

## S2k-Guideline “Prolonged Weaning”\*

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S2k-Leitlinie „Prolongiertes Weaning“

Herausgegeben von der Deutschen Gesellschaft für Pneumologie und Beatmungsmedizin (DGP)

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### Bibliography

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### Abstract

All mechanically ventilated patients must be weaned from the ventilator at some stage. According to an International Consensus Conference the criteria for “prolonged weaning” are fulfilled if patients fail at least 3 weaning attempts (i.e. spontaneous breathing trial, SBT) or require more than 7 days of weaning after the first SBT. This occurs in about 15–20% of patients.

Because of the growing number of patients requiring prolonged weaning a German guideline on prolonged weaning has been developed. It is an initiative of the German Respiratory Society (Deutsche Gesellschaft für Pneumologie und Beatmungsmedizin e.V., DGP) in cooperation with other societies (see acknowledgement) engaged in the field chaired by the Association of Scientific and Medical Societies in Germany (Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften, AWMF).

This guideline deals with the definition, epidemiology, weaning categories, underlying pathophysiology, therapeutic strategies, the weaning unit, transition to out-of-hospital ventilation and therapeutic recommendations for end of life care. This short version summarises recommendations on prolonged weaning from the German guideline.

### Zusammenfassung

Die Entwöhnung von der maschinellen Beatmung (Weaning) umfasst einen wesentlichen Teil der gesamten Beatmungszeit. Dabei kommt es bei ca. 15–20% der Patienten zu einem prolongierten Weaning, das nach internationaler Vereinbarung dann angenommen wird, wenn das Weaning erst nach drei erfolglosen Spontanatmungsversuchen (Spontaneous Breathing Trial = SBT) oder nach über 7 Tagen Beatmung nach dem ersten erfolglosen SBT gelingt. Auf Initiative der Deutschen Gesellschaft für Pneumologie und Beatmungsmedizin e.V. (DGP) gemeinsam mit anderen wissenschaftlichen Gesellschaften und unter der Moderation der Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF) e.V. wurde der aktuelle Wissensstand zum Thema „Prolongiertes Weaning“ in einer S2k-Leitlinie zusammengefasst. In dieser Leitlinie werden Definitionen, Epidemiologie und Weanungskategorien, die zugrunde liegende Pathophysiologie, die verfügbaren Therapiestrategien, die Weaningeinheit, die Überleitung in eine außerklinische Beatmung und schließlich Empfehlungen zu Therapieentscheidungen am Ende des Lebens bei prolongiertem bzw. erfolglosem Weaning abgehandelt. Die Besonderheiten bei pädiatrischen Patienten werden innerhalb der einzelnen Kapitel jeweils gesondert behandelt. In der vorliegenden Kurzfassung werden die wesentlichen Aspekte und Empfehlungen dieser Leitlinie zum prolongierten Weaning vorgestellt.

\* **Authors' contributions:** The authors listed in this publication represent the leaders of the different subject areas during the guideline development. They all participated in the consensus conferences of this project and had responsibility for the preparation of the original document. BS, OM, JG and DD structured, prepared and translated the English written document for this publication.

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## 1 Introduction

Mechanical ventilation (MV) is applied to treat respiratory insufficiency caused by failure of oxygenation and/or respiratory muscles to improve gas exchange and/or reduce the work of breathing. As soon as the clinical status is improving, the process of liberation from respirator (weaning) can be initiated. In about 15–20% of patients the weaning process is significantly delayed. “Prolonged weaning” is defined by failure of at least 3 spontaneous breathing trials (SBT) or, if the process lasts more than 7 days, after the first SBT. The population with prolonged weaning is challenging since treatment of these patients requires great experience of invasive and non-invasive mechanical ventilation, adjunctive treatment strategies and intensive care medicine. Moreover, successful weaning often requires a joint multidisciplinary treatment approach (e.g. intensive care medicine, internal medicine, thoracic surgery, otolaryngology, phoniatry/speech therapy, physiotherapy, occupational therapy, pain management, psychiatry and neurology).

If weaning fails, patients may be transferred to home or to an out-of-hospital or nursing facility, which is specialised in long-term mechanical ventilation. In a subpopulation of patients, dependant on long-term MV with low life expectancy, palliative treatment might be appropriate.

The long version of S2k-guideline was published in response to the increasing number of patients requiring prolonged weaning.

This paper summarises the background and recommendations of the guideline [1]. Moreover important aspects that were considered in the full version of the guideline, but did not lead to a recommendation, are summarised (general considerations). Special considerations related to pediatric patients, which were incorporated in the German S2k-guidelines are not presented in this summary.

## 2 Methods and proceedings

The guideline was officially initiated as S2k-guideline in November 2008 by the German Respiratory Society in cooperation with other societies (see acknowledgment) engaged in the field and chaired by the Association of Scientific Medical Societies in Germany. 15 German societies delegated 34 representatives. Representatives from the medical industry joined the conferences but had no right to vote.

### 2.1 Selection, review of literature and grading of recommendations

The initial literature review was carried out by specific search terms (key words) in the Cochrane databases, PubMed/MEDLINE and Embase. During the guideline development the literature review was updated. By October 2012, based on a total of 8130 papers, 526 references were included.

For the majority of subject areas publications had low evidence levels. In particular, no randomised controlled or other high quality studies were published on prolonged weaning. Therefore, recommendations were ranked at the level of expert opinion (evidence level V, expert opinion without explicit critical appraisal; i.e. recommendation level E), although with respect to a few topics a higher level of evidence and grade of recommendation was possible.

On the basis of 3 consensus conferences the steering committee wrote the manuscript of the guideline which was then reviewed by the associated scientific societies. The review process was finished in June 2013 with a validity period to January 2017.

