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Dyspnea Intensity, Psychological Distress, Anxiety Intensity, Inspiratory Effort: Effects on Ventilator Weaning

by

Ann R. Knebel, R.N., D.N.Sc.

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF NURSING SCIENCE

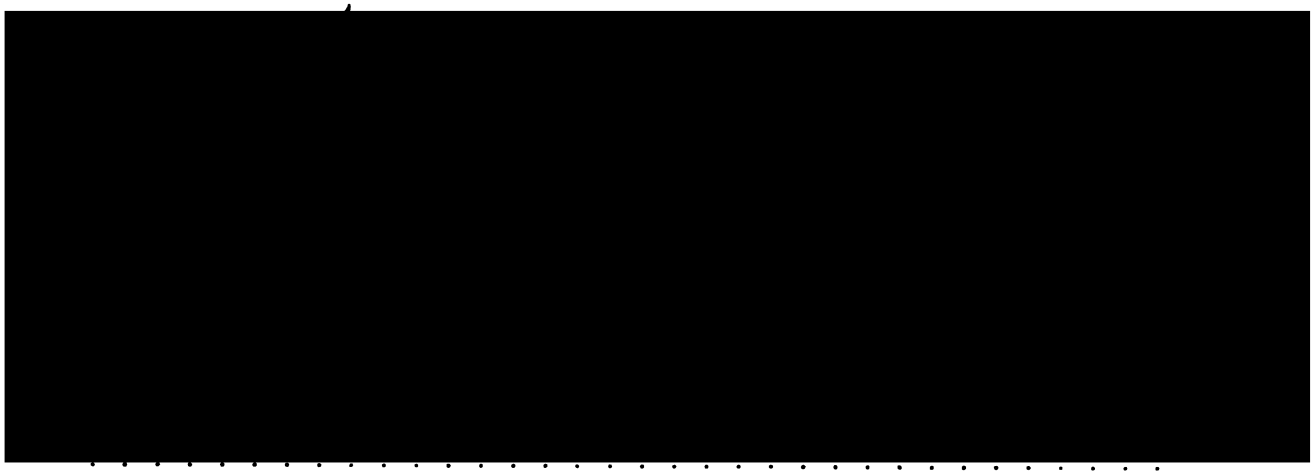
in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA

San Francisco



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Ann R. Knebel, R.N., D.N.Sc.

DEDICATION

This work is dedicated to the ventilator patients who provided the impetus to begin the work, who contributed to knowledge development by agreeing to participate in the research, and who continue to spur by desire to understand the interactions that contribute to long-term mechanical ventilation.

ACKNOWLEDGMENTS

I express my sincere gratitude to my committee. To Susan Janson-Bjerklie who has provided insight and guidance, shaping not only the dissertation, but my development throughout the doctoral program. To Jane Norbeck whose logical and methodical approach to research provided invaluable input into the dissertation. To John Marini who has contributed so much to the care of ventilator patients, not only with his own work, but also generously sharing his expertise for the current study.

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ABSTRACT

DYSPNEA INTENSITY, PSYCHOLOGICAL DISTRESS, ANXIETY INTENSITY, AND INSPIRATORY EFFORT: EFFECTS ON VENTILATOR WEANING.

Ann R. Knebel, R.N., D.N.Sc.

University of California, San Francisco, 1990

Understanding the interactions between physiological and psychological variables provides insights into the weaning process of ventilated patients. Twenty-one subjects ventilated for three days or more were studied during both intermittent mandatory ventilation (IMV) and pressure support ventilation (PSV) weaning trials. Subjects rated the intensity of their dyspnea and anxiety on 100 mm visual analogue scales prior to and during both weaning methods. Prior to weaning, subjects also reported their psychological distress on a short version of the profile of mood states (POMS). Physiological indices of work of breathing and breathing effort were obtained during the weaning trials. Subjects were followed for 24 hours after data collection to determine whether they were extubated successfully.

Despite resting on full ventilator support prior to the start of weaning, subjects reported pre-weaning dyspnea and anxiety. Subjects also reported subjective feelings of fatigue/inertia and tension/anxiety. The feelings reported prior to weaning, did not affect dyspnea intensity, anxiety intensity, nor inspiratory effort measured during the weaning trials. The pre-weaning variables failed to identify subjects able to wean from those who could not.

During the weaning trials, dyspnea intensity and anxiety intensity were

always correlated. Dyspnea intensity also correlated with inspiratory effort, but only at high work loads. In contrast, anxiety intensity correlated with inspiratory effort during IMV weaning, but not during PSV weaning. Dyspnea intensity was the only weaning process variable that related to successful weaning outcome.

Inspiratory effort was lower during PSV weaning as compared to IMV weaning. However, the difference in effort did not translate into less dyspnea or anxiety. There were no differences in dyspnea or anxiety intensities between the two methods.

In conclusion, the findings suggest that pre-weaning dyspnea, psychological distress, and anxiety do not accurately predict the weaning process, nor the weaning outcome. Dyspnea during weaning may relate more closely to anxiety than to inspiratory effort, except at high work loads. Even though inspiratory effort was less during PSV weaning, the subjects did not report less dyspnea and anxiety. Therefore, the method of weaning may be less important than a systematic approach to withdrawing ventilator support.

