Determinants of Time-To-Weaning in a Specialized Respiratory Care Unit*

Loutfi S. Aboussouan, MD; Chris D. Lattin, BS, RRT; and Vijay V. Anne, MD

Background: As the decision-making process in long-term respiratory care units often depends on time-based outcomes, we sought to identify independent predictors of time-to-weaning (TTW) in a hospital-based specialized respiratory care unit.

Methods: Characteristics that were identified in previous studies as predictors of weaning success in ICUs and long-term ventilator units were prospectively collected on 113 consecutive admissions to our unit. TTW analyses were performed with Kaplan-Meier curves, log rank test, and Cox proportional regression.

Results: The TTW was shorter in patients with static lung compliance (Cst) of > 20 mL/cm H_2O, a normal creatinine level (0.6 to 1.4 mg/dL), a rapid shallow breathing index (RSBI) of ≤ 105, intact skin, and in those patients from a surgical referral source. We found an interaction between RSBI and Cst (p = 0.02) such that patients with an RSBI of ≤ 105, regardless of Cst, had a median TTW of 11 days, those with an RSBI of > 105 and a Cst of > 20 had a median TTW of 31 days, and those with an RSBI of > 105 and a Cst of ≤ 20 mL/cm H_2O had not reached a median TTW by 60 days (p = 0.007 [log rank for linear trend]). In a Cox-proportional hazard model, both this categorization model of RSBI and Cst, and renal function had a significant impact on TTW.

Conclusions: In a multivariate model incorporating the variables reviewed, only the lung parameters (RSBI combined with Cst) and renal function remained independently associated with TTW.   *(CHEST 2005; 128:3117–3126)*

Key words: acute physiology and chronic health evaluation; creatinine; lung compliance; respiratory insufficiency; respiratory mechanics; ventilator weaning

Abbreviations: APACHE = acute physiology and chronic health evaluation; CI = confidence interval; Cst = static lung compliance; LTAC = long-term acute care; PCU = Pulmonary Care Unit; ROC = receiver operating characteristic; RSBI = rapid shallow breathing index; TTW = time-to-weaning

The increasing acuity of medical illness has resulted in a shortage of ICU beds available to ventilator-dependent patients.[1] Moreover, there are mounting challenges on hospitals to recover the costs of care for such patients.[2] As a partial solution, many individuals whose need for ventilator support extends beyond their need for acute care are now managed in settings other than ICUs, including specialized respiratory care units, and intermediate-term and long-term care facilities.[3]

Limited resources and bed availability in such hospital-based units have encouraged more optimal management in order to accelerate liberation from mechanical ventilation, accommodate incoming patients, and facilitate the transfer of patients with a poor weaning prospect to long-term acute care (LTAC) units that have a more favorable reimbursement structure. However, such management decisions depend not only on estimates of the likelihood of liberation from mechanical ventilation but also on the time frame for such an outcome. Moreover, while certain ventilator modalities[4–7] and therapist-implemented protocols[8] have been proposed to accelerate weaning, further progress in that regard depends on the accurate identification of independent predictors of delayed weaning in some individuals. Although many previous studies have identified predictors of weaning outcome, they usually have not addressed the time required to achieve weaning, did not always accommodate all potential confounders, or may have been developed in the ICU setting as predictors of rapid wean potential (*eg*, the rapid shallow breathing index [RSBI]) with uncertain applicability to the longer term ventilator units.

Therefore, we sought to prospectively assess the

performance in a hospital-based specialized respiratory care unit of variables that were identified in previous studies as predictors of wean success. Since time from hospital admission to successful weaning represents time-to-event data, we adopted a survival analysis model to simultaneously incorporate all relevant variables and to identify independent predictors of time-to-weaning (TTW).

MATERIALS AND METHODS

Patients

The Pulmonary Care Unit (PCU) at Harper University Hospital in Detroit, MI, is a specialized respiratory care unit for the care of patients with intensive pulmonary needs. The unit consists of nine beds, and provides noninvasive cardiac and respiratory monitoring. All patients who received ventilation via a tracheostomy who had been admitted to the PCU from its inception in June 2001 until August 2003 were included in the study. We excluded four patients who were admitted to the PCU through that period for a planned intervention with known disposition after completion of the intervention (eg, transfers from long-term care facilities for specialized procedures, transfers under hospice care, or for comfort measures). The PCU admission criteria included the following: the presence of an adequately sized tracheostomy tube for the patient's size with an inner diameter of at least 7 mm; hemodynamic stability; positive end-expiratory pressure of ≤ 8 cm H_2O; fraction of inspired oxygen of $< 60\%$; the failure of weaning attempts in the ICU; the absence of potentially lethal dysrhythmias; the absence of titratable drips; and the lack of need for neuromuscular blockade or continuous sedatives with the exception of patient-controlled anesthesia (PCA) pumps and epidural therapy. Additionally, though poor rehabilitation potential and mental status were not absolute contraindications, the potential ability to wean was favored for admission to the unit.