### 2.2 Definition, epidemiology and weaning categories

In general the process of MV through an endotracheal tube is divided into 6 stages according to the results of an International Consensus Conference published by Boles and coworkers [2]:

1. Treatment of acute respiratory failure
2. Readiness to wean
3. Daily screening for weaning potential
4. Spontaneous breathing trial
5. Extubation or decannulation
6. Reintubation or recannulation respectively

The weaning process starts with phase 4, i.e. the SBT. Identification of the correct time to initiate phase 4 (SBT) and phase 5 (extubation/decannulation) are of high prognostic importance, as they translate into other outcome parameters such as duration of MV, length of ICU stay as well as stay in hospital. **Weaning success** is defined as extubation/decannulation without further MV for at least 48 hours. **Weaning failure** is defined by 1) failed SBT, 2) reintubation/recannulation and/or reinitiation of MV and 3) death within 48 hours after extubation.

Non-invasive MV (NIV) is an established intervention within the weaning process. NIV may prevent secondary weaning failure after extubation, in particular in patients suffering from chronic respiratory failure or heart failure. A patient with short-term or

long-term NIV after extubation or decannulation is not completely weaned during this intervention. On this background the guideline distinguishes between “complete weaning” and “weaning from invasive MV”.

## 2.3 Weaning classification

Prolonged weaning is mainly caused by an imbalance of ventilatory demand and ventilatory capacity, which leads to hypercapnic ventilatory insufficiency due to overloaded or weak respiratory muscles, i.e. the respiratory pump. The International Consensus Conference defines 3 weaning categories (Table 1) [2]. Category 1, 2 and 3 are distributed in a ratio of about 60:25:15% [3]. Compared to category 1 and 2, patients with prolonged weaning have the highest mortality rate. Category 3 comprises a heterogeneous population with different diagnoses, severity of illnesses and co-morbidities. Therefore this group was further divided into 3 subgroups according to their weaning course (Table 1). The pathophysiology and potential causes of muscular respiratory insufficiency are given in Table 2.

## 3 Strategies in the weaning process



### Recommendations

- ▶ In particular in patients with neuromuscular diseases with a pre-extubation/decannulation peak expiratory flow of less than 60 l/min, intensive management of bronchial secretions is recommended.
- ▶ The cuff-leak-test should be performed before extubation to predict post-extubation stridor.

### General considerations:

- ▶ The criteria of weaning readiness have to be met (Table 3).
- ▶ The measurements of physiological parameters are helpful predictors of weaning success or failure.
- ▶ In case of cough insufficiency intensive non-invasive secretion management after extubation/decannulation is necessary.
- ▶ Protocol-based weaning may increase the rate of successful weaning. However, the presence of an experienced weaning team, of structured review and adequate staff numbers might produce similar results.

**Table 1** Weaning categories and subgroups of prolonged weaning (category three).

Group	Category	Definition
1	Simple weaning	Successful weaning and extubation with the first SBT
2	Difficult weaning	Successful weaning and extubation after initial failure but at the latest with the 3 <sup>rd</sup> SBT or within 7 days of mechanical ventilation after the first failed SBT
3	Prolonged weaning	Successful weaning after at least 3 failed SBT's or MV longer than 7 days after the first failed SBT
3a	Prolonged weaning without NIV	Successful weaning after at least 3 failed SBT's or MV longer than 7 days after the first failed SBT without the use of NIV
3b*	Prolonged weaning with NIV	Successful weaning after at least 3 failed SBT's or MV longer than 7 days after the first failed SBT in combination with NIV; if necessary continued into out-of-hospital (home) MV <sup>1</sup>
3c	Weaning failure	Death or discharge with invasive MV via tracheostomy

SBT = Spontaneous breathing trial; NIV = Non-invasive ventilation

\* Subgroup 3b consists of a) patients with intermittent NIV, which is finished during the stay in hospital and b) patients who continue to depend on NIV after discharge from hospital.

### Comment:

Prolonged weaning is associated with a broad spectrum of complications (e.g. early and late damage of the airways, nosocomial infections) depending on the duration of MV. Therefore strategies are needed to shorten duration of invasive mechanical ventilation and the weaning process.

In simple and difficult weaning the measurement of physiological parameters, e.g. the ratio of respiratory rate to tidal volume (Rapid Shallow Breathing Index; RSBI) during spontaneous breathing is helpful to get predictors of weaning success or failure [4,5]. In contrast spontaneous breathing trials during prolonged weaning are an essential part of the weaning strategy rather than a diagnostic tool. Spontaneous breathing alternating with MV helps to recondition the respiratory muscles [6,7].

**Table 2** Pathophysiology and causes of respiratory muscle insufficiency.

Cause for muscle insufficiency	Category	Mechanisms	Underlying diseases and/or causes
Weakness of respiratory muscles	Respiratory centre Peripheral nerves Respiratory muscles	Ischemia, infection, neuritis, nerve damage	Encephalitis, diaphragm paresis, Guillain-Barre-Syndrom, CIP, ALS, diabetes mellitus, CIM, VIDD, myasthenia, Duchenne muscular dystrophy, post-polio-syndrom
Overload of respiratory muscles	Airways	Obstruction, hyperinflation, n. laryngeus recurrens paresis	COPD, cystic fibrosis
	Lung parenchyma	Reduced compliance Reduced gas exchange area	Pulmonary oedema, fibrosis
	Oxygen transport	Anemia, methemoglobinemia Reduced perfusion	Bleeding, blood sampling, infection, drugs Heart insufficiency, PAH, pulmonary emboly
	Thoracic cage	Reduced compliance	Pleural effusions, scoliosis, post-TBC-syndrom
	Oxygen consumption	Increased metabolism	Catecholamines, agitation, infection
	Metabolism		Hypothyroidism, malnutrition, electrolyte imbalance

CIP = Critical illness polyneuropathy, ALS = Amyotrophic lateral sclerosis, CIM = Critical illness myopathy, VIDD = Ventilator induced diaphragmatic dysfunction, COPD = Chronic obstructive pulmonary disease, PAH = Pulmonary arterial hypertension

