

# SUCCESSFUL WEANING PREDICTORS IN A RESPIRATORY CARE CENTER IN TAIWAN

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Respiratory care centers (RCCs) provide effective care for patients who have been in intensive care and have undergone prolonged mechanical ventilation. Between February 2002 and December 2005, 891 patients who met the admission criteria of RCCs were referred to our RCC at Kaohsiung Medical University Hospital in southern Taiwan for attempted weaning. We recorded demographic and clinical data, including variables identified previously as predictive of weaning success among highly selected populations. The common causes of respiratory failure at RCC admission were neuromuscular disease (29.2%), pneumonia (27.5%), cancer (18.0%), cardiovascular disease (10.1%), sepsis (5.7%) and post-surgery (1.6%). The percentage of patients successfully weaned was 40.2%, while 59.8% remained dependent on ventilators. In a stepwise multivariate logistic regression analysis, significant predictors of weaning success included neuromuscular disease (odds ratio [OR], 2.64), APACHE II score (OR, 0.93) and blood urea nitrogen level at RCC admission (OR, 0.99). The results could be helpful in the accreditation of medical care quality and may provide guidelines for future research and education programs.

**Key Words:** mechanical ventilator, respiratory care center, weaning  
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Most patients who require mechanical ventilation during critical illness can be successfully liberated from respiratory support on recovery from the precipitating illness. In 2–5% of patients [1], the weaning process fails. Weaning failure is conventionally defined as dependency on mechanical ventilation for more than 3 weeks after resolving the precipitating cause of admission to the intensive care unit (ICU) [2]. It has been estimated that patients who require 3 weeks of prolonged mechanical ventilation (PMV) use approximately 40% of the ICU's budget [3,4]. In the 1990s,

economic pressure to maximize resource utilization has resulted in the transfer of hemodynamically stable PMV patients out of the ICU setting. Post-ICU care for these patients is now recognized as part of the continuing care not only for the recipient patients, but also for critical care practitioners. In Taiwan, the National Health Insurance (NHI) system designed a special transfer system for managing PMV patients. Respiratory care centers (RCCs), units downstream of the ICU, accept patients who are ventilator-dependent after more than 3 weeks of attempted weaning.

Our RCC was established in February 2002. Since then, we have collected data on the patients admitted and have accumulated information on more than 900 consecutive ventilator-dependent patients. This report presents our experience and identifies several successful weaning predictors that can be associated with the care of these patients.



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## METHODS

### Subjects

In 1998, the Taiwan NHI established an integrated delivery system (IDS) for patients who need PMV support. The IDS consists of four stages, including ICU, RCC, respiratory care ward (RCW), and home care. If patients cannot be weaned successfully from a mechanical ventilator during the first 21 days of ICU admission, these patients must be transferred to an RCC for a further ventilator weaning process. Exclusion criteria for RCC admission are the following: unstable hemodynamic status with vasopressor support, unstable hemodynamic status during hemodialysis procedure for renal failure patients, liver failure, surgical interventions that need to be performed on patients with severe gastrointestinal tract bleeding, surgical intervention that needs to be repeatedly performed within 2 weeks for the same surgical problem, unstable oxygenation ( $SpO_2 < 90\%$  or  $PaO_2 < 60$  mmHg) with  $FiO_2 > 60\%$  and positive end-expiratory pressure (PEEP)  $> 10$  cmH<sub>2</sub>O. If RCC patients experience shock, acute myocardial infarction or a surgical condition, they can be transferred back to the ICU. If these patients still cannot be weaned from the ventilator during RCC admission, the physician must then transfer them to the RCW or home care. The longest RCC stay is 42 days.

Our RCC is a designated section of the pulmonary specialty ward of the Kaohsiung Medical University Hospital. RCC patients come only from our own hospital's ICU. The 20-bed RCC is staffed by nurses with special pulmonary and rehabilitation expertise, and it features 24-hour respiratory therapy supervision and noninvasive monitoring (that is, continuous pulse oximetry and ventilator alarms) with signal outputs at each bedside. Critical care specialists are in charge of patients' treatments and weaning plans. Dietitians, physical and occupational therapists, and relevant subspecialists are all part of the care team. The case manager and social worker are responsible for the transfer plan and financial support.