Susan Janson-Bjerklie, R.N., D.N.Sc.
Chairperson, Dissertation Committee

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CHAPTER 1

THE STUDY PROBLEM

As an episode of acute respiratory failure resolves for the mechanically ventilated patient, the task of re-assuming spontaneous ventilation begins. The resumption of spontaneous ventilation, commonly referred to as weaning, is often difficult for patients ventilated for a prolonged period (Sporn & Morganroth, 1988). A lengthy weaning process often discourages patients, families and the intensive care staff (Nett, 1982). As a result, patients may never wean, succumbing to their illness, or alternatively, requiring chronic mechanical ventilation (MV) with supportive care. Many factors potentially contribute to difficult weaning, including: presence of pre-existing lung disease; duration of ventilation, with associated complications (Bone, 1981); and emotional state, defined as anxiety, anger, fear and frustration (Grossbach-Landis, 1980).

Patients who are difficult to wean and who require prolonged MV place enormous burdens on the health care system (Sporn & Morganroth, 1988). The increased cost of care and the demands placed on health care personnel suggest that efforts must be made to understand the patients who are difficult to wean. Developing insights regarding these patients may improve our understanding of the weaning process.

At the present time insufficient data defines the relationships among the variables that affect the weaning process of long-term ventilator patients. Variables that may affect the process include: dyspnea intensity, psychological distress, anxiety intensity, and inspiratory effort. Therefore, the relationships among these variables need to be defined. The effect of the method of weaning on the weaning process also warrants investigation.

Significance

Incidence of Mechanical Ventilation

Use of MV for the treatment of acute respiratory failure (ARF) secondary to a wide variety of diagnoses has become a common occurrence (Snider, 1989). Campion et al. (1981) reported intubation and mechanical ventilation as the major intervention most frequently used in their intensive care unit (ICU). Of the 2698 admissions to their unit from 1977-1979, 11-19% required MV. A more recent study found that 28% of all patients admitted to ICU's required MV, with 10% requiring more than 24 hours on the ventilator (Gillespie et al., 1986). Similarly, 33.9% of 980 admissions required respiratory treatment immediately upon admission to ICU (Zaren & Hedstrand, 1987).

For the 20-30% of ICU admissions who require ventilatory support, the first 48-72 hours represents the "critical time" to save the patient's life (Raffin, 1989). This same author describes patients who require life support past three days as being "chronically critically ill". Despite the chronicity of the critical illness, most patients can wean within the first seven days. In one series, 91.3% weaned during the first week of MV (Nett, Morganroth, & Petty, 1984). The remaining 10% required prolonged ventilation, ranging from eight to more than 30 days. The percentage of patients who require long-term mechanical ventilation increases in the presence of chronic lung disease. Menzies and coworkers (1989) reported a 58% incidence of prolonged MV (greater than 2 weeks) in a group of 95 chronic obstructive pulmonary disease (COPD) patients.

Obstructive lung disease is not the only diagnostic category precipitating the need for prolonged MV. Neuromuscular and restrictive lung diseases can

also precipitate the need for long-term MV (Nett, Morganroth, & Petty, 1984). Analysis of the diagnosis-related group (DRG) prospective payment system revealed that a large percentage of patients in the non-pulmonary, major diagnostic categories also required long-term ventilator support (Douglass et al., 1987). Nervous and cardiovascular system diagnoses, as well as poorly differentiated neoplasms, accounted for 81% of chronic ventilator patients. Patients with multisystem failure, acute lung injury, trauma (Gillespie et al., 1986), post-operative complications, (Davis et al., 1980) and those with complications from potentially harmful habits such as alcoholism (Zook & Moore, 1980) also contribute to the long-term ventilator population.

Age also contributes to the need for prolonged MV. Campion et al. (1981) found that elderly ICU patients, in contrast to younger patients, frequently required major life support with MV. In addition, patients over age 50, once extubated, often required reintubation (Witek et al., 1985). Despite the fact that elderly patients more frequently require MV, survival did not correlate with chronological age (Gillespie et al., 1986). Chronological age may therefore provide limited information about survival in the critically ill. Raffin (1989) suggests using biological age, which considers both chronological age and overall health status prior to ICU admission, as a more comprehensive index of survival.

Cost and Survival

The utilization of MV in the elderly and those with chronic disease processes precipitated questions about our current utilization of MV (Goldberg, 1988). Several studies have investigated the cost of intensive care versus survival in ICU patients. Table 1 summarizes recent studies investigating cost and survival statistics in medical and surgical patients

mechanically ventilated from two to fifteen days. Due to variability in charges, the figures are not directly comparable. However, costs were high, ranging from $5,000 to $38,000, with steady increases over the past six years. Hospital survival varied from 30 to 90%, depending upon the diagnosis. Survival rate at one to three years decreased to 20-30%. Costs and survival had no apparent relationship.

