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Guidelines

Intubation and extubation of the ICU patient☆,☆☆

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1. Introduction

Intubation and extubation of ventilated patients are not risk free procedures in the Intensive Care Unit (ICU) and can be associated with morbidity and mortality. Intubation in the ICU is frequently required in emergency situations for patients with an unstable cardiovascular system who may be hypoxicaemic [1–3]. Under these circumstances, it is a high-risk procedure with life threatening complications (20–50%) such as hypotension and respiratory failure [2]. Technical problems can also give rise to complications. Generally three unsuccessful intubations [4], or two unsuccessful attempts at laryngoscopy are needed to justify the description difficult airway. These can make up 10–20% of intubations in the ICU and are associated with an increase in morbidity [2]. Several new techniques such as videolaryngoscopy have been developed for difficult airway management but contrary to operating room practice, integrating these into ICU algorithms is not well established.

Another period of risk is extubation, which fails in approximately 10% and is associated with a poor prognosis [5,6]. Extubation follows the successful weaning of patients from mechanical ventilation [7–9], but sometimes the re-establishment of spontaneous breathing is only possible with the tube in situ. An extubation failure is defined as the need for reintubation within 48 h of tube removal [7,10] and the most recent consensus on weaning defined success as the absence of mechanical assistance for 48 h after extubation. There is a need to incorporate into these definitions the development of non-invasive ventilation (NIV) after extubation. Indeed, NIV can be used as a weaning aid during extubation or as a preventive or curative treatment in acute respiratory failure occurring after extubation [11,12]. As NIV can postpone the need for reintubation, a period of 7 days after extubation is required for a more accurate definition of extubation failure [12]. To reduce the incidence of failure to extubate, the role of pathologies such as swelling and laryngeal oedema in increasing risk must be appreciated. Screening for risk factors that might predispose to failure to extubate could improve the chances of success. In constructing these guidelines, we have made use of new data on intubation and extubation in the ICU from the last decade to update existing procedures and incorporate more recent advances.

2. Material and methods

These recommendations come from experts of the Société Française d'Anesthésie et de Réanimation (SFAR) and Société de Réanimation de Langue Française (SRLF). As a first step, the organisation committee defined the questions under consideration according to the PICO format (Patients Intervention Comparison Outcome). The system used to elaborate their recommendations is the GRADE® method. After a quantitative analysis of the literature, this method allows firstly an assessment of the quality of evidence, such as a confidence estimation needed to analyse the effect of the quantitative intervention, and secondly provides a level of recommendation. The quality of evidence is distributed into four categories:

- high: further research is very unlikely to change confidence in the estimate of the effect;
- moderate: further research is likely to have an impact on confidence in the estimate of the effect and may change the estimate of the effect itself;
- low: further research is very likely to have an impact on confidence in the estimate of the effect and is likely to change the estimate of the effect itself;
- very low: any estimate of the effect is very unlikely.

The analysis of the quality of evidence is completed for every study, then a global level of evidence is defined for a given question and criterion. The final formulation of recommendations will always be binary, positive or negative and strong or weak:

- strong: We recommend or we recommend not to do (GRADE 1+ or 1−);
- weak: We suggest or we suggest not to do (GRADE 2+ or 2−).

The strength of the recommendations is determined according to key factors, and validated by the experts after a vote, using the Delphi and GRADE Grid method, taking into account:

- the estimate of the effect;
- the global level of evidence; the higher the level of evidence, the stronger the recommendation;
- the balance between desirable and undesirable effects: the more favourable the balance, the stronger the recommendation;
- values and preferences: in case of uncertainty or large variability, the level of evidence of the recommendation is probably weak. Values and preferences must be more clearly obtained from persons affected (patient, physician, decision-maker);
- cost: the greater the costs or the use of resources, the weaker the recommendation;
- formulating a recommendation requires that 50% of participants should have an opinion and that less than 20% of participant prefer the opposite proposition;
- making a strong recommendation requires an agreement of at least 70% of participants.

The analysis of the management of intubation has been assessed according to four headings: complicated intubation in the ICU, the materials required, pharmacology, and the use of a management protocol [1]. Extubation has been assessed according to three headings: prerequisites for extubation, extubation failure, and the use of a management protocol. A specific analysis was performed for intubation and extubation in children.

A total of 19 experts were separated into 7 working groups (the paediatric experts being involved in all questions).

Data had to have been published within the last ten years (until January 2016) to be selected. In the case of no data or a very low number of publications during the considered period, the timing of publications was extended back to 2000.

The experts were faced with three situations:

- for some questions with evidence from several trials or meta-analyses with an acceptable methodological quality, the GRADE® method was totally applicable and allowed recommendations to be made;

- when no meta-analysis was available to answer the question, a qualitative analysis by the experts following the GRADE® method was possible and a systematic review was performed;
- for some questions, the lack of any recent studies made a recommendation impossible.

After collating all the work of the experts and implementing the GRADE® method, 32 recommendations were formally proposed by the organising committee. Of these, 12 were strong (Grade 1 ±), 19 were weak (Grade 2 ±), and for 1 question the application of the GRADE® method proved impossible.

All the recommendations were submitted to a reviewing group for a Delphi method assessment. After 2 rounds of voting and evaluation and after various amendments, a strong agreement was reached for 31 (97%) recommendations.

For recommendations concerning children, 15 were formally proposed by the organising committee. Of these, 5 were strong (Grade 1 ±), 9 were weak (Grade 2 ±), and for 1 questions it was impossible to apply the GRADE® method. After two rounds of voting by specific paediatric experts, a strong agreement was reached for 15 (100%) recommendations.

3. Intubation of the ICU patient

3.1. Complicated intubation in ICU

R1.1 – All patients admitted to intensive care units must be considered at risk of complicated intubation. (Grade 1+) Strong agreement.

R1.2 – To reduce the incidence of complicated intubation, respiratory and haemodynamic complications must be anticipated and prevented, by careful preparing for intubation, and taking steps to maintain oxygenation and cardiovascular stability throughout the procedure ([Grade 1+] strong agreement).

R1.3 - Risk factors of complicated intubation must be distinguished from predictive factors of difficult intubation ([Grade 1+] Strong agreement).

Airway management is one of the most frequently performed manoeuvres in the intensive care unit (ICU). Intubation may be complicated for two main reasons:

- peri-procedural complications;
- technical difficulty.

The main complications of intubation identified previously include severe and moderate complications [22,23], detailed in Table 1.

Unlike elective endotracheal intubation performed in the operating room, intubation in the intensive care unit (ICU) is often performed as an emergency, in an hypoxaemic patient with a precarious cardiovascular system [1–3]. Consequently, it is a challenging issue, as it may be associated with life threatening complications in 20% to 50% of cases (collapse, hypoxaemia, arrhythmia, oesophageal intubation, aspiration.) [2]. The incidence of complications (see Table 1) is increased when patients suffer from acute respiratory failure or cardiovascular failure before intubation, or when the intubation procedure is difficult. Moreover, obesity and pregnancy are the two main situations where functional residual capacity (FRC) is decreased and where the risk of atelectasis is increased [13]. Other "at risk" patients include those who cannot safely tolerate a mild degree of hypoxaemia (epilepsy, cerebrovascular disease, coronary artery disease, sickle cell disease etc.) [4]. To reduce the incidence of life-threatening complications, respiratory and cardiovascular complications must be anticipated and prevented by careful preparation for the procedure, whilst maintaining oxygenation and cardiovascular stability throughout [1].