### Study design

For all patients admitted to the RCC, the following data elements were prospectively recorded: their demographic features, the type of ICU from which they were admitted, their condition leading to ventilator dependence, the duration of ICU stay preceding RCC

admission, the duration of total RCC stay, the duration of mechanical ventilator support, their first day of weaning from mechanical ventilation (defined as the first day after which spontaneous breathing was maintained for 72 hours), and serum albumin level (a measure of their nutritional status) at RCC admission. The Acute Physiology and Chronic Health Evaluation (APACHE) II scoring system was also used when patients were first admitted to the RCC. We also abstracted biochemical data including arterial blood gas (ABG), O<sub>2</sub> index ( $PaO_2/FiO_2$ ), serum creatinine (Cr) level, blood urea nitrogen (BUN) level, hemoglobin, and electrolytes; these data were abstracted from the date of admission or the date nearest to the day of RCC admission. We also noted the modified Glasgow Coma Scale (GCS) score [5], obtained from two sources: the nurse's intake record and the physician's admission findings. The GCS scoring system includes a numeric code for motor, eye and verbal responses. However, the verbal component has been criticized as difficult to reliably score in intubated patients. Several investigators have recently reported that the verbal component of the GCS can be omitted without compromising the reliability and predictive validity of the score, especially in patients suffering from a neurologic event [5]. Because most of our patients had a tracheostomy and were unable to speak, only the motor and eye scores were recorded, and the maximum value of this modified GCS was 10.

Two weaning modalities were administered during the time period of the study: intermittent T-piece trial and pressure support ventilation with gradual reduction. The attending physician in the RCC decided on the modality for ventilator weaning. Weaning parameters, such as ABG, maximum inspiratory force ( $PI_{max}$ )  $< -25$  mmHg, tidal volume, minute ventilation  $> 10$  L, respiratory rate  $< 30$  bpm, PEEP  $< 5-8$  cmH<sub>2</sub>O, cuff leak volume  $< 110$  mL, and rapid shallow breathing index (RSBI)  $< 105$ , were factored into weaning decision-making. We classified patients as "successfully weaned" or "ventilator-dependent". Patients were considered to have undergone successful weaning if no ventilator support was required for 72 consecutive hours.

### Statistical analysis

Statistical analysis included descriptive statistics, frequencies, proportions, and means. To determine the variables associated with weaning success, we

performed both univariate and multivariate analyses. Univariate analysis was performed using  $\chi^2$  and  $t$  tests, as appropriate. Variables that were found to be significantly related to weaning success in univariate analysis were entered into a multivariate logistic regression model to identify independent predictors of weaning success. A  $p$  value of less than 0.05 was considered statistically significant. Statistical analysis was performed using JMP software version 5.0.1 (SAS Inc., Cary, NC, USA).

## RESULTS

Excluding repeatedly transferred patients, a total of 891 patients with PMV (57.5% male) admitted to the RCC were included in this study. The average age was  $69.9 \pm 14.3$  years (range, 17–101 years). The mean length of RCC stay was  $18.3 \pm 11.4$  days. The mean ventilator period in the RCC was  $16.2 \pm 12.0$  days. The mean APACHE II score at RCC admission was  $16.9 \pm 6.1$  (Table 1). Most PMV patients (74.6%) had received tracheostomy before they were transferred to the RCC from the ICU. Fifty-eight percent of the RCC patients came from the medical ICU, 37% from the surgical ICU, and 5% from a general ward. The most common causes of respiratory failure at RCC admission were neuromuscular disease (29.2%), pneumonia (27.5%), cancer (18.0%), cardiac disease (10.1%), sepsis (5.7%), and chronic obstructive pulmonary disease (COPD) (3.1%). A total of 358 patients (40.2%) were successfully weaned from the ventilator (Table 2). Among them, most (82.4%) were weaned during the first 21 days after RCC admission. The weaning rate of tracheostomy patients was 77.4%. We found that patients suffering from respiratory failure caused by neuromuscular disease had a higher successful weaning rate than others ( $p < 0.0001$ ). Table 1 shows the disposition of patients upon discharge. Among the RCC patients, 225 (25.3%) were transferred to the general ward and 224 (25.1%) ventilator-dependent patients were referred to an RCW for the required specialized therapies. Only 77 patients (8.6%) were transferred to a nursing home. The mortality rate was 20.1%. One hundred and six patients (11.9%) with worsening conditions returned to the ICU (Table 1). The impact on our medical ICU after RCC setup was a decreased mean length of stay in the ICU (11.2 days *vs.* 8.2 days) and an increased ICU turnover rate.

