonography can identify the cricothyroid membran prior to difficult airway management ?)

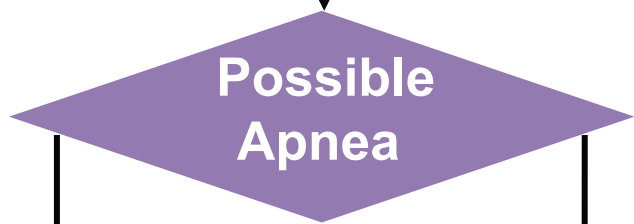
SELECT ANESTHETIC TECHNIQUES

(apnea or spontaneous ventilation ?)

ANTICIPATED INTUBATION

Effective mask ventilation

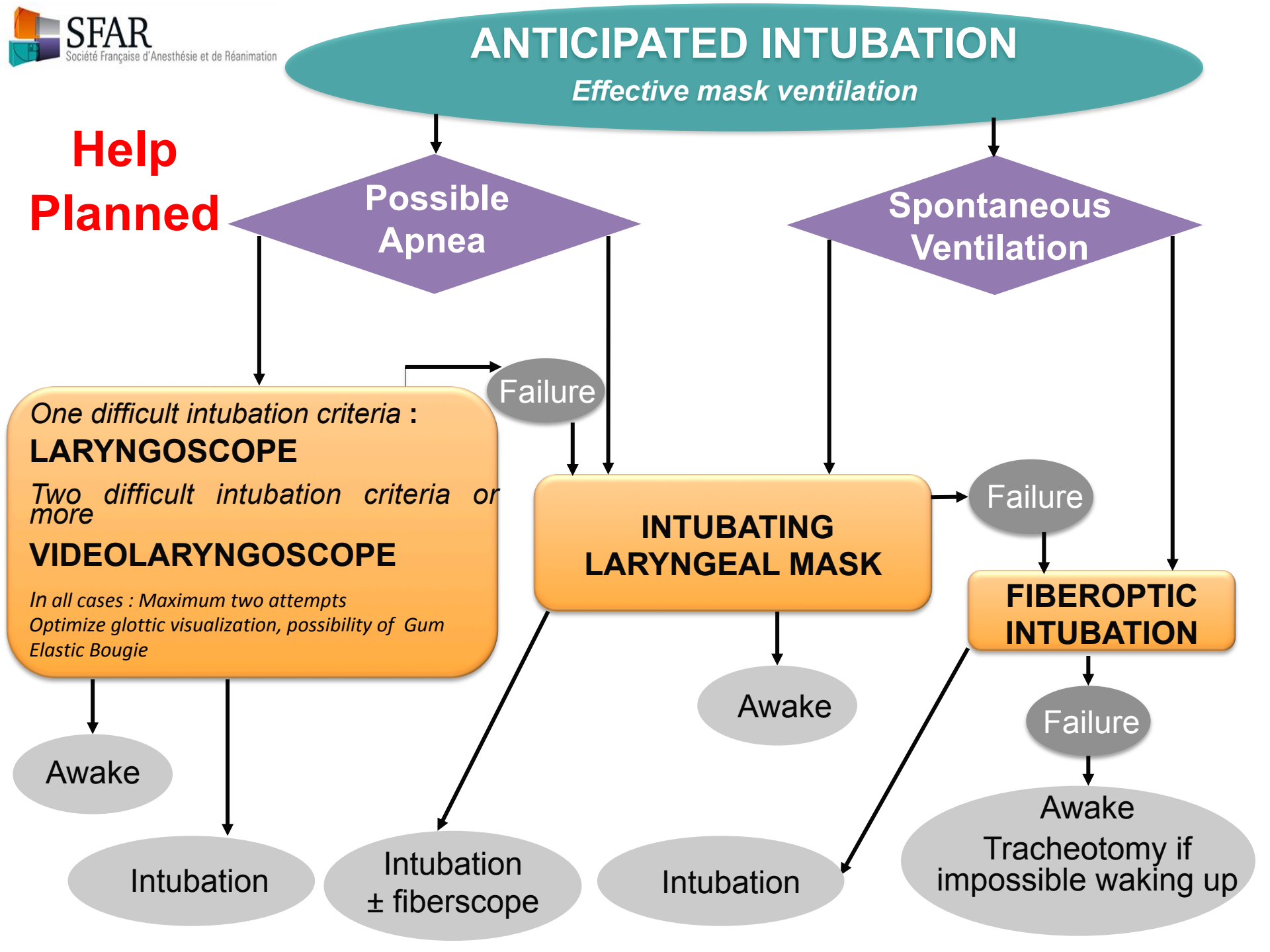
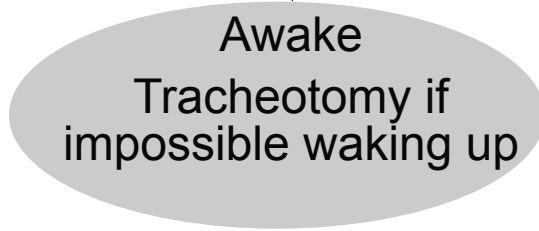
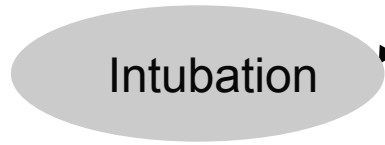
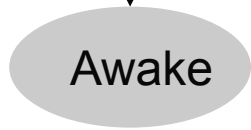
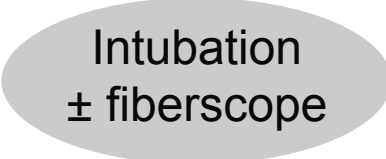
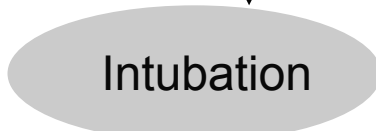
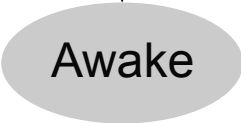
**Help
Planned**