Table 1 Cost and Survival Statistics

Authors/ Date	Diagnosis	Duration of MV	Cost	Prognosis
Douglass et al. (1987)	95 Medical patients	3 days or more	$ 38,485/ patient	35% hospital survival
Witek et al. (1985)	100 Post-op, pulmonary, & drug OD	Survivors 39.4 hrs. Non-survivors 72 hrs.	$ 11,000/ patient	50% hospital survival & 33% 1 year survival
Cullen et al. (1984)	199 Class IV surgical pts.	not stated	$ 22,000/ patient	31% 1 year survival
Schmidt et al. (1983)	137 TISS class III & IV med/surg. pts.	Survivors 12.8 days Non-survivors 15.8 days	$ 16,500/ patient	36% hospital survival & 28% 3 year survival
Fedullo & Swinburne (1983)	182 Mixed medical pts.	not stated	$ 5287/ patient	50-90% hospital survival depending on diagnosis

Progression and Prognosis of Chronic Illness

One possible reason for poor long-term survival is the presence of chronic illness in the mechanically-ventilated patient. Patients admitted to intensive care units often have underlying chronic illnesses. A study of ICU's at five Eastern United States hospitals found 79-82% of admitted patients had

mild, limiting or failing chronic illnesses (Knaus et al., 1982). Therefore, before making the decision to intubate and mechanically ventilate, the patient should be evaluated to determine if the cause of acute respiratory failure is a reversible complication or an irreversible progression of their underlying disease (Muir & Levi-Valensi, 1987).

In reality, however, the decision to intubate is frequently made on an emergency basis; without considering the patient's health status, desire to live, prior quality of life, or the family's wishes (Goldberg, 1988). With the wide-spread acceptance of advanced technology and the immediacy of providing the "breath of life", some physicians are reluctant to withhold this treatment (NIH workshop summary, 1986). Even when the patient's prognosis is considered prior to initiating ventilation, the ability to accurately predict survival is quite variable (Pearlman, 1987).

The period immediately following a surgical procedure is another instance when the chronically ill patient may require ventilation. An inability to predict response to MV in this instance may cause the care providers to overestimate the patient's ability to breathe spontaneously. The patient may then require prolonged post-operative ventilation, necessitated by an inability to wean. In summary, ventilator therapy in the chronically ill is frequently precipitated by: hesitancy to withhold treatment, difficulty predicting survival, and post-operative complications.

Quality of Life

One means of gauging the appropriateness of ventilatory support in patients with chronic illnesses is their quality of life. Reports of the quality of life experienced by patients indicates that some do benefit from ventilation. Cullen and coworkers (1984) found most survivors of critical illness alert

(87%) and living at home (92%) one year after discharge. At follow-up three years later, 74% of survivors functioned at their pre-ventilator level (Schmidt et al., 1983). Parno and colleagues (1982) studied long-term outcome in 558 general medical/surgical patients ventilated an average of 3.6 days. Two years following discharge, 88% of survivors could perform activities of daily living. Eighteen percent were not as active as they had been prior to ICU admission, with only 3.7% bedridden.

Similarly, in a group of 717 patients who required ICU treatment, 90% who did not require MV lived independently one year following admission (Zaren & Hedstrand, 1987). However, for patients who required mechanical ventilation, the percentage living independently decreased slightly to 85%. This difference was not present prior to ICU admission. Therefore, slightly fewer patients who required MV lived independently one year later. These findings indicate that the majority of survivors return home, functioning at their pre-ventilator level, able to perform daily activities.

To summarize, mechanical ventilation is commonly used to treat respiratory failure. Frequently these ventilated patients have underlying chronic illnesses that make weaning difficult, increasing the cost of their care. Despite variable survival rates, patients frequently return to their pre-ventilation level of functioning.

How can survival be improved, while keeping costs at a minimum, so that more patients can return to their pre-ventilation level of functioning? Decreasing ventilator time is one possible solution. Two major goals need to be achieved in order to decrease ventilator time. The first involves understanding the underlying progression and prognosis of chronic illness, so that intubation and MV are used appropriately. Second, better understanding

of the variables that affect weaning in long-term patients may decrease ventilator time. The second area is the focus of the present study.

Variables Precipitating Long-term Ventilation

A complex interaction of physiological and psychological factors precipitates the need for long-term ventilation. Physiological causes include: increased ventilatory requirement, excessive breathing workload, ventilatory muscle weakness or fatigue, decreased ventilatory drive, inadequate oxygenation, and hemodynamic instability (Sporn & Morganroth, 1988).

Psychological etiologies of weaning failure have not yet been investigated. However, some patients fail to wean despite stabilization of their underlying respiratory failure, indicating the possibility of a psychological etiology (American Thoracic Society, 1986). The possible psychological etiologies include negative emotions such as anxiety, fear, and depression (Grossbach-Landis, 1980; Belitz, 1983). Table 2 summarizes the possible etiologies described in the literature. Refer to the foot of the table for definition of abbreviations.

Psychological etiologies may be particularly relevant in COPD patients who score high on measures of depression, (McSweeney et al., 1982; Dudley et al., 1980) and anxiety (Dudley et al., 1980; Prigatano et al., 1984) under baseline conditions. It is possible, therefore, that the baseline negative emotions experienced by COPD patients contribute to weaning difficulties, despite clinical stability.