Table 1
Main complications related to the intubation procedure.

Severe
Severe hypoxaemia
Severe collapse
Cardiac arrest
Death
Moderate
Difficult intubation
Arrhythmia
Oesophageal intubation
Aspiration
Agitation
Dental injury

Difficult intubation [2], defined by two or more attempts at endotracheal intubation [4], is regarded as a complication of the intubation procedure. Moreover, complications of intubation increase when intubation is difficult. The incidence of difficult intubation is increased in the ICU, with rates varying from 8 to 23% depending on the report [14–17]. In the context of anticipating problems, a recent study has assessed the risk factors for difficult intubation in intensive care units [2]. A predictive score for difficult intubation, the MACOCHA score (Table 2), was developed and externally validated. The main predictors of difficult intubation were related to the patient (Mallampati score III or IV, obstructive sleep apnoea syndrome [OSAS], reduced mobility of cervical spine, limited mouth opening), co-existing pathology (coma, severe hypoxaemia) and the operator (non-anaesthesiologist). By adjusting the discrimination threshold of the score, a high discriminative ability was obtained. To reject difficult intubation with certainty, a cut-off of 3 or greater seems appropriate, allowing the best negative predictive value (respectively 97% and 98% in the original and validation cohorts) and sensitivity (respectively 76% and 73% in the original and validation cohorts). Note that the Intubation Difficulty Scale (IDS) is a quantitative scale that is useful for an objective comparison of the complexity of endotracheal intubation [18].

To improve health quality in the ICU, intensivists must possess a thorough knowledge and acceptable expertise in the performance of the intubation procedure. They should be helped to improve their knowledge and ability in terms of intubation. In this regard, high fidelity simulation seems to be an excellent device. It allows the application of theoretical knowledge, safely, and in almost real situations [19–21]. Furthermore, it is important that intubation procedures in a critical setting be standardised in each ICU, and that the entire team adhere to the protocol, if idiosyncratic practices in the use of anaesthesia drugs, pre-oxygenation technique, and deployment of personnel are to be avoided [1]. Implementation of intubation algorithms, locally adapted to each unit, is essential, with an assessment of difficult intubation risk factors [2] and a number of clearly defined strategies matched to the level of anticipated risk.

Table 2
MACOCHA score calculation worksheet (score between brackets).

M. Mallampati score III ou IV (5)
A. Apnoea syndrome (obstructive) (2)
C. Cervical spine limitation (1)
O. Opening mouth < 3 cm (1)
C. Coma (1)
H. Hypoxaemia (1)
A. Anaesthesiologist untrained or a non-anaesthesiologist (1)
Coded from 0 to 12

3.2. Intubation equipment

R 2.1 – Capnographic control of intubation in the intensive care environment is necessary to confirm the correct position of the endotracheal tube, the supraglottic device or the direct approach through the trachea ([Grade 1+] strong agreement).

R 2.2 – It is necessary to have a difficult airway trolley and a bronchoscope (conventional reusable or single use) in intensive care units, for the immediate management of difficult intubation ([Grade 1+] strong agreement).

The NAP4 recommends that a difficult intubation trolley and bronchoscope be immediately available in the proximity of the ICU [24]. A daily check must be performed to ensure that the equipment is present and in good working order and a record kept of each inspection. In addition to oral and nasal masks, tubes and cannula, the difficult intubation trolley equipment should be assembled according to a local consensus of the intensive care team: laryngoscopes with standard and short handles, metallic blades of different sizes, a videolaryngoscope, supraglottic devices (SD), and a cricothyroidotomy kit.

An intubation stylet of a malleable material that can be manipulated to give an endotracheal tube the required curvature is recommended by default in the event of an anticipated difficult intubation or secondarily in the event of unexpected difficult intubation. This device is used in anaesthesia. A specific rigid stylet is obligatory for use with the GlideScope* in accordance with the manufacturer's instructions.

Long, full or hollow guides for tracheal tubes (Cook*, Frova*) may be useful in the context of difficult intubation. They may be straight or bent and are identical to those used in anaesthesia. Their role in the intensive care intubation algorithm is under review.

Advances in the design of bronchoscopes have increased choice. Classical fiberscopes have been joined by several other types of disposable bronchoscopes for single or a limited number of uses. These devices, amongst which the aScope* is the best validated, have specific characteristics that make them particularly suitable for endobronchial procedures in intensive care, such as diagnostic endoscopy, bronchoalveolar lavage, percutaneous tracheostomy, and management of atelectasis.

For intensive care intubation, single use fiberscopes and bronchoscopes are recommended as part of the multimodal airway approach, particularly for intubations via SGDs, while the video-laryngoscope-bronchoscope combination, which imposes a longer apnoea time, is a technique mostly associated with anaesthesia [25,26].

The British National Institute for Health and Clinical Excellence (NICE) in 2013 issued recommendations on the aScope and aScope2. Apart from the elimination of infection risk from cross-transmission by multiple use fiberscopes, further benefits of this device were summarised in four essential points. These points were:

- good clinical performance;
- lower health expenditure;
- improved patient safety due to better responsiveness;
- a recommendation for use in the management of unforeseen airway difficulty.

A British survey of 2010 [27], highlights the need for improvement in this field since only 10% of intensive care units had all the desirable equipment in their difficult intubation trolley. In contrast, 94% of British intensive care units have immediate access to a bronchoscope. Although numerically different, this was mirrored in US data published the same year [28].

Having the best equipment and the best-validated approach requires a context of self-improvement and well-maintained theoretical and practical knowledge if the best result is to be obtained.

R2.3 – Metal blades should be used for direct laryngoscopy in ICU to improve the success rate of endotracheal intubation. ([Grade 1+] strong agreement).

The McIntosh laryngoscope remains the most popular device for the first attempt. The use of single use metal disposable blades seems to be widespread in France. In compliance with the SFAR recommendations, plastic disposable blades are not recommended for situations where difficult intubation is anticipated, which is the case for all intensive care intubations. In this context, the blade, whether single use or reusable, must consist of metal.

The detection of lethal infections transmitted by reusable laryngoscope handles emphasises the care that should be taken in their decontamination. Disposable laryngoscopes and disposable monoblocks (Laryngobloc*) are available but their value remains to be validated, especially in intensive care [29–31].

R2.4 – In order to limit intubation failures, videolaryngoscopes (VL) for intubation in intensive care must be used either initially or after failure of direct laryngoscopy ([Grade 2+] strong agreement).

Several VL have been evaluated for intensive care intubation. However, no head to head comparison between available VLs is sufficiently powerful and definitive to favor one particular device over another.

VLs optimize the laryngoscopic view and have their place either initially or after failure of direct laryngoscopy, in all recent DICI algorithms. However, if the VL was not used immediately, its secondary use is optional and does not constitute a prerequisite for the use of a supraglottic device [4]. The use of a VL as first line management, rather than a laryngoscope, when difficulty in intensive care intubation (MACOCHA score ≥ 3) is predicted, is preferred [32,33].

Many devices exist in this category and it is usual to classify them:

- stylets (eg Bonfils*, Sensascope*, RIFL*);
- VL with guide channel for the endotracheal tube (eg Pentax AW Scope*, Airtraq*, KingVision*);
- VL allowing direct viewing as well as optimisation by endoscopic view (eg McGrath Mac*, C-Mac*, Kaplan-Berci DCI* GlideScope*).

