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REVIEW

Prolonged weaning: From the intensive care unit to home☆

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Abstract Weaning is the process of withdrawing mechanical ventilation which starts with the first spontaneous breathing trial (SBT). Based on the degree of difficulty and duration, weaning is classified as simple, difficult and prolonged. Prolonged weaning, which includes patients who fail 3 SBTs or are still on mechanical ventilation 7 days after the first SBT, affects a relatively small fraction of mechanically ventilated ICU patients but these, however, requires disproportionate resources. There are several potential causes which can lead to prolonged weaning. It is nonetheless important to understand the problem from the point of view of each individual patient in order to adopt appropriate treatment and define precise prognosis. An otherwise stable patient who remains on mechanical ventilation will be considered for transfer to a specialized weaning unit (SWU). Though there is not a precise definition, SWU can be considered as highly specialized and protected environments for patients requiring mechanical ventilation despite resolution of the acute disorder. Proper staffing, well defined short-term and long-term goals, attention to psychological and social problems represent key determinants of SWU success. Some patients cannot be weaned, either partly or entirely, and may require long-term home mechanical ventilation. In these cases the logistics relating to caregivers and the equipment must be carefully considered and addressed.
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PALAVRAS-CHAVE
Ventilação Mecânica;
Desmame;
Unidade
Especializada em
Desmame (SWU)

Desmame prolongado: da unidade de cuidados intensivos para o domicílio

Resumo O desmame ventilatório é o processo de retirar a ventilação mecânica, que se inicia com o primeiro teste de respiração espontânea (SBT). Baseado no grau de dificuldade e duração, o desmame é classificado como simples, difícil ou prolongado. O desmame prolongado, que inclui doentes que falharam 3 SBTs ou que ainda estão sob ventilação mecânica, 7 dias após o primeiro SBT, afecta um fracção relativamente pequena dos doentes sob ventilação mecânica na UCI mas estes, no entanto, precisam de recursos desproporcionados. Existem diversas causas potenciais que podem levar ao desmame prolongado. No entanto é importante compreender o problema do ponto de vista individual de cada doente, de forma a adoptar o tratamento adequado e definir um prognóstico preciso. Um doente de outra forma estável, que continue em ventilação mecânica, será considerado para transferência para uma unidade especializada em desmame (SWU). Apesar de não existir uma definição precisa, a SWU pode ser considerada como um ambiente altamente especializado e protegido para doentes que necessitam de ventilação mecânica apesar da resolução da doença aguda. Recursos apropriados, objectivos bem definidos a curto e longo prazo, atenção aos problemas psicológicos e sociais são os principais factores determinantes do sucesso de uma SWU. Não é possível obter o desmame ventilatório em alguns doentes„ seja parcial ou totalmente, podendo estes necessitar de ventilação de longo prazo, no domicílio. Nestes casos, a logística relacionada com os prestadores de cuidados e o equipamento deve ser cuidadosamente considerada e satisfeita.
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Introduction

Generally speaking, weaning is the process of withdrawing ventilator support. Some use the term to intend a gradual reduction of ventilator assistance, while others believe that weaning covers the entire process of liberating the patient from both ventilator and endotracheal tube. A uniform and broadly accepted definition of the term weaning is crucial to avoid confusion and is an essential prerequisite for interpreting the results of the studies, and guiding clinical decisions, including site of care and management of difficult patients.[1]

It is commonly accepted that weaning starts with the first spontaneous breathing trial (SBT), during which the patient is allowed to breath for a relatively brief period of time (30–120 min) through a T-tube, or with low levels of either CPAP (2–5 cmH_2O) or pressure support ($\leq$8 cmH_2O). When the SBT is successful, the patient is considered weaned and ready to be extubated provided that the natural airway is not at risk of obstruction.[2] A recently proposed and largely accepted classification based on difficulty and duration of the weaning process includes: (1) simple weaning, i.e., the patients passes the initial SBT and is successfully extubated at the first attempt; (2) difficult weaning, i.e., up to three SBT or 7 days from the first SBT are necessary to withdraw mechanical ventilation and extubate the patient; (3) prolonged weaning, i.e., more than three SBTs or 7 days from the first SBT are required.[2]