One difficult intubation criteria :
LARYNGOSCOPE

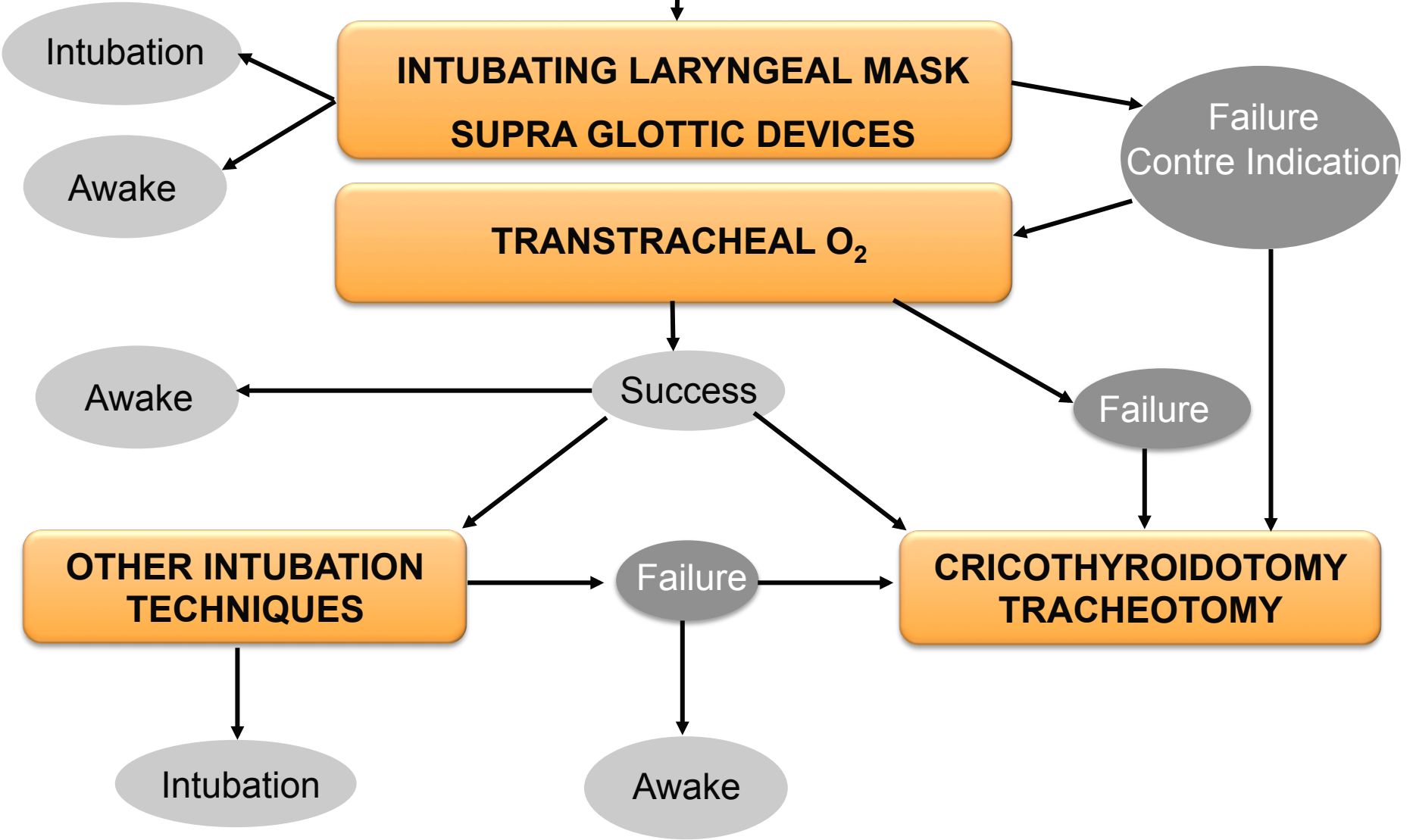
Two difficult intubation criteria or more
VIDEOLARYNGOSCOPE

*In all cases : Maximum two attempts
Optimize glottic visualization, possibility of Gum
Elastic Bougie*



OXYGENATION
Ineffective mask ventilation
Intubation failure

= Help in all cases + leadership mandatory



UNANTICIPATED DIFFICULT INTUBATION

= Help in all cases
+ Difficult airway trolley
+ Maintain anesthesia
+ Leadership mandatory

Face mask Ventilation

Effective

Ineffective

One difficult intubation criteria :
LARYNGOSCOPE
Two difficult intubation criteria or more
VIDEOLARYNGOSCOPE
In all cases : Maximum two attempts
Optimize glottic visualization, possibility of Gum Elastic Bougie

Failure

INTUBATING LARYNGEAL MASK

Intubating Laryngeal mask Ventilation masque

Effective

Ineffective

Intubation

INTUBATION ALGORITHM

OXYGENATION ALGORITHM