Table 2 Hypothesized Factors That Interfere With Weaning Success

Physiological		Psychological	
Categories	**Etiologies**	**Categories**	**Etiologies**
Workload	Airway resistance -bronchospasm Secretions Atelectasis Small/Kinked ET tube Inadequate positioning Abdominal distension	Person	Fear Pain Disorientation Anxiety Hopelessness Depression Lack of confidence Dyspnea
$\dot{V}e$ Requirement	Infection -fever -shivering Over-feeding Ineffective breathing -decreased Vt -increased f Baseline ABG's not achieved -attempting to maintain normal CO_2	Environment	Sensory overload -sleep deprivation Sensory deprivation -decreased mobility Inadequate trust/ confidence in staff Staff convey doubt Inconsistent care
Ventilatory Drive	Suppression of hypoxic drive -starvation -increased FiO_2 Metabolic alkalosis -diuretics -NG suction Sedatives	Person/ Environment Interaction	Dependency Loss of control Depersonalization Impaired communication
Muscle Weakness/ Fatigue	Poor nutrition Electrolyte imbalance -hypokalemia -hypophosphatemia Hyperinflation (muscles stretched) Inadequate muscle rest		

ET = endotracheal tube; Vt = tidal volume; f = breathing frequency; ABG's = arterial blood gases; CO_2 = carbon dioxide; FiO_2 = fraction of inspired oxygen; NG = naso-gastric

Table 2 Hypothesized Factors That Interfere With Weaning Success (contd.)

Physiological		Psychological	
Categories	**Etiologies**	**Categories**	**Etiologies**
Oxygenation	Ventilator malfunction V/Q mismatching Anemia Barotrauma Pulmonary edema		
Hemodynamics	GI bleeding Untreated heart failure Fluid overload Low cardiac output (heart failure)		

V/Q = ventilation/perfusion

In addition to the primary physiological and psychological etiologies of weaning failure, complications associated with MV can also precipitate a prolonged weaning process (Girard & Raffin, 1985). Zwillich et al., (1974) reported 400 complications in 314 consecutive mechanically ventilated patients. Potential complications include: barotrauma, infection, pulmonary embolism, gastrointestinal bleeding, ventilator malfunction, (Strieter & Lynch, 1988) decreased cardiac output, drug reactions, (Girard & Raffin, 1985) acid base disturbances and fluid retention (Montenegro, 1987). These complications can prevent patients from regaining the strength necessary for weaning (Girard & Raffin, 1985). Therefore, development of complications in the mechanically ventilated patient could potentially delay weaning.

The staff who care for ventilator patients may also contribute to a prolonged weaning process. Following the first few days of MV, the exhilaration of saving the patient wanes (Girard & Raffin, 1985) and the staff is

faced with a patient who may take weeks or months to return to spontaneous ventilation. When patients require prolonged ventilation, the ICU staff may become discouraged and convey their lack of hope to the patient (Grossbach-Landis, 1980). The staff that has given up hope will often avoid caring for the long-term patient, resulting in inconsistent care. In addition to inconsistent care, long-term patients may not be given adequate explanations prior to procedures, creating an atmosphere of distrust. In this situation, explanations are forgotten, assuming that the patient knows and remembers what will happen next (Hudelson, 1977).

The preceding discussion suggests that the complex relationships between physiological and psychological variables contribute to a prolonged weaning process. With such complex interactions, a systematic approach to the difficult-to-wean patient is necessary.

Purpose Of The Study

The purpose of this study was to determine relationships among dyspnea intensity, psychological distress, anxiety intensity, and inspiratory effort prior to and during weaning; utilizing two different methods in adults requiring mechanical ventilation for three days or more.

Specific Aims

1. To determine the relationships among the pre-weaning variables of mood state, dyspnea and anxiety intensities prior to the start of weaning.

2. To determine the impact of pre-weaning variables on weaning completion (i.e. whether the endotracheal tube or tracheostomy is removed within 24 hours of study).

3. To determine the effect of the pre-weaning variables (i.e. mood state, dyspnea intensity and anxiety intensity) on dyspnea intensity, anxiety intensity

and inspiratory effort each measured at the end of the weaning trial.

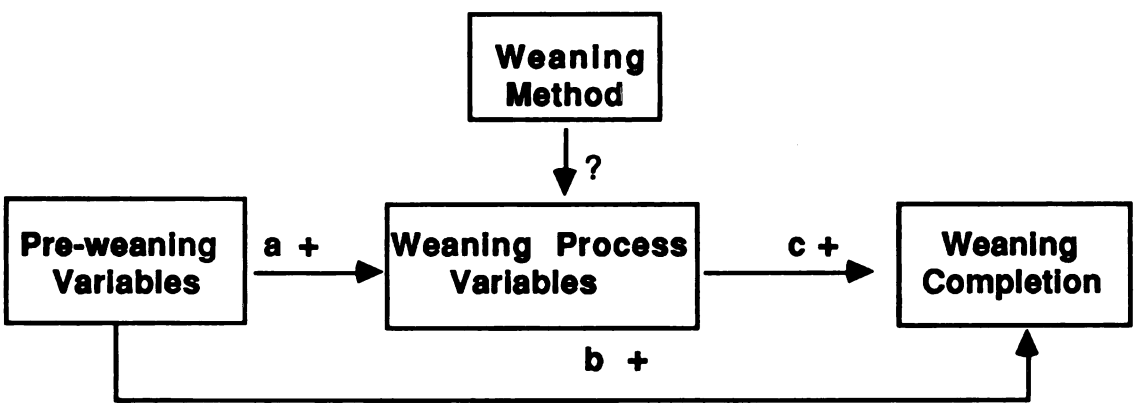
4. To determine the relationship between the end weaning variables and the ability to complete weaning within 24 hours of study.