**Criteria for weaning readiness**

Clinical criteria	<ul style="list-style-type: none"> <li>– Sufficient cough</li> <li>– No excessive secretion</li> <li>– Resolution of the acute cause of respiratory failure and need for intubation</li> <li>– No acute infection</li> </ul>	
Objective criteria	– Clinical stability	– Obstruction, hyperinflation, nervus laryngeus recurrens paresis
	– Adequate oxygenation	– $\text{SaO}_2 \geq 90\%$ at an $\text{FiO}_2 \leq 0.4$ (if existent chronic respiratory insufficiency $\text{SaO}_2 > 85\%$ ) – or $\text{paO}_2/\text{FiO}_2 > 150$ – $\text{PEEP} \leq 8 \text{ cmH}_2\text{O}$
	– Adequate pulmonary function	– $\text{RR} \leq 35/\text{min}$ – $\text{VT} > 5 \text{ ml/kg}$ – $\text{RR}/\text{VT} < 105$ (= RSBI) – No significant respiratory acidosis
	– Adequate mental/neurological function	– No sedation or adequate function under sedation (RASS-Score 0/–1)

RR = Respiratory rate; VT = Tidal volume; RASS = Richmond agitation and sedation score, PEEP = Positive endexpiratory pressure; RSBI = Rapid shallow breathing index

**Table 3** Criteria for weaning readiness.

### 3.1 Peak expiratory flow measurements in patients with endotracheal tube

In patients with neuromuscular diseases there may be difficulties to expectorate bronchial secretions after extubation/decannulation; failure to do so may lead to reintubation. A peak expiratory flow of  $>60 \text{ l/min}$  measured before extubation/decannulation is predictive of weaning success [8]. In case of an inadequate cough intensive non-invasive secretion management is necessary after extubation.

### 3.2 Cuff-leak-test

After successful extubation, post-extubation stridor may occur in 2 to 16% of patients [9], sometimes with the need for reintubation. The difference between in- and expiratory tidal volume, measured after deflation of the endotracheal tube (cuff-leak-volume) is predictive of post-extubation stridor, the critical value being  $<130 \text{ ml}$  [10].

### 3.3 Weaning protocols

In general a protocol-based standardisation of the weaning process may shorten the duration of MV and increase the rate of successful weaning. However, weaning protocols have no advantage when there is an experienced weaning team, with structured patient review and adequate numbers of staff in the weaning unit [11].

### 3.4 Mode of mechanical ventilation and concepts in prolonged weaning

#### Recommendations

- ▶ Between spontaneous breathing trials adequate muscle rest through mechanical ventilation is recommended.
- ▶ Complete unloading of the respiratory muscles by MV for a long duration leads to ventilator induced diaphragmatic dysfunction (VIDD) and should therefore be avoided.
- ▶ Synchronised Intermittent Mandatory Ventilation (SIMV) should not be used in prolonged weaning, because this mode increases the work of breathing.
- ▶ Both gradual reduction of assisted MV and intermittent assisted or non-assisted periods of spontaneous breathing are appropriate weaning strategies. The latter is possibly superior in prolonged weaning.

#### General considerations:

- ▶ Reconditioning of weak respiratory muscles may be achieved either by gradual reduction of continuous ventilator support, intermittent spontaneous breathing trials or a combination of the two.
- ▶ In case of chronic ventilatory insufficiency (CVI), i.e. hypercapnia persists after extubation, NIV is indicated.

#### Comment:

In general MV-modes are divided into controlled and assisted modes. In practice, however, applied modes may carry features of both categories.

In controlled MV – usually in form of pressure controlled ventilation – inspiratory time and respiratory rate are preset.

In patients under deep sedation or muscle relaxation controlled MV might take over the whole work of breathing. In patients with mild to moderate sedation being on controlled MV both patient and respirator share the work of breathing.

During prolonged weaning alternation between spontaneous breathing and controlled MV, which unloads the respiratory muscles, may be a reasonable strategy to recondition the respiratory muscles [12, 13].

In an assisted mode of MV the inspiratory support of the respiratory muscles is triggered by the patient's effort. The most commonly used assisted mode is Pressure Support Ventilation (PSV), in which the patient controls the breathing pattern with the help of in- and expiratory triggers. PSV reduces the work of breathing,  $\text{O}_2$ -consumption and prevents complete exhaustion of the diaphragm, while avoiding disuse atrophy [14, 15]. Combined modes such as Synchronised Intermittent Mandatory Ventilation (SIMV) are not recommended. The rapid change between controlled and triggered breaths may not be matched by the respiratory control centre and therefore leads to an increased load on the respiratory muscles, with risk of exhaustion [16].

#### 3.4.1 Concepts with application of different modes

MV in prolonged weaning aims to improve the load/capacity ratio of the respiratory muscles.

Reconditioning of weak respiratory muscles during prolonged weaning may be achieved either by gradual continuous reduction of ventilator support (continuous weaning) or through intermittent spontaneous breathing trials where the patient is disconnected