Several devices are compatible with single use blades and blades with a guide channel. Some are intended for systematic use and can also be equipped with blades, especially dedicated to difficult intubation via their curvature and/or thickness. Others have reusable blades. We can also distinguish between compact VLs equipped with a screen mounted on the handle, and devices connected to a video system and a remote screen. Devices useful for DICI have been described in detail in several recent publications [34].

Among the evaluated VLs for DICI, the C-Mac* ($n = 117$) performed much better than the MacIntosh ($n = 113$), significantly increasing the intubation success rate on the first attempt from 55% to 79%, and decreasing the incidence of Cormack & Lehane Grades III and IV from 20% to 7%. The methodology of this study has been questioned but the validity of the results remains.

The McGrath Mac* appears to be the best validated VL, since its superiority to the MacIntosh has been shown not only in terms of:

- laryngoscopy quality;
- success in intubation;
- success in the particular group of MACOCHA subjects ≥ 3 [41].

However, the MacGrath Mac does not reduce the incidence of potentially lethal complications in intensive care intubation.

A meta-analysis of 9 studies comparing videolaryngoscopy with direct laryngoscopy for intensive care intubation confirms the VLs value in this context [35]. Out of these 9 studies, 3 are randomised controlled trials in which the VL is a GlideScope*, and of 6 that are observational studies, 4 report on the GlideScope*, and one each report the MacGrath Mac* and the C-Mac*. One trial involves both the GlideScope* and the C-Mac*. In the VL category were 1066 patients (1067 for the direct laryngoscopy group). The VLs increased the success rate of intensive care intubation at the first attempt [OR 2,07 (IC 95% 1,35–3,16; $P < 0.001$)], reduced the incidence of difficult intensive care intubation defined by a need for more than 2 attempts [OR 0,29 (IC 95% 0,20–0,44; $P < 0.001$)], reduced the number of Cormack and Lehane grade 3 or 4 laryngoscopies (OR 0.26 [IC 95% 0,17–0.41; $P < 0.001$]), and reduced the incidence of oesophageal intubation (OR 0,14 [IC 95% 0.02–0,81; $P = 0,03$]) Given the potential morbidity and mortality due to oesophageal intubation in intensive care, this last result seems particularly important, even if the low power of the meta-analysis does not show any gain in terms of survival or avoidance of serious complications. The meta-analysis does not reveal any benefit of VLs for other intensive care intubation complications. It does not reveal any one studied VL to be better than the others.

R2.5 – Supraglottic devices (SGD) must be used in the management of difficult intubation in intensive care, to oxygenate the patient, and facilitate intubation under bronchoscopic control ([Grade 1+] strong agreement).

Supraglottic devices (SGD) are amongst the items of the equipment that must be available for intensive care intubation. Their role is double:

- to oxygenate the patient in the event of failure of mask ventilation or during surgical approach of the trachea;
- to serve as a guide for bronchoscopic intubation in the case of DICI.

The choice of the device depends primarily on the operator's experience but also on the availability of the equipment. The ProSeal® device and similar SGDs, with high leak pressure, could have the advantage of allowing more effective CPAP but this is not supported by trials conducted during resuscitation. The Fastrach® and other SGDs particularly dedicated to intubation, seem a logical choice in the context, despite not having been specifically validated.

It thus appears that for the indication of intensive care intubation support, the ideal SGD is not clearly identified. The choice among the many existing devices therefore remains open and largely a question of personal preference.

R2.6 – Theoretical and practical intubation knowledge must be acquired and diligently maintained ([Grade 1+] strong agreement).

In Britain, lacks of both training and proper judgment are respectively the second and third cause of serious accidents in airway management in intensive care and emergency situations [24]. A consensus of most scientific societies recommends that a training program should combine initial theoretical training, training on mannequins, high fidelity simulation, clinical companionship, and skills maintenance. Among the different modalities, simulation (high or low fidelity) provides a certain didactic benefit compared to other methods. A recent meta-analysis by Kennedy et al. [21] has made it possible to compare several training methods. Compared to no intervention, training with simulation is accompanied by significant improvement in knowledge, shorter duration of the procedure and better technical skills. Simulation instruction, when compared to a method that does not integrate simulation, is associated with a significant improvement in learner satisfaction, better technical skills and clinical effectiveness. The determination of the minimum number of procedures to be carried out by physicians in training during their course is based on studies of small numbers, some of which have been carried out on mannequins. However, the following figures are reasonable guides: 50 to 70 direct laryngoscopies [36,37] (of which 20 have been performed on a mannequin), 20 insertions of a SGD [38,39] (of which 10 have been performed on mannequins), 30 to 60 bronchoscopy assisted intubations [40,41] (including 20 performed on mannequins), 5 crico-thyroidotomies [42,43] (all performed on mannequins [44]) and 20 uses of VL [45] (including 10 on mannequins). For practicing physicians, the 6 techniques to be mastered by all practitioners and regularly re-evaluated are facemask ventilation, direct laryngoscopy, use of the SGD (10 insertions per year on a mannequin), trans-tracheal oxygenation (5 procedures per year on a mannequin) and intubation facilitated by bronchoscopy (10 procedures per year on a mannequin).

3.3. Drugs and intubation of the ICU patient

R 3.1: a hypnotic agent that facilitates rapid sequence induction (RSI) should probably be used (etomidate, ketamine, propofol), the choice depending on medical history and the clinical situation of the patient([Grade 2+] strong agreement).

R3.2: to facilitate tracheal intubation in patients with signs of distress RSI is probably recommended ([Grade 2+] strong agreement).

R3.3: succinylcholine is probably the first-line agent of choice for RSI in patients with vital signs of distress. Rocuronium at a dose above 0.9 mg/kg [1.0–1.2 mg/kg] should be used when succinylcholine is contraindicated. [Grade 1+] Sugammadex should probably be rapidly available when rocuronium is used ([Grade 2+] strong agreement).

Only a few studies have considered which hypnotic agent should be used for endotracheal intubation in critically ill patients in the emergency department or ICU [46,47]. Two randomised controlled trials compared two hypnotic agents in the emergency department and ICU [48,49] and only one of them contributed high quality evidence. Therefore, there is a need for larger phase III studies to determine what is the safest hypnotic/induction agent for use in ICU and the emergency department where the setting for intubation/induction is different to out of hospital or operating room intubation.

The lack of studies on this topic means that recommendations are mainly based on the pharmacological properties of the anaesthetic agents themselves or on experts' opinions [47,48]. None of the available hypnotic agents meet all safety criteria or ideal characteristics and none of them can be recommended as the sole agent to be used for RSI.

Three hypnotic agents can be used routinely for RSI in the critically ill. They are:

- etomidate: a single injection of etomidate for RSI can lead to an increased risk of relative adrenal insufficiency. It could also be associated with an increase in mortality and therefore it should be used with caution in septic patients [48];
- ketamine stimulates the sympathetic system and can be a good alternative to etomidate [48];
- propofol may cause adverse effects including peripheral dilatation and hypotension that can be prevented by prophylactic or early administration of vasoactive drugs [50]. Surveys show that induction with propofol is very common in Anglo-Saxon countries [49–54].

