Management of Patients Requiring Prolonged Mechanical Ventilation

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Abstract

Advances in life-sustaining technologies in critical care have resulted in more survivors from catastrophic illness, yet 4-13% of them fail weaning attempts, sometimes resulting in prolonged dependency on mechanical ventilation. This growing population has drawn much attention not only because of increased healthcare resource utilization, but also because of their poor quality of life and high mortality rate. The management of patients requiring prolonged mechanical ventilation should not be considered an extrapolation from mindsets and studies in the field of critical care. Specialized intermediate care units, respiratory care centers, have been established for comprehensive care of this population, and a growing body of literature in this field has emerged. In this review, we summarize the best available evidence for managing this specific group of patients, including weaning strategies, tracheostomy, nutritional support, and rehabilitation. We also summarize the clinical outcomes and prognostic information from studies based on data from the National Health Insurance Research Database of Taiwan, as this information is important in goal-of-care communication and shared decision making concerning not sustaining ventilator dependency. (J Intern Med Taiwan 2017; 28: 24-32)

Key Words: Prolonged mechanical ventilation, Ventilator dependency, Respiratory care center

Introduction

Most patients receiving mechanical ventilation in intensive care units (ICUs) require short-term ventilation for less than a week. However, 4-13% of them fail weaning attempts, resulting in prolonged mechanical ventilation (PMV)[1,2]. This population is rapidly increasing worldwide, likely because of an aging population with multiple comorbidities, coupled with advances in life-sustaining technologies in critical care[3-5]. PMV is associated with high health care costs, morbidity, and mortality[1,2]. Because these "chronically critical ill" patients recover slowly, development of weaning facilities that are cost-effective and suited to the needs of these patients' needs is required[6]. In 2000, the Taiwan Bureau of National Health Insurance implemented a prospective payment system to deliver comprehensive care for patients requiring mechanical ventilation. This integrated delivery system offers cost-effective, outcome-oriented respiratory care services in a step-down manner: ICUs (acute stage, <21 days of mechanical ventilation); respiratory care centers ([RCC], for patients at a subacute

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stage for aggressive weaning, 21-42 days); respiratory care wards (for patients at a chronic stage or requiring long-term care, >42 days); and homecare services (for patients at a stable stage during which they are visited routinely by a respiratory care team).

Definition of PMV

The most widely accepted consensus definition of PMV is invasive mechanical ventilation for more than 21 consecutive days over 6 hours per day[7], although there is great variation in the duration of mechanical ventilator use in different studies, ranging from 2 days to 4 weeks[7-9]. The same consensus definition has been adopted by the National Health Insurance Administration of Taiwan.

Epidemiology

The number of PMV patients in Taiwan has increased significantly in the past decade, from 9,296 to 21,818 between 1998 and 2004. There was a slight drop after 2005[10]. The incidence of PMV increased with aging, a finding consistent with studies in western countries[3,4]. Patients over 85 years had the highest incidence rate. The cumulative incidence rate (from 17 to 85 years old) increased from 0.103 to 0.145 between 1998 and 2007, which indicates that an adult Taiwanese has a 10 to 15% chance of requiring PMV by the age of 85 years[10].

Pathophysiology of ventilator dependence

Failure of multiple weaning attempts usually signifies incomplete resolution of the disease that contributed to respiratory failure, however, the etiologies may be multifactorial, as categorized in Table 1. Physiological studies have demonstrated that prolonged ventilator dependence is associated with a marked imbalance in respiratory loads/capacities, resulting from excessive respiratory demands and reduced force-generating capacity of the inspiratory muscles[11-14]. Recovery of maximum transdiaphragmatic pressure allows patients to breathe below the fatigue threshold of the diaphragm, which facilitates successful weaning later[12].