**Table 4** Advantages and disadvantages of invasive and non-invasive airway access.

	Translaryngeal endotracheal tube	Tracheal cannula	Noninvasive airway access
Advantages	<ul style="list-style-type: none"> <li>– Reduced risk of aspiration, less leakage</li> <li>– Suctioning of bronchial secretions possible and easy</li> <li>– Monitoring easy to establish</li> <li>– Airway patency</li> </ul>	Same as with translaryngeal tube plus: <ul style="list-style-type: none"> <li>– Reduced dead space, airway resistance, work of breathing</li> <li>– Improved patient comfort</li> <li>– Decreased sedation requirements</li> <li>– Maintained glottis function</li> <li>– Discharge to step down units possible</li> </ul>	<ul style="list-style-type: none"> <li>– No injury of the airways</li> <li>– Less or no sedation requirements</li> <li>– Intermittent application</li> <li>– Communication</li> <li>– Cough clearance</li> <li>– Oral nutrition</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>– Tube associated infections</li> <li>– Reduced clearance of secretions</li> <li>– Need for sedation</li> <li>– Tube related resistive work</li> </ul>	Early complications: <ul style="list-style-type: none"> <li>– Local wound infections</li> <li>– Reduced clearance of secretions</li> <li>– Communication</li> <li>– Direct complications related to tracheostomy</li> </ul> Late complications: <ul style="list-style-type: none"> <li>– Tracheal stenosis</li> <li>– Granulation tissue</li> </ul>	<ul style="list-style-type: none"> <li>– Leakage, PEEP-stability</li> <li>– Aspiration risk</li> <li>– Respiratory monitoring limited</li> <li>– Limited efficiency if lung compliance is decreased</li> <li>– Local complications (pressure ulceration, conjunctivitis, aerophagia)</li> </ul>

PEEP=Positive endexpiratory pressure

ted from the ventilator (i.e. spontaneous breathing, discontinuous weaning). These two concepts can also be combined. Comparable to endurance training, spontaneous breathing in prolonged discontinuous weaning leads to cyclic loading and unloading, aimed at reconditioning the respiratory muscles. In continuous weaning the support of MV, predominantly in PSV-mode, is gradually reduced. The pressure level is chosen based on clinical criteria, i.e. respiratory rate within 25–30/min. When the duration of spontaneous breathing is long enough or the level of pressure support is sufficiently low, the artificial airway can be removed, if there is no contraindication.

### 3.5 Airway access

#### Recommendations

- ▶ When ventilating via an endotracheal tube, larger diameters are recommended to decrease the tube related work of breathing.
- ▶ If the patient is not at risk for aspiration, deflation of the tube cuff is recommended during spontaneous breathing.
- ▶ Due to its tendency to shrink, a percutaneous dilatational tracheostomy is indicated if weaning success is expected.
- ▶ A stable epithelialised surgical tracheostomy is indicated for patients with persistent weaning failure that require long-term invasive home mechanical ventilation (HMV).
- ▶ Patients with an endotracheal tube who are expected to proceed into prolonged weaning should undergo tracheostomy within 4–7 days, unless early extubation with consecutive NIV is possible.
- ▶ If decannulation success is uncertain, a tracheostomy button/retainer is indicated to facilitate recannulation if needed.
- ▶ If spontaneous closure has not occurred within 3 weeks, surgical closure should be considered if feasible.
- ▶ If tracheal stenosis is suspected a bronchoscopy is indicated.

#### General considerations:

- ▶ There are advantages and disadvantages with regard to invasive and non-invasive access to the airways (▶ Table 4).
- ▶ The indication for tracheostomy should be based on a clear rationale (▶ Fig. 1).

- ▶ For epithelialised tracheostomies surgical closure is sometimes necessary.
- ▶ Prolonged time to spontaneous closure should lead to bronchoscopy to rule out a subglottic tracheal stenosis that can occur in up to 20% of tracheotomised patients.
- ▶ An algorithm for decannulation should be implemented (▶ Fig. 2).

#### Comment:

Invasive access to the airways with endotracheal tube or tracheostomy tube and non-invasive access with NIV and application of different mask types have specific advantages and disadvantages (▶ Table 4).

When long-term MV is needed and NIV is not an option, a tracheostomy is indicated (in form of percutaneous dilatational or surgical tracheostomy) in order to reduce complications of invasive long-term MV [17–20]. The ideal time to perform a tracheostomy, has been the focus of numerous studies. The terms 'early' and 'late' tracheostomy are not clearly defined. Studies did not show any advantage of early tracheostomy [21–23]. An algorithm how to decide whether tracheostomy as airway access is needed or NIV is possible is shown in ▶ Fig. 1.

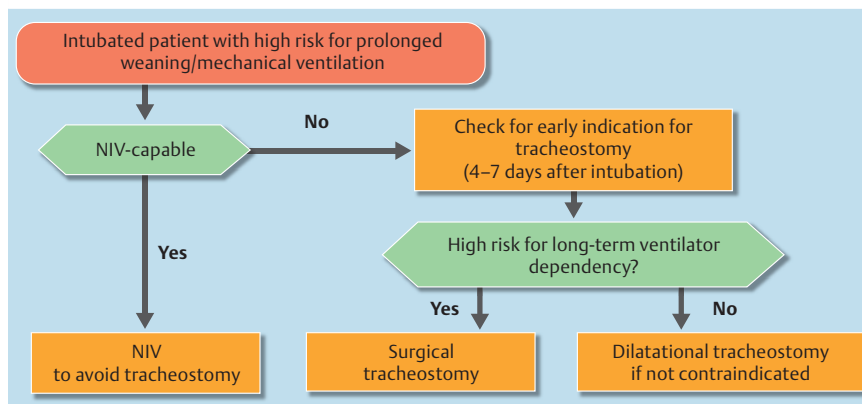
According to several meta-analyses percutaneous dilatational tracheostomy (PDT) offers the advantage of lower acute and long-term complications [24–26]. Surgical tracheostomy should only be performed, if there are contraindications for PDT or in patients with need for long-term invasive home mechanical ventilation (HMV).

During the first week after tracheostomy dislocation or complete removal of the cannula must be avoided, since reinsertion may result in life-threatening misplacement in particular with percutaneous dilatational tracheostomy.