The standard technique for tracheal intubation in patients with vital signs of distress is RSI using a sedative, and a muscle relaxant, which must have an onset fast enough for rapid intubation and duration short enough to permit swift recovery of effective spontaneous ventilation and thus ensure safety. Although succinylcholine has the required properties, it also has major side effects that include anaphylaxis, high blood potassium, bradycardia and arrhythmia that can be life-threatening, and malignant hyperthermia [55,56]. Contraindications to succinylcholine are common in intensive care (hyperkalaemia, neuromuscular junction damage, extensive burns, rhabdomyolysis, and prolonged bedrest) [56]. The only alternative drug to succinylcholine to have undergone serious study is rocuronium. A recent Cochrane review of 50 clinical trials conducted mostly in emergency departments and operating rooms concluded that succinylcholine was superior to rocuronium in achieving excellent intubation conditions (Odds Ratio= 0.86 [0.81;0.92]; $P < 0.001$) although for rocuronium doses above 0.9 mg/kg the difference between the two drugs was not significant [57] There was no difference in the incidence of serious adverse events between the two drugs. A drawback to rocuronium use is the return to recovery time of about 1 hour. However, a 16 mg/kg injection of sugammadex can ensure a fast recovery, even faster than spontaneous recovery with succinylcholine [58] In severely hypoxic patients, intubation without muscle relaxant use has been proposed but no comparative study is available [59].

3.4. Protocols, algorithms and intubation of the ICU patient

R4.1 – Non-invasive ventilation should probably be used for pre-oxygenation of hypoxaemic patients in ICU ([Grade 2+] strong agreement).

R4.2 – It is possible to use high-flow nasal oxygen (HFNO) for pre-oxygenation in ICU, especially for patients not severely hypoxaemic (Expert opinion: strong agreement).

R4.3 – A protocol for intubation including a respiratory component should probably be used in ICU to decrease respiratory complications ([Grade 2+] strong agreement).

R4.4 – A post-intubation recruitment manoeuvre should probably be used in ICU in hypoxaemic patients, by integrating it into the respiratory component. ([Grade 2+] strong agreement).

R4.5 – A PEEP of at least 5 cmH_2O should probably be applied after intubation of hypoxaemic patients ([Grade 2+] strong agreement).

R4.6 – A cardiovascular component should probably be included in the protocol during intubation of ICU patients, by defining conditions of fluid challenge and early administration of catecholamines to decrease cardiovascular complications ([Grade 2+] strong agreement).

A multicentre before and after study has shown that adopting an intubation protocol, which included a respiratory component was associated with a significant decrease in severe complications, especially respiratory events [1].

3.4.1. Respiratory component

NIV appears promising during pre-oxygenation, but no large randomised study has confirmed this [60].

Two recent studies have evaluated HFNO for pre-oxygenation during intubation in ICU (and also for apnoeic oxygenation). A single centre before-and-after study included patients with a variety of reasons for intubation [61]. Hypoxaemic patients were excluded. This study suggested that HFNO dramatically improved oxygenation during intubation in ICU, contradicting the conclusions of the first randomised study of this topic [62]. The"Preoxyflow" study evaluated HFNO for pre-oxygenation of severely hypoxaemic patients and concluded that it offered no advantage in preventing desaturation.

A single centre randomised controlled study did not demonstrate any specific advantage of HFNO for apnoeic oxygenation [63].

With regard to postintubation recruitment, a prospective two-centre intensive therapy study randomised 40 hypoxaemic patients requiring tracheal intubation into two arms: the first with an immediate post-intubation recruitment manoeuvre (RM +) (defined by a 40 cmH2O CPAP for at least 30 seconds), and the second without the recruitment manoeuvre (RM−). In the RM+ group, oxygenation improvement was significantly superior (236 ± 117 vs. 93 ± 36 mmHg and 180 ± 79 vs. 110 ± 39 mmHg, respectively at 2 minutes and at 30 minutes, $P < 0.05$ compared to the RM− group). This improvement was obtained without cardiovascular compromise or barotraumatic complications in the RM+ group [64].

3.4.2. Cardiovascular component

Identifying high cardiovascular risk was evaluated in a multivariate analysis of a first study of 885 patients [65].

The use of a cardiovascular component in the ICU intubation protocol has been evaluated in a single before-and-after study based in 3 centres with 244 patients, all of whom were combined in the analysis. The systematic application of a cardiovascular component in the intubation protocol reduced the incidence of post-intubation cardiovascular collapse and major complications from 27% (before application) to 15% (after) without effect on other secondary endpoints [1].

The application of 5 cmH2O PEEP was evaluated in the previous study and in a randomised controlled non-inferiority study conducted in 63 hypoxaemic patients. Neither of these studies reported adverse effects of PEEP on mean arterial pressure [66].

4. Extubation of the ICU patient

4.1. Prerequisite

R5.1 – We recommend a spontaneous breathing trial (SBT) before any extubation in an ICU patient ventilated for more than 48 hours to decrease the risk of extubation failure ([Grade 1+] strong agreement).

R5.2 – The SBT is inadequate as the sole means of detecting all patients at risk of extubation failure; before extubation we should probably screen for more specific causes and risk factors of failure including ineffective cough, excessive tracheobronchial secretions, swallowing disorders and altered consciousness ([Grade 2+] strong agreement).

Daily screening of simple criteria to assess readiness to wean from mechanical ventilation (MV) even arterial blood gas evaluation of a SBT are the gold standard for any weaning/extubation strategy, that ideally, should be set out in a protocol that includes withdrawal of sedation [7–9]. Despite being subject to recent debate, using a SBT to predict a successful extubation (respiratory rate = 10–30 min, SpO2 > 92%, the absence of exhaus-

tion, agitation, hypertension and tachycardia) [6], whatever the technique used (pressure support or T-tube), remains the best method [8,67]. Indeed, 30 to 40% of patients extubated following an SBT failure may need to be reintubated [11]. In the same way, 40 to 60% of unplanned extubations (self or accidental), without the benefit of a SBT by definition, could be reintubated [68,69]. The SBT does not allow, however, any prediction of the consequences of endotracheal tube removal, particularly in terms of upper-airways obstruction or increased resistance, lack of airway protection, cough efficiency and drainage of tracheo-bronchial secretions [70–76]. Consequently, despite a successful SBT, failure of planned extubation may occur in 10 to 20% of cases according to more recent clinical studies [75,77–82], with very large ranges from 5% to more than 30%, according to the populations under study (respiratory failure, cardiac failure, post-surgical etc), the previous duration of MV, the definitions used, and the results and type of observational or interventional studies analysed [83]. Although a low rate of reintubation can certainly be the result of a non-therapeutic postponement of weaning, a high rate, conversely, may imply a lack of management in the weaning and extubation process. Accordingly, the ICU clinician should make every effort to reduce the rate of extubation failure to between 5 and 10%, the level considered as potentially acceptable in ICU patients [83].

The SBT therefore, seems inadequate as the sole means of detecting patients at risk of extubation failure. To improve the success rate, specific risk factors for, and the potential causes of, extubation failure should be sought, and indeed, numerous causes and risk factors for failure of the weaning and extubation process have been described [7,73–76,78,84]. Predictably, they can be more or less chronologically associated in time in the same patient, and some of them might be more specific predictors of extubation failure. Whilst it might make sense to concentrate on these factors (upper-airways obstruction, ineffective cough, excessive tracheo-bronchial secretions, swallowing disorders and altered consciousness), there is insufficient scientific data to indicate that, either singly or together, they might be usefully employed to limit the risk of reintubation. Nevertheless, these risk factors probably merit screening before any extubation in a patient who is ready to be withdrawn (or weaned) from the ventilator [7].