Because the process of weaning implies two separate, though closely related, aspects, the withdrawal of ventilator assistance and extubation, its complete success is achieved when the patient is able to maintain spontaneous unassisted breathing after extubation. Weaning failure may occur when the patient fails to breathe soon after withdrawal of the ventilator support, as defined by the incapacity to successfully pass the SBT. Rates of weaning failure after a single SBT of between 26 and 42% have been reported by different studies.[2] Weaning failure, however, is also the need for re-intubation, conventionally within 48–72 h after extubation, so-called extubation failure.[3,4] Extubation failure can be the consequence of the inability, after removal of the endotracheal tube, either to sustain spontaneous unassisted breathing over time, or to maintain a patent upper airway or to clear tracheobronchial secretions.

There are situations, however, in which weaning can only be partially accomplished and it remains work in progress.[2] On the one hand, mechanical ventilation can be applied through a noninvasive interface, commonly a mask covering nose and mouth, referred to as noninvasive ventilation, which allows extubation while continuing to provide ventilator assistance.[2] On the other hand, though successfully disconnected from the ventilator, a patient may still be unable to get the artificial airway removed because of inability to clear secretions or maintain patent the upper airway.[2] The rates of mechanical ventilated patients undergoing a tracheotomy vary among studies and may reach values as high as 25%.[5–7]

Finally, we lack a clear definition of the ventilator-dependent patient. The ninth revision of the International Classification of Diseases defines long-term ventilated patients as those who have received five or more days of ventilation. Some studies use a time limit as short as 48 h, while others as long as 40 days.[8] A limit of two weeks has been adopted by most authors to define the threshold for ventilator dependency and the Health Care Financing Administration has expanded this limit to 21 days of mechanical ventilation for at least 6 h a day.[8] A definition based only on time, however, has limitations because it does not consider type and characteristics of the underlying disease, comorbidities, reversal of the cause responsible for acute respiratory failure, and the overall prognosis, which, for instance, makes the definition of patients who are indicated for transfer from the Intensive Care Unit (ICU) to a specialized weaning unit problematic.

Epidemiology and outcome of weaning in ICU

While for about 70% of patients, the weaning process is simple and successful, for the remaining 30% the initial attempt fails, making the weaning difficult and worsening the prognosis, ICU mortality being reported as high as 25 percent; of these patients, about half progress to prolonged weaning.[4,9] Two studies report that up to 20% of medical ICU patients remain dependent on ventilator after 21 days.[4,9]

The longer the duration of mechanical ventilation, the higher the mortality rate; this depends, at least in part, on the complications and side effects of this procedure such as the so-called ventilator-associated pneumonia.[7] If on the one hand speeding up the process of weaning may be of benefit, on the other hand, however, it may lead to undue anticipation of extubation and need for reintubation, which has been shown to be associated with a 4.5-fold increased risk of nosocomial pneumonia.[10]

The time spent in the weaning process may represent a substantial fraction of the overall duration of mechanical ventilation and, depending on the patient population, can be as high as 50%.[2] Patients with prolonged weaning account for 6% of all ventilated patients but consume 37% of ICU resources.[11]

Therefore, prolonged weaning is not only a medical, but also a social and economic problem. US costs for mechanical ventilation are estimated to be 27 billion dollars, corresponding to more than 10% of all hospital costs. Each year about 300,000 people receive prolonged mechanical ventilation in ICU in the US, and this number might double within a decade, with costs increasing up 50 billion dollars.[12]