**Table 1.** Characteristics and outcomes of patients on admission to the RCC\*

Age (yr)	$69.9 \pm 14.3$ (range, 17–101)
Male gender	512 (57.5)
APACHE II score at RCC admission	$16.9 \pm 6.1$
Ventilator period before RCC (d)	$22.4 \pm 7.2$
Ventilator period RCC (d)	$16.2 \pm 12.0$
Total days on mechanical ventilation	$40.4 \pm 18.5$
RCC length of stay (d)	$18.3 \pm 11.4$
Disposition	
General ward	225 (25.3)
RCW	224 (25.1)
Dead	179 (20.1)
ICU	106 (11.9)
Nursing home	77 (8.6)
Other hospital	73 (8.2)
Home	7 (0.8)

\*Data presented as mean  $\pm$  standard deviation or  $n$  (%). APACHE = Acute Physiology and Chronic Health Evaluation; RCC = respiratory care center; RCW = respiratory care ward; ICU = intensive care unit.

On univariate analysis, the correlates of successful weaning included patient age ( $68.3 \pm 14.7$  years old *vs.*  $71.0 \pm 13.9$  years old,  $p = 0.0056$ ), APACHE II score at RCC admission ( $15.1 \pm 5.8$  *vs.*  $18.1 \pm 6.0$ ,  $p < 0.0001$ ), hemoglobin level at RCC admission ( $10.1 \pm 1.6$  g/dL *vs.*  $9.4 \pm 1.4$  g/dL,  $p < 0.0001$ ), albumin level at RCC admission ( $3.0 \pm 0.5$  g/dL *vs.*  $2.8 \pm 0.6$  g/dL,  $p < 0.0001$ ), BUN level at RCC admission ( $34.4 \pm 29.9$  mg/dL *vs.*  $53.1 \pm 40.2$  mg/dL,  $p < 0.0001$ ), and Cr level at RCC admission ( $1.5 \pm 1.6$  mg/dL *vs.*  $2.1 \pm 2.0$  mg/dL,  $p < 0.0001$ ) (Table 2).

Multivariate analysis confirmed that neuromuscular disease (odds ratio [OR], 2.64; 95% confidence interval [CI], 1.90–3.67;  $p < 0.001$ ), APACHE II score at RCC admission (OR, 0.93; 95% CI, 0.91–0.96;  $p < 0.001$ ) and BUN level at RCC admission (OR, 0.99; 95% CI, 0.99–1.00;  $p < 0.001$ ) were associated with successful weaning (Table 3). To investigate the weaning predictors of groups of patients with different diagnoses, we performed multivariate analysis among neuromuscular disease, pneumonia, cancer, cardiac disease and sepsis. The small sample size of the other three groups, including post-surgery, sepsis and miscellaneous, limited the results of analysis.

**Table 2.** Determining factors for successful weaning\*

	Ventilator independence (n=358)	Ventilator dependence (n=533)	p
Age (yr)	68.3±14.7	71.0±13.9	0.006
Male gender	213 (43.9)	299 (56.1)	0.31
APACHE II score at RCC admission	15.1±5.8	18.1±6.0	< 0.01
RCC length of stay (d)	14.4±8.5	20.9±12.4	< 0.01
Total days on mechanical ventilation	32.4±10.7	45.5±14.9	< 0.01
Admission PaO <sub>2</sub> /FiO <sub>2</sub> ratio	356.9±171.1	311.3±156.2	< 0.01
Admission Hb level (g/dL)	10.1±1.6	9.4±1.4	< 0.01
Admission serum albumin (g/dL)	3.0±0.5	2.8±0.6	< 0.01
Admission BUN (mg/dL)	34.4±29.9	53.1±40.2	< 0.01
Admission serum Cr (mg/dL)	1.5±1.6	2.1±2.0	< 0.01
Coma scale	7.3±2.5	6.7±2.8	< 0.01
Route on transfer			
Endotracheal tube	75 (35.4)	137 (64.6)	0.12
Tracheostomy	257 (41.4)	364 (58.6)	
Source of admission			
Medical ICU (n=513)	180 (35.1)	333 (64.9)	0.01
Surgical ICU (n=330)	162 (49.1)	168 (50.9)	
General ward (n=48)	16 (33.3)	32 (66.7)	

\*Data presented as mean ± standard deviation or n (%). APACHE = Acute Physiology and Chronic Health Evaluation; RCC = respiratory care center; Hb = hemoglobin; BUN = blood urea nitrogen; Cr = creatinine; ICU = intensive care unit.