Patient selection and assessment

Patients who are expected to need the assistance of mechanical ventilation beyond 3 weeks of intuba-

Table 1. Etiologies associated with prolonged mechanical ventilation

Systemic factors
Severity of illness
Number of comorbidities
Respiratory factors
Increased work of breathing
High resistance of airway
Low compliance of lungs or chest wall
High minute ventilation
Reduced respiratory muscle capacity
Steroid myopathy
Ventilator-induced diaphragm atrophy
Disuse atrophy
Ventilation/ perfusion mismatch
Cardiovascular factors
High cardiac output due to increase work of breathing
Increase afterload secondary to negative pleural pressure swings
Increase venous return during spontaneous ventilation and pressure reduction
Metabolic factors
Poor nutrition status
Overfeeding with elevated CO_2 production
Electrolyte imbalances with muscle weakness (hypokalemia, hypophosphatemia)
Hypothyroidism, myxedema
Neurological factors
Impaired respiratory central drive
Obstructive sleep apnea
Critical illness polyneuropathy
Psychological factors
Fear of loss of life support
Sleep deprivation
Acute delirium,
Affective disorder: depression, anxiety
Iatrogenic or caring factors
Failure to recognize withdrawal potential
Inappropriate ventilator settings
Absence of weaning protocols
Absence of sedation protocols; prolonged sedation
Inadequate nursing staffing

tion in an ICU should be considered for transfer to an RCC, which is specialized in respiratory care and aggressive ventilator liberation using an interdisciplinary team approach[15]. A level of medical and respiratory stability should be met before admission to an RCC. Patients should be hemodynamically stable with no need for invasive monitoring, no uncontrolled sepsis, hemorrhage, arrhythmia, or heart failure, and no anticipated surgical intervention in the near future[16]. In addition to the patient's current medical condition, the likelihood of eventual weaning, quality of life, and life expectancy should also be assessed[6]. Alternatives to ventilator dependency, such as time-limited weaning trials or palliative care, should be offered in family conference when deliberating a post-ICU care plan[17].

Weaning strategies

Readiness for weaning should be assessed daily to determine whether patients fulfill the following criteria: (1) reversal of the underlying cause of respiratory failure, (2) stable hemodynamic status, (3) reliable respiratory drive, and (4) adequate oxygenation (PaO_2/FiO_2 >150-300, PEEP ≤5-10 cm H_2O, FiO_2 ≤0.4)[15]. A commonly reported weaning strategy for patients requiring PMV involves two processes: (1) progressive reduction of assistance level, such as pressure support ventilation (PSV) and (2) progressive lengthening of the duration of spontaneous breathing trials (SBTs), usually beyond 120 minutes.[7] Two randomized controlled studies compared different weaning methods in patients requiring PMV[18,19]. A tracheostomy collar resulted in shorter time to wean than PSV (15 vs 19 days), although there were no significant differences in the 6 and 12-month survival[18]. However, in another multicenter study comparing PSV and T-piece SBT using weaning protocols in patients with chronic obstructive lung disease (COPD), no significant differences were found in the time of ventilation (181±161 vs 130±106 h), weaning rate (73% vs 77%), and mortality rate (11.5% vs 7.6%). When the results (using weaning protocols) were compared with historical usual practice, the time of ventilation was shorter (103±144 vs 170±127 h), and 30-day weaning rate was higher (87% vs 70%)[19]. A study by Scheinhorn et al. also showed significant benefits of using a therapist-implemented protocol, with a shorter weaning time (17 vs 29 days) in 252 patients requiring PMV over a 2-year period, compared with historical controls[20]. Taken together, these studies suggest that implementation of a defined protocol may have a greater effect on weaning outcomes than the weaning strategy itself.