Pathophysiology of difficult and prolonged weaning

Any patient who does not manage simple weaning should be carefully evaluated for potentially reversible underlying disorders. The success of weaning depends primarily on the ability of the respiratory muscle pump to cope with the load placed upon it. Although neuromuscular capability can be impaired because of pre-existing neurological and neuromuscular underlying disorders, more frequently it is altered as a consequence of Critical Illness Neuro-muscular Abnormalities (CINMA), which combine in a single definition Critical Illness Polyneuropathy and Myopathy. CINMA may intervene and complicate the ICU stay in up to 25% of ICU patients undergoing mechanical ventilation for one week or more.[13] CINMA affects predominantly septic patients with multiple organ failure, although drugs such as steroids, aminoglycosides, and neuromuscular blocking agents may also contribute to its occurrence. Avoidance of hyperglycaemia and early rehabilitation have been suggested to reduce CINMA severity and facilitate recovery.[14] CINMA may cause, in the context of a generalized weakness, a critical reduction of the force-generating capacity of the respiratory muscles.

In humans, diaphragm atrophy and injury may occur after relatively few hours. In a group of brain-death donors, 18–69 h of mechanical ventilation and complete diaphragm inactivity resulted in marked atrophy of the diaphragm fibers.[15] In addition, the force-generating capacity of the diaphragm is reduced by one-third in ICU patients after 6 days of controlled mechanical ventilation.[16] Nutritional state, metabolic and endocrine factors should be also considered as potential causes of reduced force generation capacity of the respiratory muscles.[2,17,18]

The inability of the patient to generate a maximal inspiratory pressure of at least 20–25 cmH_2O is considered a predictive index of unsuccessful weaning.[19] Higher values, however, can also be insufficient when the load imposed on the respiratory muscles is increased.

The respiratory load depends on the elastic and resistive properties of the respiratory system. An additional threshold load may substantially add to the overall respiratory load when there is dynamic hyperinflation which causes intrinsic positive end-expiratory pressure (PEEPi). The elastic load increases when the compliance of the respiratory system decreases, which may be due to either lung (pneumonia, pulmonary edema of different etiologies, or fibrosis) or chest wall (obesity, pleural thickening or abdominal distension of different etiologies) restriction, or both. Any condition determining airway bronchoconstriction leads to an increased resistive load. The additional resistance imposed by the endotracheal tube also adds to the resistive load, which may be particularly relevant when the internal size of the tube is small or reduced by concrete secretions, frequently as a consequence of inadequate air humidification. In addition, patients who successfully passed the SBT may develop post-extubation respiratory failure because the resistive load increases as a consequence of glottis edema or inability to effectively clear tracheobronchial secretions.

The heart-lung interaction may affect the respiratory load. In fact, excessive inspiratory negative intrathoracic pressure swings increase cardiac preload and afterload, which determines in turn lung congestion and edema of the bronchial wall.[20,21] This may be particularly important in patients with cardiac dysfunction, sometimes latent or unrecognized, undergoing a SBT that exposes them to an increased inspiratory effort following the interruption of mechanical ventilation.

The load can be further increased because of inappropriate ventilator settings, such as inadequate inspiratory flow rate, excessive time lag between onset of inspiratory effort and the onset of ventilator assistance delivery, ineffective triggering, double triggering, expiratory effort prior to switchover from mechanical inflation to exhalation, causing patient-ventilator dyssynchrony.[22–25]

Recent work has shown that neuro-psychological disorders such as delirium, anxiety and depression may also substantially contribute to weaning failure.[2,25] Poor sleep, excessive noise, lack of darkness during nighttime, and an overall unfriendly environment, as the ICU is generally perceived by the patient, may substantially contribute to these neuro-psychological disorders.