**Table 3.** Predictors of successful weaning

	OR (95% CI)	p
Neuromuscular disease	2.64 (1.90–3.67)	<0.01
APACHE at RCC admission	0.93 (0.91–0.96)	<0.01
Admission BUN	0.99 (0.99–1.00)	<0.01

OR = odds ratio; CI = confidence interval; APACHE = Acute Physiology and Chronic Health Evaluation; RCC = respiratory care center; BUN = blood urea nitrogen.

Age was used as a control variable to avoid added confusion. We found that albumin concentration at admission (OR, 2.25; 95% CI, 1.19–4.26; *p*=0.01) and APACHE II score (OR, 0.94; 95% CI, 0.90–0.98; *p*<0.01) were important factors for predicting weaning in the pneumonia group. BUN at admission was important for the neuromuscular disease group (OR, 0.98; 95% CI, 0.97–0.99; *p*<0.001). For patients with cardiac disease or cancer, APACHE II score was the best predictor of weaning: OR, 0.91; 95% CI, 0.84–0.98; *p*=0.02 (*vs.* OR, 0.90; 95% CI, 0.84–0.97; *p*=0.01).

## DISCUSSION

For PMV patients without active disease, intensive care may no longer be needed, but these patients still cannot be safely sent to a general ward. There is an increasing trend toward transferring these PMV patients to special weaning units such as RCCs or RCWs. Information about weaning success rates and predictors of weaning success would be helpful in making decisions about transferring such patients from the ICU to the RCC. In our study, 40.2% of RCC patients were successfully weaned. In previous investigations, the success rates ranged from 38% to 70% [2,6–8]. Studies by Pilcher et al [2] and Carson et al [6] had patient categories that were similar to ours (more medical patients than surgery patients), and their successful weaning rates were nearly 40% in a regional weaning center. Gracey et al [7] studied transferring care for 964 patients from ICUs to chronic ventilator-dependent units: ventilator weaning was successful in 64% of 549 patients.

Our low successful weaning rate may be due to the following reasons. First, a higher proportion of cancer patients (160 patients [18%]) received intubation and these results may be because of our traditional custom "to keep patients alive even when facing untreatable malignancy". After the Legislative Yuan of Taiwan passed the *Statute for Hospice and Receding Medical Treatment Revised Rules* on November 11, 2002 in Taiwan, a positive outcome for patients, families and medical staff was achieved without doubt. However, the biggest barrier to the thorough practice of this rule is how to reinforce appropriate hospice and palliative care when terminally ill patients experience complications because they are often unable to express or act for themselves. Although there is broad consensus about the patient's right to refuse life support, little has been written about the applicable procedure of withdrawing mechanical ventilation until recently [9]. Second, the mean APACHE score of other reports of successfully weaned patients was 15.2, but our mean APACHE score of successfully weaned patients was 16.9. Third, our NHI system limits our selection of PMV patients, regardless of their weaning potential and underlying disease. Severe infection was not an excluding criterion for PMV patients admitted to the RCC.

We also found several parameters affecting the weaning rate. Among different groups of PMV patients, we found that neuromuscular disease patients were more likely to wean successfully than patients with other diagnoses. Concerning the neuromuscular group, we divided them into two groups according to the GCS. The group with  $GCS \geq 8$  had a higher successful weaning rate (53.6%) compared with the other groups ( $p < 0.05$ ). Our results were consistent with those of Hendra et al [10] who reported that patients with a modified  $GCS \geq 8$  were 6.5 times more likely to wean than those with a modified  $GCS < 8$  (95% CI, 1.6–26.3). The modified GCS defined in this investigation is a potentially useful predictor of long-term weaning potential in similar neurologic patients. Except for their neurologic problems, these patients had fairly good lung function, thus making weaning easier and more rapid. For the group of patients with neuromuscular disease, serum BUN was the most relevant predictor. We found that APACHE II score and serum albumin concentration were the best weaning predictors in patients with pneumonia. APACHE II score was the most important predictor