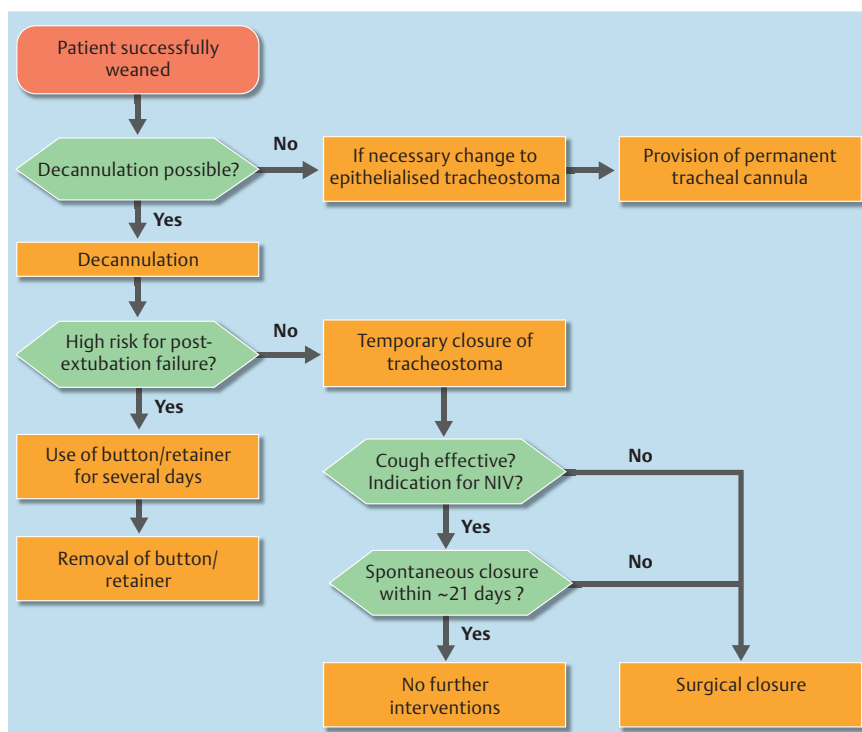
During the weaning process cuff deflation should be performed during spontaneous breathing trials to lower the work of breathing [27] and to recondition the upper airway. In addition communication is facilitated by this approach. However, it has to be weighed against the risk of aspiration.

When the patient is weaned from the ventilator, decannulation has to be considered.

After decannulation a PDT will usually close spontaneously in a short time. To prevent this closure, if successful decannulation is uncertain, a button or tracheostomy retainer can be used to facilitate recannulation [28]. This will also simplify NIV after decan-



**Fig. 1** Decision algorithm for tracheostomy. The indication for tracheostomy should be based on clear rationale. NIV: Non-invasive MV.



**Fig. 2** Algorithm for decannulation or definitive provision with a tracheostomy. NIV: Non-invasive MV.

nulation since leakage through the tracheostomy channel is usually prevented.

Once weaning is successfully completed or NIV safely established, the button or tracheostomy retainer can be removed (algorithm see [Fig. 2](#)). Spontaneous occlusion of a PDT then usually takes place within a few days. In case of a surgical tracheostomy surgical closure is sometimes necessary. If a spontaneous closure takes longer time a bronchoscopy should be performed to rule out a subglottic tracheal stenosis which can occur in up to 20% of tracheotomised patients [21].

### 3.6 NIV in prolonged weaning and in post-extubation phase

#### Recommendations

- If CVI persists after weaning, NIV should be initiated and if necessary continued as HMV in patients with COPD, obesity-hypoventilation syndrome, thoracic restriction, and neuromuscular disease.

#### General considerations:

- NIV might be an alternative to invasive MV in prolonged weaning and in the post-extubation phase in particular in hypercapnic respiratory failure.
- If NIV is considered after extubation/decannulation it has to be critically reviewed if the patient qualifies for this form of treatment. Absolute contraindications have to be considered.

#### Comment:

NIV might be an alternative to invasive MV in prolonged weaning and in post-extubation phase in particular in hypercapnic respiratory failure.

If NIV is considered after extubation/decannulation, contraindications such as lack of spontaneous breathing, gasping, fixed or residual upper airway obstruction, active gastrointestinal bleeding or ileus should be ruled out [29,30].

Patients with persistent hypercapnic respiratory failure are candidates for intermittent NIV to prevent acute-on-chronic respiratory failure type II. Observational studies report that up to 30% of patients with prolonged weaning are treated with home mechanical ventilation after being weaned, most commonly due to

**Table 5** Adjunctive treatment strategies during prolonged weaning from mechanical ventilation.

Content	Treatment	Aim
Pleural effusion/generalised oedema	– Drainage – If necessary pharmacotherapy; e. g. diuretics	Improvement of breathing mechanics and gas exchange
High breathing drive	– O <sub>2</sub> -treatment for hypoxia (e. g. lung emphysema)  – Treatment with opioids	Reduction of inadequate high breathing drive/minute ventilation Reduction of work of breathing
Body position	– Body position to facilitate breathing; e. g. upright upper body	Reduction of work of breathing by unloading the diaphragm (especially in massive obesity, neuromuscular diseases, thoracic restriction)
Malnutrition Catabolism	– Intake of calory-enriched nutrition with relatively low portion of carbohydrates (35 – 40 %)	Avoiding excessive CO <sub>2</sub> -production
Delirium and anxiety	– Treatment with antipsychotics and anxiolytics (e. g. Clonidine, Haloperidole and Benzodiazepine) – Preserve day-night-rhythm – Relaxation techniques	Improvement of vegetative and neurophysiologic function
Immobility and muscular deconditioning	– Physiotherapy	Mobilisation and reconditioning of atrophic muscles
Ineffective cough	– Percussion – Vibration and oscillation – Autogene drainage – Positional drainage – Technical tools/aids to improve cough efficacy: e. g. – Mechanical cough assist – Manually assisted cough (compression of thorax) – Minitracheostomy	Improved clearance of bronchial hypersecretion

COPD, obesity-hypoventilation syndrome, kyphoscoliosis and neuromuscular disease with hypercapnic respiratory failure [31, 32].