Potential Determinants of Wean Outcome

The following potential determinants, based on a review of the literature, were prospectively collected on the day of admission to the PCU: the location of the patient before admission to the PCU (medical vs surgical unit)[9–12]; age and race[12]; acute physiology and chronic health evaluation (APACHE) II score[13]; creatinine level[14]; skin integrity[15]; respiratory parameters, including static lung compliance (Cst)[16] and the RSBI[17,18]; and whether the patient had emphysema.[9,10,12] Other variables collected included the albumin level within 1 week of admission to the PCU[10,12] and ejection fraction, if it was available from a cardiac echocardiography report within 2 months of admission to the PCU.[19] We also recorded the number of days from admission to the PCU to placement of a tracheostomy, the number of hospital days before admission to the PCU, and the use of the following medications on admission to the PCU: systemic steroids; benzodiazepines; opioids; β-blockers; and the use of nebulized or inhaled steroids or bronchodilators. The disposition of patients at hospital discharge was recorded as follows: home (including home ventilator); rehabilitation facility; nursing home; LTAC unit; hospice (including home hospice); and dead.

Weaning Protocol

A therapist-driven protocol, which was modeled after the available comparative studies of wean modalities, was implemented to optimize the time required to achieve wean weaning.[4–6,8] The respiratory therapists who were in charge of the weaning protocol were blinded to the Cst and RSBI, which were separately obtained by the investigators. In each case, an attempt was made to identify and address the impediments to weaning in weekly multidisciplinary meetings that included a nutritionist, respiratory therapist, speech pathologist, physical therapist, social worker, pharmacist, physician (LSA), unit manager, and members of the nursing staff. Impediments to weaning were included only in as much as they were deemed to contribute to the respiratory failure, and were classified as neurologic (including central, spinal, or neuromuscular causes), cardiac (including coronary artery disease and congestive heart failure), infectious (any cause including pneumonia), or pulmonary (including COPD, asthma/bronchitis, obesity hypoventilation, ARDS, and interstitial lung disease). Patients were placed on assist-control ventilation on arrival in the PCU and were considered ready for a weaning trial if systolic BP was between 90 and 180 mm Hg, heart rate was between 50 and 130 beats/min, temperature was $< 101°F$ ($< 38.3°C$), and minute ventilation was < 15 L/min. On each of the first 2 days following admission to the PCU, patients who considered to be ready for weaning underwent spontaneous breathing trials, and a successful trial was followed by use of a tracheostomy mask with oxygen supplementation to maintain a pulse oximetry saturation of $\geq 94\%$. Those failing the spontaneous breathing trials on the first 2 days were rested using assist-control ventilation for the remainder of the day and spent subsequent days receiving pressure support ventilation at a level sufficient to maintain a respiratory rate of < 30 breaths/min. For patients who tolerated the trials, pressure support was decreased by 2 cm H_2O at least twice daily. The tolerance of pressure support at 5 cm H_2O for at least 2 h was followed by use of a tracheostomy mask. Patients undergoing a spontaneous breathing trial or a pressure support trial were returned to therapy with assist-control ventilation if they had a respiratory rate of > 30 breaths/min, and an increase in heart rate by 20 beats/min, a decrease in systolic BP by ≥ 20 mm Hg, or a decrease in oxygen saturation by $\geq 5\%$. The TTW was calculated as the number of days from admission to the PCU to the first day of the last successful 48-h weaning trial regardless of ultimate outcome.

Definitions and Measurements

The term wean as used in this study conforms to its use in general practice as reflecting the process of liberation from mechanical ventilation without implying a protracted process. Although the majority of patients originated from the different ICUs of Harper Hospital, $< 10\%$ were directly admitted from LTAC facilities and were considered for the purpose of our analysis to have originated from a medical (as opposed to surgical) unit regardless of their location prior to the LTAC facility admission. A diagnosis of emphysema was not based on a chart report but rather on a review of chest radiographs, confirmed history, or prior documentation by a pulmonologist. A decubitus ulcer was considered to be present for any stage skin breakdown of the sacrum.[20] Renal function on admission to the PCU was categorized based on the creatinine level as normal (0.6 to 1.4 mg/dL) or abnormal (including creatinine values of < 0.6 or > 1.4 mg/dL, and dialysis). Cst was measured by dividing the delivered tidal volume (in milliliters) by the difference between plateau and positive end-expiratory pressures (in centimeters of water). To obtain a plateau pressure, we used the inspiratory hold function of the ventilator for 0.5 to 1 s and confirmed an adequate plateau by visual inspection of the pressure-time curve on the ventilator display. The RSBI was obtained by dividing the respiratory frequency (in breaths per minute) by the tidal volume (in liters). Tidal volume and respiratory rate were obtained from