4.2. Extubation failure in ICU

R6.1 – A cuff leak test should probably be performed before extubation to predict the occurrence of laryngeal oedema ([Grade 2+] strong agreement).

R6.2 - A cuff leak test should be performed before extubation in ICU patients with at least one risk factor for inspiratory stridor to reduce extubation failure related to laryngeal oedema ([Grade 1+] strong agreement).

R6.3 – Measures to prevent and treat laryngeal pathology should probably be implemented during mechanical ventilation ([Grade 2+] strong agreement).

R6.4 – If the leak volume is low or nil, corticosteroids should probably be prescribed to prevent extubation failure related to laryngeal oedema ([Grade 2+] strong agreement).

R6.5 – Once corticosteroid therapy is decided, it should be started at least 6 hours before extubation to be effective ([Grade 2+] strong agreement).

Laryngeal pathology is present in more than 75% of ventilated patients [85]. Its forms include in decreasing order of frequency: oedema, mucosal ulceration, vocal cord paresis, and granuloma [85]. More than one pathology may be present at the same time and, with the exception of ulcers, may contribute, after extubation, to inspiratory stridor. Data on risk factors for inspiratory stridor are controversial and reports are sometimes contradictory, but the main criteria reported are: female gender, nasal route for intubation, difficult, traumatic or prolonged intubation, use of a large endotracheal tube (compared to patient size), and high tracheal cuff pressures [86–88].

Laryngeal oedema is best diagnosed by a cuff leak test performed immediately before extubation in those who have successfully completed a trial of spontaneous breathing [89]. The leak volume is usually estimated as follows:

- oral and tracheal aspiration is performed with the patient in the semi-recumbent position and the ventilator set in the assist-control mode;
- inhaled and exhaled tidal volumes (Vt) must be equal before deflating the balloon;
- after balloon deflation the expired Vt is estimated (average of the three lowest values among the six values recorded); the absolute leak volume is the difference between the inspired Vt (before deflating the balloon) and the expired Vt (after deflation of the balloon); the relative leak volume is the ratio of the absolute leak volume and the inspired Vt. A lower leak volume defines a positive cuff leak test.

The most frequently used thresholds are < 110 mL of absolute leak volume or $< 10\%$ of relative leak volume, but these thresholds and the Vt used vary widely from study to study. The variation may be due to the lack of standardisation of the ventilatory settings, the contribution of inspiratory and expiratory leaks, and also the influence of respiratory mechanics on the leak [90]. This quantification is sometimes complex in clinical practice and may be replaced by a qualitative test where the tube is obstructed with a finger while the patient is normally breathing, and the presence of leaks is assessed by an audible respiratory flow [91].

The cuff leak test generally has a good specificity and negative predictive value (effective for identifying low-risk patients) but a low sensitivity and positive predictive value (inefficient for identifying high-risk) [92]. It is probably useful in patients with at least one risk factor for post-extubation inspiratory stridor. Other diagnostic approaches that have been proposed include comparison of the relative leak volume just after intubation and just before extubation [93], and ultrasound assessment of the column of air around the endotracheal tube before and after deflating the balloon [94–96], but they have not significantly improved the clinical value of the test.

Inspiratory stridor usually occurs within minutes following extubation, and affects 1 to 30% of patients depending on the series reported [85,87]. The occurrence of severe inspiratory stridor increases the risk of reintubation [87], affecting around 15% in recent series. Some 15% of early reintubations (within 48 hours of extubation), are attributable to inspiratory stridor, representing 1–4% of all extubations [85,87,97].

The prevention of pathology in the larynx requires eradication of risk factors whenever possible, including the choice of a "moderate" diameter for the endotracheal tube (typically 8 mm in men and 7 mm in women), accelerating weaning from mechanical ventilation to minimise its duration, monitoring and regulating the pressure of the balloon to prevent undue pressure on the mucosa.

Prophylactic treatment of inspiratory stridor with corticosteroids (prednisolone 1 mg/kg/day or equivalent) may be considered for patients with a low cuff leak volume before extubation, but the low positive predictive value, and its associated false positives, exposes some to unnecessary treatment [87]. For a course of steroid to be effective, it requires the selection of patients at risk (low cuff leak volume) and its initiation at least 6 hours before extubation, at best with fractioned doses [98]. Not all studies have shown that steroid reduces the incidence of reintubation [99]. The use of an exchange catheter during extubation for reintubation in

the event of severe laryngeal oedema or for emergency ventilation is theoretically interesting; however, the identification of patients likely to benefit from this device is not easy.

The treatment of post-extubation inspiratory stridor is not standardised; systemic corticosteroids together with aerosols of adrenaline have been suggested [87,100]. If respiratory distress develops, reintubation should not be unduly postponed, and the use of non-invasive ventilation post-extubation could be deleterious [101]. However, some paediatric series suggest that helium to reduce turbulence and airway resistance in this setting could be helpful [102,103].

4.3. Respiratory therapy and extubation in the ICU

R7.1 – As a prophylactic measure, we suggest high-flow oxygen therapy via a nasal cannula after cardiothoracic surgery ([Grade 2+] strong agreement).

R7.2 – As a prophylactic measure, we suggest high-flow oxygen therapy via a nasal cannula after extubation in ICU for hypoxaemic patients and those at low risk of reintubation ([Grade 2+] strong agreement).

R7.3 – As a prophylactic measure, we suggest the use of non-invasive ventilation after extubation in ICU for those at high-risk of reintubation, especially hypercapnic patients ([Grade 2+] strong agreement).

R7.4 – As a therapeutic measure, we suggest the use of non-invasive ventilation to treat acute postoperative respiratory failure, especially after abdominal surgery or lung resection ([Grade 2+] strong agreement).

R7.5 – As a therapeutic measure, we suggest that non-invasive ventilation may not be used to treat acute respiratory failure after extubation in ICU, except in patients with underlying chronic obstructive pulmonary disease (COPD) or when there is obvious cardiogenic pulmonary oedema. ([Grade 2−] weak Agreement).

R7.6 –Treatment from a physiotherapist is probably required before and after endotracheal extubation following mechanical ventilation for more than 48 hours to reduce the duration of weaning and the failure of extubation ([Grade 2+] strong agreement).

R7.7 – A physiotherapist should probably attend endotracheal extubation, to limit immediate complications such as bronchial obstruction in patients with high risk of extubation failure ([Grade 2+] strong agreement).

In the ICU, extubation failure is usually defined as the need for reintubation within 48 or 72 hours following planned extubation [7,10]. This time is sometimes extended up to 7 days, especially when non-invasive ventilation has been used after extubation [11,12]. The longer time limit is proposed because around one-fourth of patients who fail extubation are reintubated after the first 48 h [12]. The overall rate of reintubation is around 15% in ICU, but rises to 20–30% in those most at risk [11,77]. The decision to extubate is difficult for clinicians because failure carries a high mortality, with a rate as high as 25% to 50% [10].