### 3.7 Adjunctive treatment strategies

#### Recommendations

- ▶ Delirium and agitation do not necessarily need antipsychotic and anxiolytic medication and may be treated with simple non-pharmaceutical methods, e. g. communication, cognitive stimulation and early mobilisation.
- ▶ Passive and active mobilisation should start during MV as soon as possible to avoid contractures and further deconditioning.
- ▶ Physiotherapy for reconditioning, mobilisation and elimination of bronchial secretion is an essential component of the treatment during prolonged weaning and must be performed on a daily basis.
- ▶ A “minitracheostomy” may be helpful to remove bronchial secretion by suctioning, in particular in patients with neuromuscular diseases and in other conditions with hypersecretion refractory to other therapies.
- ▶ A swallowing evaluation is indicated prior to resumption of oral nutrition. Dysphagia has to be treated immediately.

#### General considerations:

- ▶ Different adjunctive treatment strategies are indicated to support the process (• **Table 5**).
- ▶ No consensus on the haemoglobin level that requires red blood cell transfusions was reached by the task force.

#### Quality indicators:

- ▶ Physiotherapy and elimination of bronchial secretion must be performed on a daily basis (incl. weekends).
- ▶ Prior to resumption of oral nutrition after invasive long-term MV a swallowing evaluation is recommended.

#### Comment:

#### Transfusion and Weaning (trigger for transfusion of red blood cells)

Patients with prolonged weaning often suffer from anaemia. There was a controversial discussion in the consensus conference, whether an increase of haemoglobin by transfusion of erythrocytes has a positive or negative impact on weaning outcome. The main argument supporting a liberal transfusion strategy is based on the concept that an increase in the haemoglobin level might facilitate the weaning process by decreasing the work of breathing [33] while the contrapoint was the risk of transfusion related complications [34 – 36] which might outweigh theoretical benefits. Because of the absence of consensus no recommendation concerning the impact of transfusion was made in this guideline.

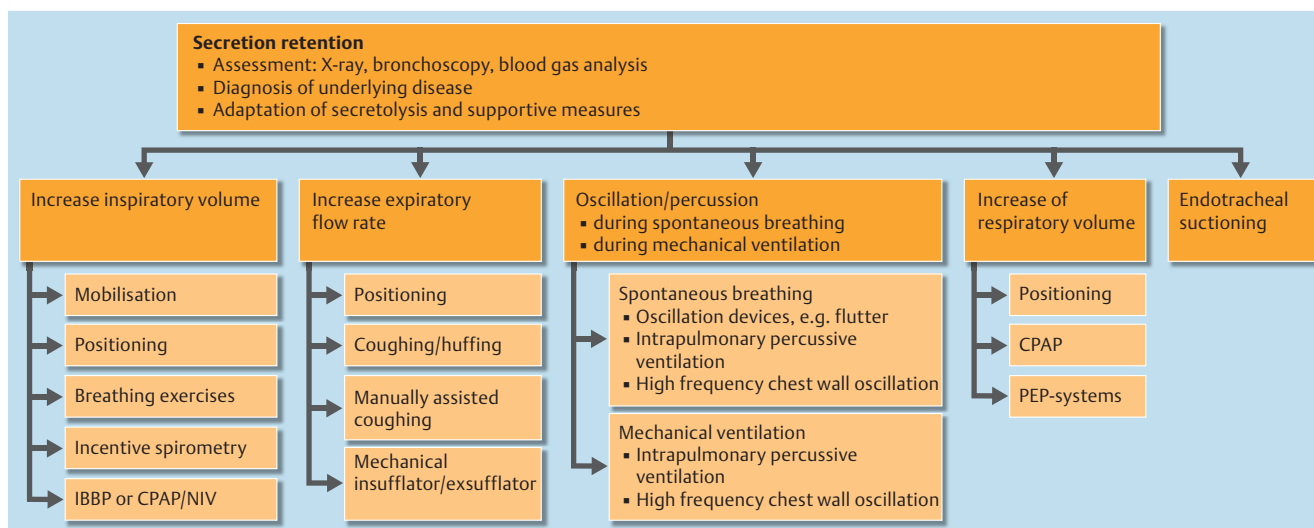
#### 3.8 Improvement of nutritional status and metabolism

Being over- or underweight can prolong the weaning period. In the presence of pulmonary cachexia, which is often present due to underlying pulmonary disease, inadequate nutrition is especially deleterious [37] and should be avoided. Nutrition should be provided preferably by the enteral route. If a mechanical ventilation time of more than 4–6 weeks is expected, a percutaneous gastrostomy should be considered early. With respect to recommendations for nutrition the guideline refers to national and international guidelines on nutritional therapy [38].

#### 3.9 Treatment of delirium

Delirium is an acute state of confusion with disturbed consciousness, perception and orientation. In prolonged weaning delirium occurs frequently. A recently published paper states a frequency of 7.6% of severe delirium and up to 20% of milder forms of delirium in a respiratory step-down unit [39].

The treatment of delirium consists of both, specific pharmaceutical treatment and non-pharmaceutical approaches, e. g. maintaining the day-night-rhythm, reorientation, cognitive stimula-



**Fig. 3** Strategies to mobilise and remove secretions in prolonged weaning (based on [42]). HFCWO: High frequency chest wall oscillation; IPPB: Intermittent positive pressure breathing; CPAP: Continuous positive airway pressure; NIV: Non-invasive MV; PEP: Positive expiratory pressure; IPV: Intrapulmonary percussive ventilation.

tion and early mobilisation. If agitation occurs other causes such as inadequate settings of the ventilator or pain have to be ruled out before antipsychotic therapy is started.

### 3.10 Improvement of sleep quality

Sleep fragmentation and deprivation of rapid eye movement and slow wave sleep are well-known phenomena in the intensive care unit environment. Non-pharmaceutical methods should first be used to improve or restore normal sleep architecture, i.e. physiologic day-night-rhythm. Noise reduction and dimmed light during the night are useful to improve sleep quality. In general the latter is easier to realise in a specialised weaning unit than in a typical intensive care unit.