5. To determine the effect of intermittent mandatory ventilation (IMV) versus pressure support ventilation (PSV) on dyspnea intensity, anxiety intensity, and inspiratory effort during weaning.

6. To determine the effect of weaning method on weaning completion.

The hypothesized relationships are depicted in Figure 1.

Figure 1 Hypothesized Relationships



Pre-weaning Variables: Psychological distress, Dyspnea and Anxiety Intensities. **Weaning Process Variables:** Dyspnea Intensity, Anxiety Intensity, Inspiratory effort. **Weaning method:** Intermittent mandatory ventilation versus Pressure support ventilation. **Weaning Completion:** Ability to wean within 24 hours of data collection.

Research Hypotheses

1. Increased distress prior to weaning (pre-weaning mood state, dyspnea and anxiety intensities) will be associated with higher dyspnea intensity, anxiety intensity and inspiratory effort during weaning, and will also

be associated with decreased ability to complete weaning within 24 hours of data collection. (relationships a and b, Figure 1).

2. The weaning process variables (dyspnea intensity, anxiety intensity and inspiratory effort) will have a positive relationship to each other: if one increases, the others also increase.

3. When the weaning process variables are elevated, the ability to wean within 24 hours of data collection will be decreased relationship c).

4. Subjects will have less dyspnea intensity, anxiety intensity and inspiratory effort with the PSV weaning method as compared to the IMV weaning method.

5. The lower levels of dyspnea intensity, anxiety intensity and inspiratory effort will be associated with an increased ability to complete weaning.

The weaning methods used for the study, IMV and PSV, are similar in that the patient remains on the ventilator during the weaning process, breathing through the ventilator circuit while the level of support is gradually decreased. The two methods are different, however, in that the IMV method is a volume-cycled mode whereas the PSV method is pressure-cycled. Because the PSV method is pressure-cycled, the patient controls the length and depth of respiration, theoretically making this a more comfortable mode of ventilation (MacIntyre, 1986). Therefore, weaning with PSV may be a preferable alternative to the standard IMV weaning method.

Conceptual Approach

Dyspnea, a subjective sensation that reflects physiological and/or psychological alterations, may provide a framework for separating the complex etiologies contributing to prolonged ventilation. Ventilator patients commonly experience dyspnea in response to environmental stimuli (Lush et

al., 1988) or, in response to increased breathing load (Truwit, Lamb, Knebel, & Marini, 1989). In alert patients, this sensation may be a limiting factor during the weaning process. Measurement of dyspnea intensity during weaning quantifies the patient's breathing comfort and charts progress during the weaning trial. By measuring dyspnea intensity, mood state, anxiety intensity and a physiological correlate of oxygen consumption (inspiratory effort), differentiation of complex interactions that affect weaning may be possible. For example, increased dyspnea intensity due primarily to psychological distress will be reflected by emotional descriptions. In contrast, if dyspnea intensity is related primarily to inspiratory effort, muscle oxygen consumption will be elevated.

Therefore, determining the interactions among these variables may provide clues to the etiologies contributing to prolonged MV. This information can then guide the weaning process in patients who require prolonged mechanical ventilation. By keeping ventilator time to a minimum, the demands placed upon the patient, family and health care system would be reduced.

CHAPTER 2

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

The Literature

This chapter focuses on the research literature related to weaning adult patients from mechanical ventilation (MV). The patient studies published in the last nine years will be reviewed to summarize the current state of knowledge related to weaning.

A Medline search for the years 1980-89 produced 140 citations related to the topic of weaning from mechanical ventilation. Abstracts, non-research articles and related topics such as extubation were excluded from the review. This review focuses on published patient studies pertaining specifically to weaning, excluding animal and lung models. Weaning studies specific to clinical problems such as coronary artery bypass, poisoning and sleep apnea were also excluded. Based upon these criteria, 35 studies are described. For completeness, several classic studies published before 1980 were also included.

The 35 research studies can be divided according to the following categories: methods of weaning (n=5), criteria to predict weaning (n=13), weaning failure (n=12), and treatment of weaning failure (n=5). The purpose, methodology and primary conclusions of each study will be highlighted in the text. Major validity threats will also be addressed. Study details are presented in Appendices A-D.

Methods of Weaning

Intermittent mandatory ventilation versus T-piece.

The methods most commonly used to wean patients from mechanical ventilation include T-piece and intermittent mandatory ventilation (IMV). The

T-piece method provides progressive spontaneous breathing time, off the ventilator. During the periods of spontaneous ventilation the patient breathes oxygen through a reservoir system attached to the endotracheal tube via a T-shaped adapter. The periods of spontaneous ventilation alternate with periods of full ventilator support (Luce, Tyler, & Pierson, 1984). The amount of time the patient breathes on the T-piece, relative to the ventilator, depends upon the patient's ability to tolerate spontaneous breathing. Eventually, if weaning is successful, the patient no longer returns to the ventilator to rest and the endotracheal tube is removed. The time frame in which weaning occurs varies from patient to patient, ranging from hours to days or months. The criteria used to predict weaning are described in the following section. However, individual differences in underlying physiological and psychological status frequently prohibit accurate estimations of weaning time, especially in patients who have been ventilated for a prolonged period.