ICU management of prolonged weaning

Because the pathophysiology of prolonged weaning is complex and often multifactorial, the clinical approach must include either a meaningful evaluation of the specific causes for that specific patient and applying proper interventions. As a rule of thumb, considering that an unfavorable balance between respiratory muscles force and imposed load is the chief cause of weaning failure, any treatment effective in either reducing load and/or augmenting muscle force is beneficial.[2,26]

Reduction of the respiratory load

To reduce an excessive elastic load secondary to a decreased lung compliance, it is crucial to consider any possible cause of acute lung volume restriction that can be reverted by specific therapies, such as diuretics to decrease lung congestion in cardiac or renal failure and other conditions of fluid overload, antibiotics to treat pneumonia, chest physiotherapy for treatment (and prevention) of atelectasis. Causes of abdominal distensions determining chest wall restriction should be also evaluated and eliminated whenever possible, for instance by treating stipsis, abdominal gas distension, and large pleural effusions and ascites.

A significant reduction in airway resistance can be achieved by medical therapies, such as bronchodilators to treat bronchoconstriction, steroids and antibiotics to control bronchial inflammation and infections, diuretics to contain bronchial wall edema due to lung congestion.

Chest physiotherapy may also help decreasing the respiratory load by removing bronchial secretions, which reduces airway resistance[27] and prevents atelectasis.[28,29] Chest physiotherapy includes interventions such as patient positioning and mobilization, breathing exercises, incentive spirometry, manual or mechanical insufflation, aimed at increasing lung volume, regional ventilation and pulmonary compliance, and maneuvers aimed at reducing airway resistance and increasing expiratory flow during forced expiration either with an open (huff) or closed glottis (cough). In spite of a robust physiological background,[30] however, the evidence supporting this form of treatment is so far very limited; on the one hand, trials evaluating the impact of chest physiotherapy on the outcome of lack of weaning, on the other hand the contemporary association of different treatments makes a proper evaluation of the physiotherapic techniques problematic.[31]

While tracheal stenosis, granuloma and tracheomalacia can complicate prolonged endotracheal intubation with a cuffed tube,[32] some unrecognized abnormalities, glottis inflammation and edema being the most common, determining increased upper-airway resistance may lead to extubation failure, often irrespective of the duration of intubation. Some advise routine endoscopic evaluation before decannulation.[33] A more practical bedside procedure is the so-called ''cuff leaked test'', which consists of the evaluation of the amount of leaked volume during volume-targeted mechanical ventilation with uncuffed tube. The preset (insufflated) and the exhaled volume are measured and the percentage of leaked volume is calculated. Leaks $\leq$12% identifies patients at high risk of developing post-extubation stridor and then failing extubation.[34]

Medical therapies aimed at reducing airway resistance may also help to decrease PEEPi. Inappropriate ventilator settings, such as those determining hyperventilation or patient-ventilator dyssinchrony, may consistently add to the occurrence and extent of PEEPi and must be, accordingly carefully avoided.[23]

Improvement of neuromuscular capability

A tight control of sepsis and hyperglycaemia, and avoidance of neuromuscular blocking agents, aminoglycosides and steroids, may help to decrease the risk of developing CINMA.[35] It is important to reduce the time spent on full mechanical support as much as possible, i.e., controlled mechanical ventilation, to avert the risk of diaphragm injury and atrophy.[16] Considering and correcting poor nutritional status, electrolyte disturbances and hormone deficiency states, such as hypothyroidism, which may all play a role in decreasing muscle force.[2]

Lessening dynamic hyperinflation and PEEPi in patients with Chronic Obstructive Pulmonary Disease (COPD) also improves diaphragm force-generating capacity. In fact, when hyperinflation occurs, diaphragm myofibers are shortened at end expiration and their force–length relationship is impaired.[36] Unnecessarily high levels of external PEEP and ventilator settings determining iatrogenic hyperinflation should, accordingly, also be carefully avoided.