### 3.11 Physiotherapy and secretion management

Physiotherapy is very important in prolonged weaning. Although mobilisation of patients undergoing prolonged weaning is complicated by muscular deconditioning, cachexia or ICU-acquired weakness (i.e. CIP and CIM), it should be started as soon as possible. However, in this process muscular overloading must be avoided. Electrical stimulation may also be helpful to avoid further muscle loss [40, 41]. The use of devices that allow gradual increase of active load lead to an adaptive training of muscle groups [42].

Disturbed mucociliary clearance and reduced cough efficacy, due to the underlying pulmonary diseases or muscle weakness and/or invasive access to the airways promote accumulation of secretions, increased work of breathing and risk of infection [43]. Endobronchial or transthoracic oscillatory systems, in combination with inhalation (e.g. saline solution with high osmolarity) may improve mobilisation of secretions [44]. The technique to remove bronchial secretions has to be tailored to the pathophysiology of the underlying disease, e.g. endotracheal suction, bronchoscopy or mechanical devices to improve cough efficacy. The algorithm proposed (● Fig. 3) illustrates different options for secretion mobilisation and removal of bronchial secretions [43].

### 3.12 Diagnosis and treatment of dysphagia

Frequently dysphagia causes failure of decannulation and repetitive infections of the lower airways. Aspiration can be diagnosed both clinically (e.g. swallowing coloured material or food with the endotracheal tube cuff deflated) or based on technical methods such as FEES (Fiberoptic Endoscopic Examination of Swallowing), videofluoroscopy or by means of nuclear medicine [45, 46]. If dysphagia is confirmed swallowing training is indicated.

### 3.13 Weaning failure and life on long-term MV

#### Recommendations

- ▶ Ideally long-term invasive MV should be initiated in a specialised weaning unit or at least in cooperation with a specialised centre for home mechanical ventilation (HMFV).
- ▶ Prior to discharge requirements for technical equipment, materials, medical and nursing care and adjunctive treatments have to be defined and the equipment has to be available at the home care site.
- ▶ The medical discharge report should provide information about:
  1. The weaning center or center for ventilation providing further care for the patient.
  2. The primary care physician or specialist involved in the home care of the patient.
  3. Treatment goals
  4. Treatment plan including current ventilator settings as well as the ventilation protocol and strategies for secretion management.
- ▶ Patients with out-of-hospital MV need scheduled follow-up visits in their weaning center or ventilation center at least yearly to check the treatment quality and weaning potential.

#### General considerations:

- ▶ Patients with persistent ventilatory insufficiency after prolonged weaning (Group 3b) may benefit from NIV.

- ▶ Prior to discharge of patients with invasive MV to out-of-hospital facilities, a structured patient assessment is required.
- ▶ Discharge to outpatient care with the primary goal to continue weaning is not acceptable.

#### Indicator of quality:

- ▶ Presence of a structured transfer process and home care plan

#### Comment:

Patients with persistent ventilatory insufficiency after prolonged weaning (Group 3b) may benefit from NIV. The discharge process in this situation is usually focused on the provision of technical equipment such as ventilators and accessory parts and future caregivers are being instructed how to handle them correctly.

In weaning failure category 3c patients with NIV failure and continuous invasive MV, discharge to an out-of-hospital facility or to the patient's home is feasible.

Outpatient care providers are frequently less experienced to give care to invasively ventilated patients when compared to caregivers within the hospital. This might compromise the quality of care. To improve outpatient care in ventilated patients national guidelines with detailed recommendations how to organise out-of-hospital MV have been published [47–50].

Requirements for discharge of patients receiving invasive MV to out-of-hospital facilities are:

- ▶ Definitive weaning failure or weaning success not expected within the next 4 weeks
- ▶ Stability of underlying diseases and co-morbidities, considering potential for the development of complications
- ▶ Completed clinical evaluation
- ▶ Established out-of-hospital care and treatment plan

An expert centre is needed, to evaluate the ongoing weaning potential. The physician in charge of organising out-of-hospital MV is responsible for a proper transfer process.

Different models of care exist for patients still dependent on MV [47].

- ▶ Self-care in the patient's home (predominantly when treated with NIV)
- ▶ Home care with support from outpatient nursing services or personalised assistance (1:1 care – in particular in high dependency invasive MV)
- ▶ Outpatient care in an assisted care facility/living group for patients with long-term MV
- ▶ Specialized long-term ventilation care facility
- ▶ Palliative care facility with special expertise in MV

The choice of care is up to the patient and relatives. Furthermore, this decision is influenced by other medical and technical needs (e.g. ongoing dialysis). The out-of-hospital care network, that usually includes the general practitioner, (respiratory care) nurses; physiotherapists, and continuation of (ambulatory) rehabilitation has to be established.

The discharge process should be initiated about 3 weeks prior to the expected date of discharge [47]. Discharge must not occur before a care plan and the necessary out-of-hospital professional support is established and reimbursement is guaranteed. Follow-up appointments are to be scheduled.

### 3.13.1 Life on long-term MV

Patients with out-of-hospital MV want to live an individual, mostly self-determined life with high quality and want to have a dignified death. Patient care should meet these individual goals.

If the quality of life remains unacceptable for the patient, if the dying process is prolonged by MV or the patients wishes to terminate MV, a living will should be documented in the form of an advanced directive and the responsible weaning center or ventilation center should be contacted.

Decannulation or transfer from invasive MV to NIV is not recommended in the home care setting.

### 3.13.2 End-of-life decisions and management

#### Recommendations

- ▶ Patient autonomy is an important ethical principle and (if expressed) has to be taken into account for end-of-life decisions.
- ▶ The patient might create a living will before entering an end-of-life situation in order to the patient's wishes.
- ▶ If autonomous decision-making by the patient or next of kin is not possible, decision-making involving doctors, nurses and family should be attempted.
- ▶ To reduce distress during the dying process, anxiolytics and sedatives should be administered in appropriate doses and their administration has to be documented. Although such medication might shorten life, symptom control is paramount.
- ▶ The documentation of decision to terminate ventilation, of the process itself and of adjunctive measures in the end-of-life process is important.