Predictors of weaning success

Research on weaning predictors has been limited to observational, retrospective, and single-institute-based studies. There is no single universally accepted weaning parameter which predicts successful liberation from PMV[21]. The rapid-shallow-breathing index (RSBI) with a threshold value of ≦105, which has been widely used in the ICU, had poor predictability for successful weaning in patients requiring PMV (predictive accuracy 59%) in one study. However, when the RSBI (using a threshold value ≦130) was measured 2-3 hours after SBT, the predictive accuracy improved to 92%[22]. A model was proposed to predict the chance of successful weaning using a scoring system incorporating the alveolar arterial (A-a) gradient, blood urea nitrogen and gender, with an accuracy of 70% in the authors' population of PMV patients[23]. However, later studies found that this model was no better than chance in predicting weaning success[24]. In a physiological study, patients requiring PMV who were successfully weaned showed significant improvement in maximum transdiaphragmatic pressure (Pdi_{max}), a better load/capacity ratio ($Pdisw/Pdi_{max}$) and breathed below a fatigue threshold (tension-time index of the diaphragm, TTdi), compared with the unsuccessful weaning group[12]. However, measurement of these physiological indexes is too sophisticated for clinical use and a more practical surrogate should be developed.

Optimization for weaning

Tracheostomy

A tracheotomy is generally considered after failure of several weaning attempts and in patients who are expected to require PMV in the immediate future[15]. However, the decision to perform a tracheostomy should be made with caution before adequate goal-of-care communication has been conducted between clinicians and patients/ families, as the procedure might increase the rate of unnecessary dependency on life-sustaining treatments[25]. The potential benefits of tracheostomy include easier tracheal approach and suction, greater patient comfort with less sedative use, better communication, early mobilization, and improved lung mechanics and it facilitates weaning from the ventilator[26,27]. The optimal timing of tracheostomy in patients requiring PMV is still debated. Meta-analyses comparing early versus late or no tracheostomy did not show differences in all-cause mortality at 1 year or long-term severe disability[28-32]. Although early tracheostomy was associated with a shorter ICU stay and duration of mechanical ventilation, the total hospital stay was not reduced. The tracheotomy rate of PMV patients in Taiwan is about 60%[10], which is much lower than in studies conducted in western countries[33,34]. This may be explained by common myths about tracheostomy and ethnic Chinese culture which seek to avoid creating a stoma in patients with a short life expectancy.

Nutrition

The optimal nutritional intake in critically ill patients remains controversial. Some recent randomized trials demonstrated that intentional underfeeding for the first week in the ICU resulted in better short-term outcomes[35-37]. In contrast, a large-scale observational dataset showed that increased nutritional intake (>two-thirds of caloric prescription) was associated with a significant reduction in mortality[38]. In a multicenter cohort study specifically focusing on patients requiring PMV, adequate caloric intake as early as the first week of ICU stay was associated with better 6-month survival and faster physical recovery to 3 months[39]. While some of the current guidelines recommend intentional underfeeding for the first week in the ICU, caution should be taken as this may cause harm in some high risk chronically ill patients, such as those requiring PMV.

Physical therapy

Patients requiring PMV are frequently deconditioned, possibly due to catastrophic illness, prolonged immobilization, and adverse effects of medications[40,41]. A randomized controlled study showed that a 6-week physical training program in patients requiring PMV resulted in improvements of limb and respiratory muscle strength (P_{Imax}, P_{Emax}), ventilator-free time, and functional status, compared with the control group[42]. Although the mechanisms underlying the beneficial effects of physical training on respiration are not clear, strengthening exercises for the upper extremities may facilitate the actions of the pectoralis major, as well as other accessory respiratory muscles[43]. A strategy of initiating physical and occupational therapy in the earliest days of critical illness, coupled with discontinuation of sedative agents, resulted in better functional outcomes, a shorter duration of delirium, and more ventilator-free days[44]. On the basis of these reports, early physiotherapy should be considered as an integral part of the management of patients requiring PMV.