IMV has been described as a combination of assisted mechanical ventilation and spontaneous ventilation (Weisman, Rinaldo, Rogers, & Sanders, 1983). With IMV, patients spontaneously breathe a humidified gas mixture through the ventilator inspiratory circuit. They also receive positive pressure breaths, synchronized to their inspiratory effort, at a predetermined rate and tidal volume (Popovich, 1986). The number of mechanical breaths per minute is reduced and the patients' rate of spontaneous ventilation increases to fulfill their minute ventilation requirement (Sahn, 1986). If weaning is successful, the ventilator rate is decreased to zero and the endotracheal tube is removed. Again, the time frame for achieving successful weaning varies.

Four studies compared the efficacy of these two weaning methods, in

terms of ventilator time and airway pressure. Table 3 describes the studies, including the weaning method and the duration of ventilation. Refer to Appendix A for study details.

Table 3 Methods of Weaning

Method	Duration of Ventilation	Authors
IMV vs T-piece	IMV 145 ± 175 hours T-piece 142 ± 190 hours	Schachter, Tucker, Beck, G. (1981)
IMV vs T-piece	Greater than 30 days	Ashutosh (1983)
IMV vs T-piece	Group A: < 72 hours Group B: ≥ 72 hours Group C: did not meet criteria after 7 days or failed 3 weaning trials	Tomilinson, Miller, Lorch, Smith, Reines, Sahn, (1989)
IMV vs T-piece	Not stated except 3 of 9 were long-term patients	Khan, Mukherji, Chitkara, Juliano, Iorio, (1983)
PSV	Greater than 9 days	Brochard, Harf, Lorino, Lemaire, (1989)

Retrospective chart review identified a sample of 65 patients with primarily surgical causes of acute respiratory failure (ARF) who required short-term ventilation, and who were weaned with IMV (Schachter, Tucker, & Beck, 1981). This sample was matched on age, race, sex, history of smoking and pulmonary disease, diagnosis, and location of therapy to a group of 65 patients weaned by T-piece during the same time period the previous year. The study's purpose was to determine whether IMV shortens weaning time. Duration of ventilation and hospitalization were not significantly different between the two groups by Wilcoxon signed rank test. The authors concluded that IMV offered no benefit in terms of ventilator time or length of stay.

The retrospective nature of the study prohibited adequate testing of the hypothesis. Despite attempts to match the samples, IMV was routinely used

for patients who were difficult to wean, therefore the samples were not comparable. Consequently, the effect of weaning method on ventilator time and length of hospitalization cannot be determined.

The efficacy of IMV compared to T-piece was also evaluated in a study by Ashutosh (1983). The sample consisted of 14 males with COPD who were mechanically ventilated for at least 30 days for ARF. Eighteen episodes of ARF in the 14 patients were examined. Duration of ventilation was shortest in the T-piece group 42 ± 12.5 days versus 83 ± 47 days in the IMV group. T-piece weaning was also more successful. Nine of 13 weaning attempts succeeded with T-piece, whereas three of 14 attempts with IMV were successful. The frequency of success was significantly different between the two groups with Chi square analysis. The author concluded that long-term ventilator patients with COPD do not benefit from the gradual IMV method.

The statistical conclusions were not appropriate since the sample was small and the Chi square cell sizes were less than five. In addition, the difference in weaning outcome between IMV and T-piece may have been influenced by other factors. For example, assignment to weaning method was determined by physician preference and not randomization; therefore, the groups may not have been equivalent. Also, nine of the patients were exposed to both weaning methods. Having failed one method, they were then switched to the other. Group inequality and contamination reduced internal validity.

A recent study by Tomlinson and colleagues (1989) prospectively evaluated the efficacy of IMV versus T-piece weaning. Two hundred consecutive medical/surgical patients were randomly assigned to either an IMV or T-piece weaning method. Each method had one short, and two longer

protocols, based upon the duration of ventilation prior to weaning. Weaning readiness was determined by specific criteria. Of the 165 patients who reached the weaning phase of the study, all but ten weaned with the assigned protocol. However, 19 required more than one attempt to successfully wean. The authors concluded that short-term ventilator patients can be weaned successfully with either IMV or T-piece, when simple bedside criteria are met.

This well-controlled study provides useful information about weaning methods in short-term ventilator patients. However, the researchers do not discuss why 19 patients required more than one attempt to wean with the assigned protocol. In addition, the explanation of what happened to the ten patients who did not wean by protocol was confusing. Finally, the two longest protocols (seven hour and three day) were combined for the statistical analysis, since only a small numbers of patients required the three day protocol. Combining the two groups may have affected the statistical conclusion validity. Therefore, the study results regarding short-term ventilator patients seem appropriate. However, further clarification of the unsuccessful weaning trials and clearer separation of long- and short-term ventilator patients would have been helpful.

Observations that COPD patients deteriorated clinically when changed from 0 IMV to T-piece initiated this study (Khan, Mukherji, Chitkara, Juliano, & Iorio, 1983). The authors hypothesized that decreases in end-expiratory airway pressure may precipitate the deterioration they observed. Therefore, airway pressures measured on IMV and T-piece breathing circuits were compared. Nine intubated patients with a variety of etiologies for ARF were studied to see if changes in airway pressure accounted for the clinical deterioration. Duration of ventilation prior to study was not reported.