#### Quality indicator:

- ▶ The weaning unit has access to an ethics committee, which is involved in difficult and controversial end-of-life decisions.

#### Comment:

Patients with weaning failure have an increased risk of dying within a year [51]. After a long period of hospitalisation and if the prognosis is considered poor, a decision may be made to terminate MV. It is difficult to predict the individual prognosis exactly and only a minority of patients are able to participate actively in the process of decision making [52]. Treatment decisions are mainly based on the physician's judgement of life expectancy and the presumed will of the patient.

The main legal requirements for medical measures at this point are medical indication and patient consent. The physician has to reevaluate the indications for prolonged MV (i.e. life extension or preservation of the quality of life).

The binding character of advanced directives follows one of the main ethical principles – patient autonomy. The commitment to obey these advanced directives differs between countries and depends on local legislative rules. In Germany advanced directives must be considered if there are no indications for a change in patient's mind.

Ethics consultations may be helpful in case of divergence about the decision to withhold or withdraw therapy [53].

Early and continuous communication with patients and their families should have the highest priority. A feasible way of communication is to elaborate new therapeutic goals, which might have changed at that point of care. During conversations with a competent patient, the physician must recognise (if possible supported by nurses and/or relatives), if and when the patient is willing to talk about death.

### 3.13.3 Methods to terminate MV

MV can either be withdrawn gradually or abruptly. A recent survey in European respiratory intermediate care units revealed an end-of-life decision being taken in 21.5% of chronic pulmonary patients [54]. In 11% of patients withdrawal of therapy was performed.

Terminal weaning is characterised by a gradual reduction of ventilation while keeping the airway access in place – in contrast to terminal extubation (removal of the airway access and termination of ventilation). If consciousness is already compromised the patients might require no or only mild sedation [55].

According to national regulations the relief from suffering has priority and therapy related shortening of life has to be accepted. Shortening life by intention is equivalent to assisted dying or euthanasia, which according to German law is illegal and can lead to prosecution.

Patient's discomfort such as agitation, shortness of breath and anxiety must be continuously evaluated and treated medically with analgesics and sedatives (preferably with Morphine and Benzodiazepines).

Instructions for how life support is withdrawn are considered useful by nurses and physicians. In a recent retrospective survey of 50 patient charts, Kirchhoff et al. found that the decision to terminate therapy was documented in every case but the way of terminating life support was documented less frequently [56].

### 3.14 Weaning unit

#### General considerations:

- ▶ Technical equipment (masks, ventilators) used for out-of-hospital MV should be available to allow patient adaptation.
- ▶ The requirements of patients undergoing prolonged weaning often exceed the resources available in general hospitals. Specialised weaning units can relieve this situation.
- ▶ Outcome data should be assessed and ideally collected in multicentre data platforms.

#### Comment:

Prolonged weaning applies only to about 10% of all weaning patients, however an increasing number of these cases often exceeds available resources of hospitals. Therefore specialised weaning units can relieve the situation. The structure and technical equipment of a weaning unit has to be diverse. The following issues are necessary for prolonged weaning: technical equipment, an intensive care unit and special expertise in NIV. According to a recent survey, about 30% of patients who were successfully weaned in pulmonary weaning centers were discharged on non-invasive ventilation [57].

#### 3.14.1 Initiation of NIV for out-of-hospital MV in prolonged weaning

A high expertise with NIV is pivotal for a weaning unit; alternatively, an inter-hospital cooperation with a center with appropriate expertise in NIV is possible. However, experience has proven that geographical distance between patient and centre causes problems.

#### 3.14.2 Quality management and outcome

In intensive care medicine outcome data are often missing. It is highly recommended that the weaning units should collect and analyse data using multicentre data platforms. Systems designed for this purpose are already available.

## 4 Conclusion

Prolonged weaning patients have failed earlier phases of the weaning process and have progressed from simple to difficult weaning and finally into the prolonged weaning category. These patients require a specialised weaning approach, targeted to restore the balance between respiratory demand and capacity. The route of ventilation and nutrition has to be adapted to the extended weaning period of these patients and physiotherapy, as well as respiratory therapy, plays a very important role. If patients cannot be liberated from invasive MV a complex process is necessary to organise out-of-hospital care. The patient's decision expressed directly or by means of a living will is paramount and binding, including the decision to terminate MV.

The objective of this guideline was to provide a structured approach to prolonged weaning.

The complexity of the requirements shown suggests, that these patients are best treated in units specialised in prolonged weaning.

### List of abbreviations

ALS	Amyotrophic lateral sclerosis
CIM	Critical illness myopathy
CIP	Critical illness polyneuropathy
COPD	Chronic obstructive pulmonary disease
CPAP	Continuous positive airway pressure
CVI	Chronic ventilatory insufficiency
FEES	Fiberoptic evaluation of swallowing
HFCWO	High frequency chest wall oscillation
HMV	Home mechanical ventilation
ICU	Intensive care unit
ICUAW	Intensive care unit acquired weakness
IPPB	Intermittent positive pressure breathing
IPV	Intrapulmonary percussion ventilation
MV	Mechanical ventilation
NIV	Non-invasive ventilation
PAH	Pulmonary arterial hypertension
PDT	Percutaneous dilatational tracheostomy
PEEP	Positive endexpiratory pressure
PEP	Positive expiratory pressure
PSV	Pressure support ventilation
RASS	Richmond agitation and sedation score
RR	Respiratory rate
RSBI	Rapid shallow breathing index
SBT	Spontaneous breathing trial
SIMV	Synchronized intermittent mandatory ventilation
TBC	Tuberculosis
VIDD	Ventilator induced diaphragmatic dysfunction
VT	Tidal volume

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