Even though the majority of extubated patients are treated with facial oxygen immediately after planned extubation, the use of high-flow oxygen therapy via a nasal cannula or non-invasive ventilation (NIV) could help to avoid extubation failure. Therapeutic NIV in patients with post-extubation respiratory distress should be clearly distinguished from prophylactic NIV aimed at preventing respiratory distress. Prophylactic NIV is initiated immediately after extubation for a period of 24–48 hours, when there are no signs of respiratory failure. By contrast, therapeutic NIV is started when the patient exhibits the first signs of respiratory distress. In both cases, the patient must be ready for extubation; having successfully passed a weaning trial that conforms to the international conference consensus on weaning [7].

During the post-extubation period, NIV may theoretically have beneficial effects that include improvement in oxygenation and alveolar ventilation, alveolar recruitment in patients with atelectasis, improvement of left ventricular function in patients with cardiac heart failure, decreased intrinsic PEEP in COPD patients and, especially, a significant reduction in the work of breathing [104]. However, NIV may have also deleterious effects by masking signs of respiratory distress and delaying reintubation [101].

Six randomised controlled trials (RCTs) of prophylactic NIV have been carried out in ICUs [105–110]. The majority of these studies included patients at high risk of reintubation [105–109]. Despite differing inclusion criteria, the patients considered at high risk were mostly those aged over 65 years or with heart failure or underlying chronic lung disease. Immediately after planned extubation, they were randomised and treated with either NIV or facial oxygen. Most of these studies found that NIV had beneficial effects with a significantly decreased risk of acute respiratory failure [105–108], and those patients who seemed to benefit the most were hypercapnic [105–107]. However, only two studies found that the reintubation rate was significantly decreased [105,108]. Only one study included patients without risk factors for extubation failure and in this situation NIV failed to show higher efficacy compared to facial oxygen [110]. By pooling results from these 6 multicentre studies of prophylactic NIV in the ICU [105–110], the odds ratio for reintubation was found to be lower in patients given prophylactic NIV than in those treated with facial oxygen, but the difference was not significant: OR 0.80 (95% CI, 0.64–0.01), $P = 0.06$. By considering only the five studies that included high-risk patients [105–109], the odds ratio for reintubation was found to be significantly lower with prophylactic NIV than with facial oxygen: OR 0.63 (95% CI, 0.45–0.87), $P = 0.003$.

For therapeutic NIV in the ICU there are only two studies published to date [101,111]. After planned extubation, patients who developed signs of respiratory distress were randomised and given either NIV or facial oxygen. Although the majority of patients included were there for medical reasons, 16% in the first study [111] and 27% in the second [101] were either admitted postoperatively or following polytrauma. When the results of these two studies were pooled, the odds ratio for mortality was significantly higher in those treated with NIV than with facial oxygen: OR 1.36 (95% CI, 1.09–1.69), $P = 0.01$. Few patients with COPD were included; they were excluded in the first study and represented less than 10% in the second. Several studies used therapeutic NIV in COPD patients who had developed acute respiratory failure during the post-extubation period [108]. In these studies, the rate of failure was particularly high and around 40 to 50% needed reintubation. Whereas NIV is clearly recommended as first-line therapy in COPD with acute respiratory failure or with severe cardiogenic pulmonary oedema, it is difficult to determine a beneficial effect of NIV in the treatment of acute respiratory failure post-extubation.

There are two studies of NIV in postoperative patients that showed no difference between prophylactic NIV and facial oxygen after cardiac surgery [112] and thoracic surgery [113]. Only one randomised controlled trial has assessed therapeutic NIV in patients with acute respiratory failure after lung resection [114]. In a small sample, the rate of intubation was lower in patients treated with therapeutic NIV than in those treated with facial oxygen. After abdominal surgery, a large RCT recently observed a significantly decreased rate of intubation with therapeutic NIV compared to facial oxygen in patients with acute respiratory failure within the first 7 postoperative days [115]. Another postoperative study found that the intubation rate fell in patients with hypoxaemia following abdominal surgery if they received prophylactic continuous positive airway pressure (CPAP) [116].

Three RCTs of the use of high-flow oxygen therapy via a nasal cannula after extubation have recently been published [101,117,118]. In two, patients extubated in the ICU were treated with either HFNC or facial oxygen [117,119]. The rate of reintubation decreased in both hypoxaemic patients [119], and in those considered at low risk for extubation failure [119]. In another RCT, HFNC was compared to prophylactic and therapeutic NIV after cardiothoracic surgery [118]; no difference was found between these two oxygenation strategies. Physiotherapy in mechanically ventilated patients incorporates a variety of respiratory techniques and physical therapy [120]. Physiotherapy for bronchial obstruction, including hyperinflation techniques, modulation of expiratory flow, and postural drainage can significantly limit reintubation [121–123]. The benefits of these techniques are seen in the time to wean [124,125], the success rate of weaning [120,124] and the duration of mechanical ventilation [120,121,123,124,126–129]. However, physiotherapy for bronchial obstruction does not appear to limit post-extubation atelectasis.

The results of several studies, mainly paediatric, are contradictory [121–123,126].

Finally, the presence of a physiotherapist to administer cough-assist techniques to manage bronchial obstruction after extubation would limit the number of reintubations [130]. Another physiotherapy technique in mechanically ventilated patients involves the ‘‘training’ of inspiratory muscles. Study results show a significant benefit in the incidence of success with weaning with this technique [131–134], but there is no significant benefit in the rate of reintubation [132,135], the duration of mechanical ventilation [134,136,137] and data on the time to wean are contradictory [131–133,136].

There are conflicting results on the effects of physiotherapy to the limbs on the duration of mechanical ventilation. Some studies show a significant reduction in the duration of mechanical ventilation [128,138,139], but overall the results tend to contradict [140,141]. No significant effect was found on the success rate of weaning [139]. The mobilisation of extubated patients shows conflicting results [137,142,143]. There is little data to support the role of the physiotherapist before and after extubation, but experts emphasise the need for the presence of a physiotherapist at the extubation of patients with impaired cough force and a high risk of bronchial obstruction.

5. Paediatric Intensive Care

5.1. Intubation

5.1.1. Complicated intubation in PICU

R1.1 (paediatrics) – All patients admitted to paediatric intensive care units must be considered at risk of complicated intubation ([Grade 1+] strong agreement).

R1.2 (paediatrics) – To reduce the incidence of complicated intubation in the paediatric intensive care unit, respiratory and cardiovascular complications must be anticipated and prevented by diligent preparation for intubation that includes preservation of oxygenation and cardiovascular stability throughout the procedure ([Grade 1+] strong agreement).

R1.3 (paediatrics) – For children, risk factors of complicated intubation must be distinguished from predictive factors for difficult intubation ([Grade 1+] strong agreement).