Early whole-body physiotherapy has been shown effective in improving ICU and hospital outcomes, including the duration of mechanical ventilation, primarily by averting the side effects of prolonged immobilization.[37] Since inactivity weakens the respiratory muscles too,[15,38] inspiratory muscle training, as obtained by intermittent loading of the respiratory muscles, has been proposed to attenuate respiratory muscle deconditioning.[39,40] A recent randomized trial comparing inspiratory muscle training at moderate intensity, i.e., about 50% of the maximal inspiratory pressure generated by the patient, with Sham training in patients with weaning failure showed that a significantly higher proportion (76%) of patients in the treatment group was weaned, as opposed to those (35%) included in the Sham group.[41] These findings were subsequently confirmed in a case-series of ventilator-dependent patients.[42] Two evaluations of an early use of inspiratory muscle training in acute critically ill patients from the onset of mechanical ventilation produced contrasting results. While one randomized trial did not report any physiologic or clinical benefit in a group of patients undergoing two daily sessions of inspiratory muscle training, as opposed to controls,[43] another one reported reduction of the weaning time (3.6 vs. 5.3 days) in the group of patients going through twice-daily 5-min inspiratory muscle training sessions of moderate intensity, compared to a control group.[44] Indeed, the rationale for inspiratory muscle training exists for only a limited number of the patients with reversible diaphragm weakness. In addition, there is a definite lack of a standardized technique to re-train the respiratory muscles. Therefore, further studies are necessary before such an approach can be suggested for clinical use.

Poor cough strength leading to ineffective clearing of tracheobronchial secretions may cause extubation failure in patients who successfully completed a SBT. In patients with an artificial airway, a peak expiratory flow while coughing through the tube $\leq$60 L/min has been shown to be correlated with a five-fold increase in the incidence of extubation failure.[45]

Tracheotomy

Tracheostomy is the most commonly performed procedure in the critically ill, approaching 10% of all intubated patients.[46] However, a tracheotomy rate as high as 25% was reported by a 1-d point-prevalence study performed in 412 medical-surgical ICUs from North America, South America, Portugal, and Spain.[5] The incidence of tracheotomy varied with the underlying disease, it was 39% in neuromuscular patients, 28% in COPD, and 20% in patients with de novo acute respiratory failure.[5] The decision to perform a tracheotomy is predominantly based on the anticipated duration of mechanical ventilation.[5,46] The timing of tracheotomy varies between 3 days and 21 days in the different studies. The routine use of bedside percutaneous techniques is likely to have contributed to anticipating the timing of tracheotomy. In fact, while perioperative complications are quite rare (<2%) with both percutaneous and surgical techniques,[47] percutaneous, as opposed to surgical tracheotomy, reduces costs, would-be infections, unfavorable scarring, and overall complications.[48] An expected intubation for more than 14 days is nowadays considered as reasonable deadline for considering tracheotomy. Poor airway protective reflexes and severe upper-airway obstructions are additional reasons for tracheotomy.[46]

Though never proved by large randomized controlled studies, the benefits ascribed to tracheotomy vs. prolonged translaryngeal intubation include improved patient comfort determining less need for sedatives, ease of airway suctioning, enhanced mobility and speech, which may all potentially contribute to facilitating the process of weaning from mechanical ventilation. Whether this translates into an increased ability to transfer ventilator-dependent patients from the ICU is not clear and might actually vary from hospital to hospital. As a matter of fact, not infrequently, the point in time at which tracheotomy is first considered corresponds or just slightly anticipates the decision to discharge the patient from the ICU.

Management of prolonged weaning beyond ICU

In principle, when the acute disorder which led to admission to ICU is reversed and clinical stability is achieved, the patient may be considered ready for ICU discharge. At that point, while most ICU patients may be transferred to a hospital ward, some of them who are experiencing prolonged weaning may still be dependent on the ventilator, the tracheotomy, or both. In fact, some patients, though successfully extubated, still need NIV for several hours a day; for others, though successfully weaned off the ventilator, the tracheotomy cannot be concomitantly removed; in the worst scenario, invasive mechanical ventilation may still be necessary for several hours a day.