of weaning in patients with cardiac disease or cancer. It has been shown that PMV is primarily determined by the admitting diagnosis and APACHE [11], which is consistent with our results. We also discovered that younger patients were more quickly weaned from the ventilator. Ely et al [12] found that age had an independent effect on the outcome of patients treated with mechanical ventilation, and that advanced age was associated with higher rates of ventilator dependence. Esteban et al [13] reported that patients older than 70 years had more subsequent complications, such as acute renal failure and shock, caused by the mechanical ventilator. However, the duration of mechanical ventilation used, ICU and hospital stay were similar among the younger patients. The mortality rates of the regional weaning center were around 13–27%, according to studies by Pilcher et al [2] and Ceriana et al [14]. Our overall mortality was around 20%, which is similar to that of other reports.

The investigation of Modawal et al [15] identified significant predictors of weaning success, including Caucasian race, serum albumin level and BUN level. Dasgupta et al [16] reported that patients with lower serum albumin ( $p < 0.001$ ) and transferrin ( $p = 0.05$ ) levels have higher rates of hospital mortality. In our study, we also identified successful weaning parameters, including neuromuscular disease, APACHE II score at RCC admission and BUN level at RCC admission. Serum albumin level has been demonstrated to be associated with successful weaning in critically ill patients in previous studies [17]. A low serum albumin level is a marker of malnutrition. Malnutrition is usually caused by PMV use and prolonged admission. Thus, malnutrition may have deleterious effects on weaning [16].

We also found that a higher serum albumin level is associated with successful weaning. Anemia is common in the critically ill and may be an important factor that interferes in a patient's ability to be weaned from mechanical ventilation. In our study, higher hemoglobin levels above 10.2 g/dL seemed to increase the successful weaning rate. Similowski et al [18] found that COPD patients with low hemoglobin levels had a poorer prognosis than COPD patients with normal hemoglobin levels. Raising hemoglobin through transfusion can decrease minute ventilation and breathing work in COPD patients [18]. Chronic renal failure results in poor responsiveness to a ventilator control system and makes patients less capable

of weaning from mechanical ventilation [19]. Previous reports have also demonstrated that admission BUN and serum Cr can influence the weaning outcome [20].

In conclusion, the RCC is an adequate and useful alternative weaning facility for PMV patients. The factors associated with successful weaning are better nutrition status, normal renal function and hemoglobin at RCC admission. It is likely that these different outcomes reflect different selection criteria for ventilator unit admission. Understanding the causes of these differences will require longitudinal tracking of outcomes among a complete inception cohort of mechanically ventilated patients, as well as a severity-of-illness adjustment. For the different PMV groups, several parameters play an important role in the weaning process. The results of this study provide a useful insight into an increasingly important field of respiratory medicine.

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# 台灣呼吸照護中心呼吸器 脫離之預測因子

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呼吸照護中心主要提供延長使用呼吸器病患之加強照護。本研究對象為自 2002 年 2 月 1 日至 2005 年 12 月 31 日止南台灣高雄醫學大學附院 891 位轉入呼吸照護中心嘗試脫離呼吸器病患。我們收集病患基本資料及臨床報告，包括過去研究認為可作為預測呼吸器脫離的預測變項。研究結果發現，呼吸照護中心病患呼吸衰竭原因包括神經肌肉疾病 (29.2%)、肺炎 (27.5%)、癌症 (18.0%)、心臟血管疾病 (10.1%)、口敗血症 (5.7%) 及手術後病患 (1.6%)，其中 40.2% 病患脫離成功，59.8% 仍需依賴呼吸器。進一步以邏輯式回歸分析發現，呼吸器脫離預測因子包括診斷神經肌肉疾病 (相對危險比：2.64)、疾病嚴重度 (相對危險比：0.93) 及尿素氮 (相對危險比：0.99)。此研究結果將可作為未來呼吸照護中心之醫療照護品質評鑑準則，並作為臨床研究教學之參考。

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