Intubation in the PICU (paediatric intensive care unit) is a common procedure carried out in 90% of respiratory admissions [144]. It is linked to complications (cardiopulmonary arrest, unrecognized oesophageal intubation, massive aspiration, severe hypotension requiring volume expansion and/or vasopressors, laryngospasm, malignant hyperthermia, pneumothorax or pneumomediastinum, direct injury of the airways) in about 20% of non-severe, and 3 to 6% of severe cases [144,145]. Care should be taken to prevent these complications by improving the management of intubation in the PICU. Few studies have examined risk factors for difficult and/or complicated intubation in the PICU. A US registry (NEAR4KIDS) that included data from 15 PICU, recently provided more accurate data on the subject [144,146]. It showed an association between severe complications of intubation (115 out of 1715 intubations, 6.3%) and either haemodynamic instability or respiratory failure or both [144]. There was also an association between less severe complications of intubation and a history of difficult intubation, haemodynamic instability and the degree of operator experience. In children from the same register, the rate of difficult intubation was 9% of 1516 children. The risk factors for difficult intubation from univariate analysis with no adjustment for the experience of the operator were: younger age, low weight, intubation for respiratory failure, inadequate sedation or neuromuscular blockade, and signs of upper airways obstruction. A history of difficult intubation, limited mouth opening, limitation of cervical mobility, low thyroid-chin distance, and mandibular hypoplasia were all associated with difficult intubation, but only the negative predictive value was indicative. By adjusting these criteria for skilled operators for intubation, only two risk factors for difficult intubation were identified: a history of difficult intubation (OR 1.83 95% CI (1.02–3.29); $P = 0.04$), and the presence of signs of upper airways obstruction (OR 1.91 95% CI (1.09–3.35); $P = 0.02$). The Macocha score has not been validated in children.

5.2. Intubation equipment

R2.1 paediatric: for tracheal intubation in the PICU, laryngoscope blades familiar to clinicians should be used (Miller straight blade or Macintosh curved blade). After failure to achieve a laryngeal view with one blade, an attempt with another should be made ([Grade 2+] strong agreement).

The selection of the type of direct laryngoscopy blade is a frequent issue in PICU and Paediatric Emergency Department, especially in children under 2 years of age. Intubating with a Miller straight blade requires lifting the long and floppy epiglottis out of the line of sight to visualise the glottis, whereas the Macintosh curved blade is inserted into the vallecula depressing the hyoepiglottic ligament and flipping the epiglottis upwards, exposing the laryngeal inlet (epiglottis and glottis) [147]. Two recent studies compared these two types of blades for direct laryngoscopy in children [147,148]. The first [147] compared the POGO (percentage of glottic opening) score between the two types of blades in 50 children under 2 years of age, randomised into two groups of 25 children. POGO scores were similar in the two groups. The second [148] was a crossover-randomised study in 120 children under 2 years of age comparing Miller and Macintosh blades (one laryngoscopic view with each blade then intubation after the second laryngoscopic view). The authors found no difference in laryngoscopic views and intubation conditions and suggested switching from one blade to the other in the case of poor visualisation. These two studies are judged to be of a weak level of evidence because of small effectives and objectives limited to visualisation, and failing to give success and complications of intubation adequate priority.

R2.2 paediatric – In order to limit intubation failure in children, videolaryngoscopes (VL) for intubation in intensive care must be probably used either initially or after failure of direct laryngoscopy ([Grade 2+] strong agreement).

Paediatric studies addressing the use of videolaryngoscopes in children for tracheal intubation were conducted in the setting of anaesthesia [149] outside any emergency context. A few studies on manikins with emergency scenarios [150,151] found no improvement in intubation conditions or successful intubation with the use of videolaryngoscopes. A recent meta-analysis [149] included 14 paediatric randomised controlled studies. The primary outcome was the time to intubation and secondary outcomes were visualisation of the glottis, successful intubation at the first attempt, and intubation associated complications. Studies included in the meta-analysis were rather heterogeneous (I^2 90% for time to intubation and 67% for successful intubation) with children of various ages and various types of videolaryngoscopes used. Only one study addressed complicated intubation by simulating cervical stiffness; all other children included had routine intubating conditions. Glottis visualisation was better with videolaryngoscopes compared to direct laryngoscopy (sub-group analysis). Successful intubation (10 studies, 718 patients) was not different between groups (RR: 0.96; 95% CI: 0.92–1.00; $I^2 = 67\%$). Time to intubation (14 studies, 980 patients) was prolonged with the videolaryngoscope (WMD: 4.9 s; 95% CI: 2.6–7.1; I2 = 90%), except in the Airtraq sub-group (WMD: 0.6 s; 95% CI: 7.7–8.9; $I^2 = 94\%$). Global rate of complications was similar (RR: 1.11; 95% CI: 0.39–3.16; I2 = 0%).

This meta-analysis does not support the use of videolaryngoscopes in the PICU because there are numerous potential flaws and no studies in the PICU were included.

A recent multicentre prospective observational study including 1053 intubations over 10 years in 13 centres in Australia, USA and Canada, found a significantly enhanced success at first-attempt with videolaryngoscopy (51 intubations) and rapid sequence induction. This study has numerous limitations such as a collection bias (self-reporting), modification of practices during the study period, and non-randomisation [152].

R2.3 (paediatrics) – Oral intubation is probably preferred for children in intensive care units ([Grade 2+] strong agreement).

R2.4 (paediatrics) – Cuffed tubes are probably preferred in children in intensive care units in order to limit the number of reintubations for leakage ([Grade 2+] strong agreement).

Publications comparing complications of oral versus nasal intubations in paediatric intensive care mostly study neonates. One such Cochrane review from 2000 [153] found that nasal intubation in neonates is more difficult and oral intubation is preferred for inexperienced operators. The incidence of post-extubation atelectasis appears to be more frequent following nasal intubation, but this was mainly in preterm infants of very low birth weight. There were no significant differences between oral and nasal intubation with regard to incorrect positioning of the tube, the incidence of accidental extubation, tube obstruction, the need for reintubation after extubation, infections and local trauma. These findings in neonates can probably be extrapolated to infants but not to children of all ages. Only one article from Moore et al. [154] compared the incidence of sinusitis in paediatric resuscitation according to the type of intubation and no significant difference between the two groups (subgroup analysis) was found.

Since Eckenhoff's work about the laryngeal anatomy of children, many manuals have recommended the use of uncuffed tubes for children under 7–8 years. However, this dogma has been the subject of widespread discussion ever since. With uncuffed tubes, even of the appropriate size, the leakage pressure is not predictable. Indeed, a small leak could be deliberately sought. If the leak becomes too large and compromises ventilation, the child must be re-intubated with a larger tube. The number of reintubations for leaks is reduced by the use of a cuffed tube [155]. The main complication feared when using a cuffed tube for children under 8 years admitted to the PICU is the risk of mucosal damage and respiratory complications after extubation. Several paediatric studies deal with this subject. Provided cuff pressure monitoring is rigorous there is no evidence that the cuff increases the incidence of post-extubation stridor or subglottic lesions. In 1994, Deakers et al. [156] published a non-randomised series of 282 intubations with or without a cuffed tube. No difference in the incidence of post extubation stridor was found. A second non-randomised report with 860 cases [157] found that the use of epinephrine aerosols for subglottic laryngeal oedema in the cuffed tube group was no more frequent than in the uncuffed. Finally, a meta-analysis including studies in the operating room and intensive care unit did not find any increase in the risk of post-extubation stridor in the cuffed tube group [155]. In this meta-analysis the cuffed group is mixed and it includes studies testing cuffs of different shapes and textures (PVC or polyurethane, Microcuff®). The risks and benefits of tubes with a polyurethane balloon of modified shape (microcuffed® type) have not been tested in the PICU. One other possible benefit from the use of a cuffed tube comes from a subgroup analysis that shows a tendency for a reduced incidence of microinhalation in the cuffed tube subgroup [158].