Patients dependent on non-invasive ventilation

Noninvasive ventilation is increasingly used especially, though not exclusively, in patients with acute or chronic respiratory failure, in order to reduce the need for intubation and invasive ventilation.[49] Some studies have repeatedly shown that noninvasive ventilation can also facilitate the process of weaning in patients with underlying chronic respiratory disease and particularly those with COPD.[50–53] While most of these patients undergoing noninvasive ventilation are successfully weaned off the ventilator, some may need to keep on non-invasive ventilation for some hours/day for weeks[54] or on a long-term basis[55] to guarantee acceptable values of arterial blood gases and avoid repeated hospital readmission.[56]

Patients dependent on tracheotomy

For patients who have regained respiratory autonomy and resumed overall clinical stability, the removal of tracheotomy represents a major objective, for reasons related to both clinical, i.e., increased risk of infections and long term complications, and social, i.e., negative impact on daily life activities and relationships. In spite of these considerations, the few recommendations currently available are still largely based on subjective criteria rather than on standardized protocols.[57] Only one study systematically addressed the problem of weaning from tracheotomy in patients with different underlying disorders, such as COPD, post-surgical complications, hypoxemic respiratory failure, neuromuscular diseases, by means of a relatively simple decisional flowchart.[58] This was based on a few parameters aimed at assessing swallowing function and patient ability to spontaneously clear secretions, after determining patient capability of maintaining spontaneous unassisted breathing.[58] By using this simple decisional flowchart, it was possible to remove the tracheotomy in almost 80% of the patients with spontaneous breathing autonomy.[58] A lower rate of successful decannulation was observed in patients affected by chronic respiratory diseases, and in particular in those with neuromuscular disorders, for whom a more sophisticated approach is likely to be necessary.[59]

Patient dependent on tracheotomy and mechanical ventilation

Observational studies indicate that 34–60% of patients in specialized weaning unit can be weaned successfully from the ventilator support.[2] These studies also suggest that successful weaning can occur up to 3 months after admission to these units and that the transfer to a specialized unit does not adversely affect long-term mortality.[60,61] The clinical outcome of patients requiring prolonged mechanical ventilation is largely influenced by the underlying disease, the chances to be completely weaned off both ventilator assistance and tracheotomy approaching 60% in patients with post-operative (58%) and de novo respiratory failure (57%), and slightly exceeding 20% in patients with COPD or neuromuscular disease.[62] Also, the long-term survival rate after successful weaning is worse in COPD than in non-COPD patients.[2,63]

In patients with neuromuscular disorder, it is crucial to assess the ability to clear secretions. Bach et al.[59] showed that peak expiratory flow during cough, so-called peak cough expiratory flow (PCEF) is a better predictor of the likelihood of being weaned from tracheotomy. A variety of cough-augmentation physical therapies, alone or in combination, can be used to increase PCEF and enhance cough efficacy. While the patients with weak expiratory muscle strength, but relatively well preserved inspiratory strength, may benefit from the abdominal-thrust maneuver, also termed ''quad cough'' or ''manually assisted cough,'' which replaces or enhances abdominal muscle contraction, those who combine weakness of both the inspiratory and expiratory muscles necessitate, in addition to manually assisted cough, manual or mechanical forms of inspiratory assistance (i.e., insufflation, air staking, glossopharyngeal breathing, etc.) to increase the pre-tussive volume.

An increasing number of devices specifically designed to assist an insufficient cough have been introduced for clinical use in recent years, which apply to the airway opening positive pressure during the inspiratory phase and negative (sub-atmospheric) pressure during forced expiration.[64] These techniques of mechanical cough-augmentation can be successfully used with neuromuscular patients through an artificial airway, but an intact glottis function is required for those breathing through the native airway at which cough assistance is applied by means of an oro-nasal mask. A program including periodic evaluation of cough strength and timely initiation of effective cough-augmentation therapy may dramatically improve the possibility of weaning neuromuscular patients from tracheotomy.[65]