Clinical outcomes and prognoses

In a meta-analysis of 124 studies from 16 countries, 50% (95% CI 47–53%) of PMV patients were successfully liberated from mechanical ventilation[45]. However, successful weaning did not ensure long-term survival. While pooled mortality at hospital discharge was 29% (95% CI 26–32), more than half of these patients died within 1 year (pooled 1-year mortality 62%, 95% CI 57–67%)[45]. This was possibly due to multiple underlying co-morbidities in patients with PMV. A population cohort study based on the National Health Insurance Research Database of Taiwan from 1998 to 2007 showed that the median survival of 50,481 PMV patients was 0.37 years, and overall life expectancy was 2.68 years[10]. The prognosis was influenced by different underlying diseases, co-morbidities, and age. The life expectancies were shortest for PMV patients with chronic renal failure (1.32 years) and cancer (1.49 years), compared with degenerative neurological diseases (4.08 years), stroke (3.32 years), liver cirrhosis (3.5 years), and injuries (6.19 years) (Table 2)[10,46]. Among PMV patients with multiple co-morbidities, those with COPD survived longer than those with other co-morbidities. PMV patients over 85 years old had the shortest survival, with a median survival <4.6 months and life expectancy <21.8 months, compared with younger age groups[10] Approximately 62% of PMV patients had impairment of cognitive function. Even among PMV patients with fair to good cognitive function, more than 80% were confined to bed, had impaired self-care ability, and were dependent in activities of daily living. Taking these factors into account, the overall quality-adjusted life expectancy was only 0.3 to 0.4 years, while quality-adjusted life-years was 0.6 to 0.7 years[47,48].

Communication of goal-of-care planning

Although the outcomes of PMV are generally poor, most patients and their surrogates in one prospective observational study expressed over-optimistic expectations in terms of 1-year survival (93%), functional status (71%), and quality of life (83%)[49]. Meanwhile, up to three-quarters of surrogates reported receiving no prognostic information on PMV from their clinicians[49]. In another questionnaire-based prospective study[17], more than half of surrogates reported receiving no information on majority topics (10 out of 18 items) which were considered essential for communication and decision making in goal-of-care planning for patients with PMV, including 1-year survival (93%), expected functional status (80%), alternatives to continuing mechanical ventilation (83%), services needed after discharge (82%), and financial burden (75%). Deficiency in communication between clinicians and patients/surrogates may cause inappropriate use of life-sustaining treatment, although the decision may be inconsistent with the preferences of patients or surrogates[50]. Since an optimal clinical decision takes into account both evidence-based information and the patient's goals, values and preferences, the majority of critical care organizations recommend shared decision- making (SDM) as a model when practicing patient-centered care, particularly when making value-laden decisions and defining overall goals of care (including decisions on time-limited weaning trials and timing of palliative care)[51-54]. Table 2 provides useful evidence-based prognostic information for PMV patients in Taiwan, including life expectancy and quality-adjusted life expectancy (which take cognitive function into account), as well as lifetime financial burden (health care costs and out-of-pocket expenses for family)[46]. This information, along with specific weaning outcomes for individual RCCs, should be provided to patients/ surrogates in SDM in goal-of-care communication.

Conclusion

Advances in mechanical ventilation in critical care have saved lives from catastrophic illnesses, but on the other hand, have created a new health-care problem of prolonged dependency on mechanical ventilation. Although the prognosis is generally

Table 2*. Life expectancy, lifetime cost and cost per QALY (quality-adjusted life year) for patients requiring PMV in Taiwan