Student's t test revealed significantly higher peak expiratory airway pressures with 0 IMV as compared to T-piece. The authors concluded that the elevated expiratory airway pressures induced by IMV breathing circuits prevented airway collapse. Therefore, weaning with low IMV may be preferable to T-piece in the COPD population.

However, the data do not support these conclusions. The original clinical observations that precipitated the research question were made in COPD patients, yet the study sample included patients with diagnoses such as asthma and ARDS. The hypothesis should have been tested in the COPD population prior to testing in a different population. Construct validity of the study is therefore questioned.

In summary, the weaning methods most commonly used are T-piece and IMV. Schachter et al. (1981) found no difference between the 2 methods, but the comparison group was not comparable to the experimental. Ashutosh (1983) found T-piece promoted weaning in long-term patients, but group assignments and overlapping protocols prevent conclusions. In a controlled comparison of these two methods, Tomlinson and colleagues (1989) found no difference between IMV and T-piece in short-term ventilator patients. However, conclusions about long-term patients remain uncertain. Khan et al. (1983) investigated airway pressures and their relationship to weaning outcome with IMV. However, this study lacked construct and internal validity. At the present time, the research literature does not support a preference for either of these commonly used methods.

Pressure support ventilation.

Pressure support ventilation (PSV), a relatively new mode of ventilation, may offer an alternative to the previously described methods. PSV delivers a

preset level of airway pressure, yet the patient controls the length, depth and timing of the inspiratory cycle (Marini & Wheeler, 1989). Clinically, weaning with PSV uses two approaches. It can be used in combination with IMV, supporting spontaneous breaths, or it can be a stand alone method (Hess, 1987). When used alone, the airway pressure is set so that a desired tidal volume (Vt) is achieved (usually 10-12 cc/kg), which is similar to other modes of ventilation. The level of PSV is then gradually decreased, depending upon the patient's ability to maintain an adequate Vt (Hess, 1987). The final goal is to reduce the level of support to 0 cm H_20 (where the patient is no longer being supported), and then extubate.

Brochard and colleagues (1989) investigated the ability of PSV, used alone, to prevent diaphragmatic fatigue during weaning. They posed the question: If PSV did prevent fatigue, was there an optimal level of pressure support (PS) that maintained diaphragmatic activity without inducing fatigue? A small sample of eight ventilator patients with primarily COPD and pneumonia were studied. The researchers found (with two-way analysis of variance) that higher levels of PS prevented a decrease in the high/low ratio of electrical activity of the diaphragm (evidence of diaphragmatic fatigue). The breathing pattern at higher levels of PS was also more compatible with sustainable ventilation (i.e. higher tidal volume and lower breathing frequency). An optimal level of PSV, that maintained diaphragmatic activity without signs of fatigue, was identified. Clinically, the optimal level of PSV could be assessed by palpating the activity of the sternomastoid muscle. The authors concluded that optimal PSV during weaning maintains spontaneous activity of the diaphragm, while preventing diaghragmatic fatigue.

Although this study (Brochard et al., 1989) was internally valid, the

external validity is questioned due to convenience sampling and the small sample size. The conclusions are interesting and possibly helpful for clinicians. However, the results need validation in larger groups of patients. The scant research available about PSV weaning, and the inconsistent data on weaning long-term ventilator patients with IMV and T-piece, suggests that further research is needed in order to determine the appropriate weaning method for specific clinical situations.

Criteria to Predict Weaning

Thirteen studies evaluated the utility of various criteria for predicting weaning success. These determinants of weaning success can be conceptualized as: ventilatory requirement, endurance and strength; breathing pattern and gas exchange; ventilator dependence and presence of "adverse factors"; metabolic requirement; ventilatory drive; breathing work load; inspiratory effort; and premorbid activity, pulmonary function, and nutritional status. Table 4 summarizes these studies, including the hypothesized determinants and the criteria used to measure them (refer to Appendix B).

Conventional criteria.

Sahn & Lakshminarayan (1973) operationalized ventilatory requirement as minute ventilation ($\dot{V}e$), endurance as maximal voluntary ventilation (MVV), and muscle strength as negative inspiratory force (NIF). A $\dot{V}e$ < 10L/min, MVV 2x $\dot{V}e$, and NIF more negative than -30 cm H_20 predicted weaning by T-piece in a convenience sample of 100 alert medical and surgical patients who required short-term ventilation (2 hours - 6 days). Statistics were reported as number of correct predictions. Weaning success or failure was correctly predicted in 93 of the 100 patients. The seven wrong predictions anticipated