Although the combination of invasive mechanical ventilation and tracheal suctioning can be successfully used when ventilator assistance is also necessary, in neuromuscular patients this approach has been shown to be associated with increased morbidity.[64] The advent of non-invasive ventilation NIV as a means of supporting chronic neuromuscular respiratory insufficiency has spurred on the development of noninvasive cough-augmentation therapies to favor airway clearance. Unfortunately, the need to support cough clearance has not been properly addressed; indeed, guidelines for the management of a weak cough did not exist until relatively recently.[64]

Specialized weaning units

Definition

There is no uniform, widely recognized definition for ''specialized weaning units'', and confusion can arise, as for the term ''weaning'', from imprecise language. Generally speaking, these units are protected environments for the treatment of patients requiring prolonged mechanical ventilation. As mentioned by Nava & Vitacca in a dedicated book chapter, several terms are used to characterize these units, such as long-term acute-care facilities, respiratory special care units, chronic ventilator-dependent units, regional weaning centers, ventilator-dependent rehabilitation hospitals, prolonged respiratory-care units, non-invasive respiratory-care units, high-dependency units, and respiratory intensive-care units.[8] Beyond the terminology, remarkable differences exist among units, which are primarily, though not exclusively, a consequence of the different healthcare systems and reimbursements, varying not only from country to country, but also often from region to region, and not infrequently from town to town.[2,8] A helpful approach to this problem has been provided by Nava & Vitacca who classified, depending on the type of location, weaning units into two categories, step-down units sited within acute care hospitals, and Weaning Centers serving different acute care hospitals in dedicated areas.[8] While the former, with organization and staffing closer to ICUs may often result in not being able to meet the needs of these patients beyond their clinical problems, the latter require a proper environment and a dedicated and composite organization.[25]

Rationale

Weaning from prolonged mechanical ventilation is a complex and time-consuming process covering several procedures. Quick patient turnover, high workloads for the staff, need for continuous monitoring and treatment, and, in some countries, paucity of ICU beds, make ICUs in appropriate for managing patients with prolonged weaning, requiring care with dedicated personnel, which is often not available in the ICU.[66] In addition, prolonging the ICU stay may have detrimental consequences on the psychological and cognitive function, which may further complicate and protract the weaning process and affect patient outcomes.[67,68]

It has been shown that a substantial proportion of patients, not ready to be separated from the ventilator at ICU discharge can be weaned off the ventilator soon after admission to a specialized weaning unit, which suggests that discontinuation of mechanical ventilation was not a priority for the referring ICUs.[69,70]

In a retrospective study including more than 400 ICU patients who had undergone tracheostomy and prolonged mechanical ventilation following an episode of acute respiratory failure, the rate of survivors successfully weaned at the time of ICU discharge was less than 60%.[71] The patients who were weaned off both ventilator and tracheotomy had better survival rates than those who did not. This improved survival, however, came at higher hospital costs secondary to longer ICU stay, which indicates that the balance between outcome and economic burden represents a major problem when treating patients with prolonged weaning exclusively in ICU.[71] One controlled study compared outcomes and costs of patients with prolonged weaning assigned to either ICU or weaning unit. The rates of mortality were no different between the two groups, but readmissions were fewer, hospital lengths of stay shorter, and costs lower for the patients weaned in the specialized unit.[60]

In point of fact, patients who are no longer in the acute phase, but are not fully weaned, may benefit from the discharge to specialized units. These units offer several advantages, including an environment with reduced noise and night-time light favoring the return to more physiological circadian rhythms and better sleep, open visiting hours to allow unrestricted visits by relatives and friends, easier access to personal belongings, such as books, computers, tablets, TV, music players, and so on.[72,73] The management of these individuals generally involves more than just expertise in mechanical ventilation, but rather an integrated approach with harmonized procedures conducted by a multidisciplinary team.