Single specific disease		Life expectancy (years)	Quality-adjusted life expectancy		Lifetime cost (10 thousand TWD)		Cost per QALY (10 thousand TWD)	
			Partial cognition	Poor cognition	Healthcare cost	Out of pocket	Partial cognition	Poor cognition
Cancer		1.49	0.46	0.20	46.0	40.5	188.0	432.3
Renal failure		1.32	0.40	0.18	70.5	35.5	265.0	588.9
Liver cirrhosis		3.50	1.15	0.50	57.0	94.6	131.9	303.4
Degenerative nerve diseases		4.08	1.28	0.56	228.4	107.2	262.2	599.3
Parkinson’s diseases		2.01	0.59	0.26	129.9	50.7	306.1	694.6
Trauma		6.19	2.04	0.89	125.1	165.0	142.3	326.1
Stroke		3.32	1.05	0.46	123.3	87.0	200.3	457.1
	<65 years	5.24	1.60	0.72	158.9	137.9	185.5	412.2
	65-74 years	2.93	1.14	0.40	125.9	75.9	177.0	504.5
	75-84 years	2.03	0.61	0.27	116.5	52.2	276.6	624.9
	>85 years	1.42	0.49	0.21	87.3	36.3	252.2	588.5
Intracranial or spinal injury		6.19	2.04	0.89	125.2	165.0	142.3	326.1
	<65 years	10.06	3.40	1.47	165.2	270.0	128.0	269.1
	65-74 years	3.71	1.18	0.51	111.2	97.1	176.5	408.3
	75-84 years	2.64	0.82	0.33	97.0	68.9	202.4	502.9
	>85 years	1.51	0.52	0.22	87.8	38.7	243.2	574.8
COPD	<65 years	5.18	1.66	0.72	172.2	136.2	185.8	428.3
	65-74 years	2.49	0.76	0.33	107.3	64.5	226.1	520.7
	75-84 years	2.05	0.63	0.28	94.3	53.7	235.0	528.8
	>85 years	1.46	0.42	0.19	77.7	37.5	274.1	605.9
Heart diseases	<65 yrs	4.97	1.61	0.70	137.2	132.1	167.3	384.7
	65-74 years	2.49	0.77	0.34	89.9	65.4	201.6	456.6
	75-84 years	1.78	0.54	0.24	75.2	46.6	225.6	507.5
	>85 years	1.43	0.41	0.18	72.7	36.8	266.9	608.0
Septicemia/shock	<65 years	4.42	1.22	0.64	80.8	118.1	163.0	310.7
	65-74 years	2.08	0.65	0.28	72.2	54.7	195.2	453.1
	75-84 years	1.60	0.49	0.22	65.2	42.4	219.5	488.8
	>85 years	1.07	0.31	0.14	55.8	33.2	287.0	635.6
Cases >2 specific diseases		2.90	0.93	0.40	93.4	76.8	183.0	425.5
Cancer and renal failure		1.14	0.36	0.16	67.5	31.3	274.5	617.6
Cancer and others		1.82	0.58	0.26	57.4	48.9	183.4	409.2
Renal failure and others		1.65	0.52	0.23	77.6	45.0	235.7	532.8

* modified under permission[46].

poor, this population represents a heterogeneous group of patients who need to be managed individually. We recommend a patient-centered, outcome-oriented approach. For patients with substantial weaning potential, a protocolized weaning process of daily SBTs integrated with early rehabilitation and nutritional intervention may facilitate stepwise liberation from PMV. For those with multiple failed weaning attempts, alternatives to ventilator dependency, such as time-limited weaning trials, a shift to noninvasive positive pressure ventilation, or palliative care, should be offered to patients and their surrogates, using SDM when making a goal-of-care plan. As prognostic information and long-term outcomes of PMV become available, they should be provided in family conference, along with information on medical expenses and resources needed after discharge. Well-designed multicenter randomized trials are needed to assess the results of specific interventions, such as weaning strategies, nutritional intervention, and physical therapy. Models with better predictive power which assess weaning potential and long-term outcomes are required for communication and decision making. Basic research on the pathophysiology of PMV, such as ventilator-induced diaphragm dysfunction and critical illness polyneuropathy, are essential in the development of preventive strategies.

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長期使用呼吸器病患之處置

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摘 要

隨著重症醫療維生技術的進步，使得許多病患得以從最危急的重症中存活，然而仍有4-13% 的病人因無法脫離呼吸器，而最終變成呼吸器依賴。近年來呼吸器依賴人口因日益增加而漸受重視，他們不但耗費可觀的醫療資源，生活品質亦普遍不佳且死亡率甚高。然而，此類病患之照護不應視為重症領域知識及思維之延伸。為了提供完善之呼吸照護，專屬的中期照護機構（如呼吸照護中心）應運而生，且相關領域的研究亦日益累積。本篇將探討長期使用呼吸器病患之照護實證，包括呼吸器脫離策略、氣切、營養及復健等。同時，以台灣健保資料庫為基礎的研究相繼出現，為臨床照護目標溝通及醫病共享決策提供了實用的預後資訊。