5.3. Drugs and intubation of the PICU patient

R 3.1 (paediatrics): probably the hypnotic agents of choice should permit rapid sequence induction (etomidate, ketamine, propofol) depending on medical history and the clinical situation of the child in PICU ([Grade 2+] strong agreement).

R3.3 (paediatrics): succinylcholine is probably the first-line agent of choice for RSI in the PICU for children with respiratory or cardiovascular compromise. Rocuronium at a dose above 0.9 mg/kg [1.0–1.2 mg/kg] should be used when succinylcholine is contraindicated. [Grade 1+] Sugammadex should probably be rapidly available when rocuronium is used ([Grade 2+] strong agreement).

In 2012, an updating of a 1999 French experts' conference on sedation and analgesia for the tracheal intubation of children in an emergency was published as formal recommendations. They recommended that Etomidate should be the first choice agent in children of more than 2 years of age except in condition such as sepsis. In other situations, ketamine was the recommended option (3 to 4 mg/kg before 18 months of age and 2 mg/kg after) [159].

A recent study conducted in 19 North-American PICU showed that Midazolam was used in 58%, ketamine in 27%, propofol in 14% and etomidate in 2% of 3366 tracheal intubations. Ketamine was used more often in children with haemodynamic instability but its use was not associated with a significantly lower prevalence of new hypotension. Propofol was used preferentially in patients undergoing tracheal intubation for an elective procedure and its use was not associated with higher prevalence of new hypotension [160].

The same recommendations from 2012 advocated the use of RSI in emergency situations [159]. The use of neuromuscular blockade is a part of RSI, whether in an emergency setting or in the PICU, in order to improve conditions of intubation and to limit associated adverse events.

A recent Cochrane meta-analysis [57] included 5 randomised controlled paediatric studies comparing intubating conditions with either succinylcholine or rocuronium. It showed no significant differences between muscle relaxants in obtaining excellent intubation conditions (RR 0.86–CI 0.7 to 1.06) (but high heterogeneity of the meta-analysis: $I^2 = 0.81$). Among the studies analysed, two

found that intubating conditions between succinylcholine (1.5 mg/kg) and rocuronium (0.9 mg/kg) were similar but were worse with rocuronium at 0.6 mg/kg. One study found similar intubating conditions between 1 mg/kg of succinylcholine and 0.6 mg/kg of rocuronium but with rocuronium muscle blockade at one minute was incomplete [161]. One study compared 1.2 mg/kg of rocuronium to 1.5 mg/kg of succinylcholine and found similar excellent intubation conditions at 60 seconds.

There is no significant difference between rocuronium and succinylcholine in obtaining excellent intubation conditions but the longer duration of action of rocuronium may represent a limitation to its use. Furthermore, there is no study addressing the use of the rocuronium antagonist sugammadex in paediatric RSI. When there are contraindications to the use of succinylcholine or a longer duration of muscle blockade is desirable, rocuronium might be the preferred choice.

5.4. Cardiovascular stability and intubation in PICU

R4.1 (paediatrics)–Atropine should probably be administered during induction and before intubation in the PICU for children aged from 28 days to 8 years. This applies particularly in children with septic shock, hypovolaemia or when suxamethonium is used ([Grade 2+] strong agreement).

Tracheal intubation can induce bradycardia through vagal stimulation (in response to hypoxia and/or laryngoscopy) or through a direct effect of drugs such as suxamethonium given at induction. This bradycardia may have no dramatic cardiovascular consequences if there is an associated vasoconstriction [162], but in situations of cardiovascular instability (septic shock or hypovolaemia) with a risk of vasodilatation, bradycardia can induce a significant haemodynamic decompensation [163]. A strong association between bradycardia and arrhythmia and/or conduction disturbances during tracheal intubation was also reported [164].

Some recent studies have addressed the use of atropine in children undergoing tracheal intubation in an emergency context. These were non-randomised prospective cohort studies where the use of atropine was at the discretion of individual intensivists. This methodological bias was corrected with the use of a propensity score. The first study, involved 111 children aged from 29 days to 8 years (66 without atropine and 45 with), and addressed mortality in the PICU [164]. It showed a significant reduction of PICU mortality in children who received atropine before intubation. The second one, involved 103 children aged from 29 days to 8 years (61 without atropine and 42 with), and addressed the prevalence of arrhythmia during the first intubation [164]. It showed a significant reduction in the prevalence of new arrhythmia during intubation in children who received atropine before intubation.

Also, the 2009 consensus conference of the American College of Critical Care Medicine on paediatric septic shock recommended the use of atropine before the intubation of a child in septic shock [165].

6. Extubation

6.1. Prerequisites

R5.1 (paediatrics) – A spontaneous breathing trial (SBT) should probably be performed before extubation of children ventilated in the PICU to decrease the risk of extubation failure ([Grade 2+] strong agreement).

R5.2 (paediatrics)– The SBT being insufficient by itself to detect all children at risk for extubation failure, more specific causes and risk factors for extubation failure including ineffective cough, excessive tracheo-bronchial secretions, swallowing disorders, altered consciousness and factors specific to paediatrics should probably be sought before extubation ([Grade 2+] strong agreement).

One paediatric study showed that a SBT with pressure support was often performed in the PICU [166]. The use of T-piece or a self-inflating bag with a PEEP valve, have also been studied. Repeating the SBT daily reduced the duration of ventilation [167]. The efficiency of a SBT in a child is the same as in adults, with a frequency of reintubation between 10 and 15% [168–170]. Increasing the pressure level in order to compensate for low diameter tube resistance could increase the reintubation risk [171]. A multicentre study including 16 PICU and 1459 children [166] identified risk factor as follows: age $<$ 2-year-old, syndromic and genetic pathologies, chronic respiratory failure, chronic neurologic failure and the necessity to reintubate new ICU admissions.

6.2. Extubation failure in PICU

R6.5 (paediatrics) – When corticosteroid therapy is prescribed, it should be started at least 24 hours before extubation to be effective ([Grade 1+] strong agreement).

In the paediatric literature, the main risk factors for stridor after tracheal extubation are duration of intubation ($>$ 72 hours) [142], age $<$ 2 [143] or $<$ 5 years old [172] and a low level of sedation. The leak test is usually done by applying pressure support of 25 cmH2O and listening for leaks [173]. A negative test might be associated with post-extubation stridor [172], but some authors maintain that this is only true after 7 years of age [174]. Many studies show that the leak test cannot predict an extubation failure. Its sensitivity to predict extubation success varies with studies. When corticosteroid therapy is prescribed (Dexamethasone), at least 24 hours should be allowed for it to become effective [175].

6.3. Respiratory therapy and extubation in the PICU

R7 (paediatrics) – We should probably not use non-invasive ventilation after extubation in the PICU in low risk patients (Expert advice: strong agreement).

In children, non-invasive ventilation (NIV) has been used to prevent reintubation, as a prophylactic measure or as a therapy for respiratory distress. Only one randomised study (a pilot study) compared NIV to oxygen via a nasal cannula after extubation in infants and children (29 days to 3 years old) with a risk of reintubation. No difference was found between groups [176].

Disclosure of interest

J. Pottecher declares to have competing interest with Medtronic. C. Guitton declares to have competing interest with Fisher Paykel. E. l'Her declares to have competing interest with Smith Medical. The others authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.accpm.2017.09.001.

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