Beside any other consideration, a weaning unit should also represent a cost-effective alternative to the ICU for the management of patients with prolonged weaning.[25]

Staffing

The components of this team should be physicians, nurses and respiratory therapists or physiotherapists capable of providing comprehensive respiratory care. While one physician should be present around the clock, the therapists need not be present overnight. The nurse–patient ratio should range between 1:4 and 1:8 depending on the time of the day. Overall, the skills must encompass invasive and noninvasive mechanical ventilation, suctioning, tracheotomy management, and chest physiotherapy including cough assistance techniques. Physical therapists, occupational therapists, for daily living activities, speech therapists, for evaluation and treatment of swallowing dysfunctions, and nutritionists, to optimize calories and proteins administration, should also be part of the team. Psychology and social services should be also available for patient and family evaluation, education and counseling.

Understaffing is one of the major determinants of a suboptimal or ineffective or even harmful weaning unit, and should definitely be avoided when building up an accredited effective unit.[25]

Admission and discharge criteria

Although it is advisable for a weaning unit to define and apply admission criteria, these cannot be generalized and depend on the characteristics of each specific unit. While, the possibility of promptly assessing arterial blood gases and having daily access to chest X-ray and routine blood examination represent the minimum standard for a specialized unit, other facilities may enhance the possibility of accepting patients with higher levels of clinical complexity. Most weaning units that are located outside acute-care hospitals, however, clearly cannot offer sophisticated diagnostic procedures and treatments.

The patients admitted should obviously be dependent on ventilator assistance, or need an artificial airway, or both.[74] It is worth remembering that prolonged weaning is defined by more than three previously failed SBTs or at least 7 days from the first attempt of SBT.[2] Several units include in the admission criteria for invasively ventilated patients the presence of a tracheotomy, to avoid the risk of emergency maneuvers consequent to the need to change an obstructed endotracheal tube. Some units require the proposing physician to provide a written statement that the patient has the potential to be weaned from the ventilator or to return to her/his community under ventilator assistance.[75]

The team should work with the patient and the family to define short and long term goals leading to final discharge home.[25] If, based on objective data, the whole team consider additional weaning attempts to be worthless, these should be interrupted to avoid further frustration, anxiety and depression, and patient and family promptly and clearly informed. When everyone involved in the process, i.e., the team, the patient and the family, agree on the futility of pursuing the weaning efforts, the primary goal becomes the setting up of the best possible discharge program, in which complexity will clearly depend on the level of patient dependence. Of course, it is much more complex to discharge a tracheotomized patient on full ventilator support around the clock, rather than a patient on nocturnal noninvasive ventilation. Once it has been established that the patient's clinical condition, motivation and home environment are suitable for undertaking a long-term domiciliary ventilation program, several logistical aspects remain to be carefully considered and addressed with respect to both the care givers and the equipment.[25,74]

Summary

Weaning failure is commonly understood to be an incapacity to successfully pass the SBT, while extubation failure is the inability to sustain spontaneous breathing after removal of the endotracheal tube. Whereas the process of weaning is simple and completely successful for most of the patients who are able to maintain spontaneous unassisted breathing after extubation, some experience difficult or prolonged weaning. For these patients it is crucial to properly assess the underlying causes of failure in order to facilitate the process of discontinuation of mechanical ventilation. A few patients, however, experience prolonged weaning and undergo tracheotomy, requiring a more gradual reduction in ventilator support and lengthening of spontaneous breathing periods. Patients who are no longer in the acute phase, but are not fully weaned, may benefit from being discharged to specialized units that must be characterized by a proper environment and a dedicated and composite organization. Location, staffing, admission and discharging criteria are key issues for these units and need to be further evaluated by future well-designed studies.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

Conflicts of interest

Inamed GmbH is a Contract Research Organization specialized in the respiratory area and has been commissioned by Linde AG to provide consulting for the REMEO® development project. P. Navalesi worked as consultant for Inamed GmbH on this project, A. Patzlaff and S. Häußermann are employees of Inamed GmbH, P. Henseke and M. Kubitschek are employees of Linde AG. There is no other conflict of interest in connection with this paper.

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