Table 4 Determinants and Criteria to Predict Weaning Success

Variables	Measurements	Authors
ventilatory requirement ventilatory endurance muscle strength	minute ventilation ($\dot{V}e$) maximal voluntary ventilation (MVV) negative inspiratory force (NIF)	Sahn & Lakshminarayan (1973)
ventilatory requirement muscle strength breathing pattern gas exchange	minute ventilation ($\dot{V}e$) negative inspiratory force (NIF) tidal volume (Vt), breathing frequency (f) arterial blood gases (ABG's)	Krieger, Ershowsky, Becker, Gazeroglu (1989)
ventilator dependence adverse factors	ventilator score (VS) adverse factor score (AFS)	Morganroth, Morganroth, Nett, & Petty (1984)
metabolic requirement	Carbon dioxide production ($\dot{V}CO_2$) Oxygen consumption ($\dot{V}O_2$)	Kemper, Weissman, Askanazi, Hyman & Kinney (1987)
metabolic requirement	$\dot{V}O_2$ during spontaneous and controlled ventilation	Lewis et al. (1988); Harpin, Baker, Downer, Whitwell, & Gallacher (1987)
ventilatory drive	Mouth occlusion pressure ($P_{0.1}$) Mean inspiratory flow rate (Vt/Ti)	Herrera et al. (1985); Sassoon, Te, Mahutte, & Light (1987); Montgomery, Holle, Neagley, Pierson, & Schoene (1987); Murciano et al. (1988)
breathing work load	mechanical work of spontaneous breathing (Wi)	Fiastro, Habib, Shon, & Campbell (1988)
inspiratory effort	intrapleural pressure drop (ΔPt) divided by the negative inspiratory force (NIF)	Kline, Zimnicki, Antonenko, & Bander (1987)
premorbid activity pulmonary function nutritional status	lifestyle category, forced expiratory volume in one second (FEV_1), dyspnea, NIF, f, Vt, serum albumin	Menzies, Gibbons, & Goldberg (1989)

failure, yet the patient tolerated spontaneous breathing for 2-8 hours (false negative).

Weaning success, therefore, was accurately determined by the measures of strength, endurance and ventilatory requirement in this study of short-term ventilator patients. However, since the MVV and NIF required patient

cooperation the reliability of the measurements are questioned. In addition, since only short-term patients were studied, the validity of these measures in weaning long-term patients cannot be determined. Despite the potential measurement problems, these criteria, plus the patient's tidal volume (Vt) > 5 cc/kg, and vital capacity (VC) > 10 cc/kg, have become the standard most frequently used to predict weaning success (Sahn & Lakshminarayan, 1973; Sahn, Lakshminarayan & Petty, 1976).

Since these standard criteria were validated in younger individuals, Krieger and colleagues (1989) investigated the ability of $\dot{V}e$, NIF, Vt, f and arterial blood gases (ABG's) to predict weaning in elderly patients. A retrospective chart review of 269 patients, ≥ 70 years of age, with a wide variety of diagnoses was completed. Patients were weaned with IMV following short-term mechanical ventilation during an 18 month period at one hospital. Using the Mann Whitney U test, the only variables different between the patients who weaned successfully (n = 241) and those who did not (n = 28) were NIF and the pH on ABG analysis. However, these statistical differences were based upon relatively small differences in the absolute values. The authors concluded that since no one parameter predicts weaning in elderly patients, the overall clinical status needs to be considered.

These results contradict the previously described work of Sahn and colleagues (1973; 1976). The conflicting results may stem from differences in the study designs. The study by Krieger et al. (1989) was retrospective, whereas the work of Sahn et al. (1973) was based upon prospective trials. Another possible explanation may be the differences in their NIF measurement procedures. Therefore, the instrument validity is questioned. Prospective evaluation of the traditional criteria in elderly patients, using

comparable measurement techniques, needs to be done before drawing conclusions.

Other authors have also questioned the predictive ability of the traditional or "conventional" criteria (Morganroth, Morganroth, Nett, & Petty, 1984). These authors compared the "conventional" criteria to other possible determinants of weaning ability, ventilator dependence and adverse factors.

Ventilator dependence and adverse factors.

A scoring system was developed to operationalize ventilator dependence and adverse factors as determinants of weaning success (Morganroth, Morganroth, Nett, & Petty, 1984). A retrospective chart audit of 10 long-term ventilator patients (30 days or more), with diverse causes of respiratory failure, generated items included in the scores. No information was given on how the included items were chosen. Levels of the items were then assigned numerical values, as dictated by the researchers' clinical judgement, according to the potential for interfering with weaning. For example, emotional status was rated as calm = 0, depressed and/or anxious = 1, and agitated = 3. No information was given on how the investigators standardized the numerical weights. The ventilator score (VS) contained 6 items such as fraction of inspired oxygen (FiO_2), static compliance, and triggered respiratory rate. Minimal and maximal values were 0 to 27. The adverse factor score (AFS) included items such as temperature, medications, level of consciousness and emotional status. Since more items were included in this score, the range was larger, 0 to 48. All patients were weaned with T-piece. Data were analyzed by percentages as well as paired and unpaired t tests.

Scores were calculated 179 times in the 10 patients. The combined VS

+ AFS was more sensitive in predicting weaning success than either score alone. A combined score of < 55 predicted weaning success with 93% accuracy, and > 55 predicted weaning failure with 86% accuracy. This scoring system therefore successfully predicted weaning in a small group of long-term ventilator patients.

The predictive ability of the newly developed scoring was then compared to "conventional" criteria including: breathing frequency, Vt, NIF and VC. The conventional criteria were not significantly different between successful and progressive weaning periods, as measured by multiple paired t tests. However, testing with analysis of variance (ANOVA) would have been more appropriate, since more than two groups of variables were tested.

The authors concluded that the combined VS + AFS predicted weaning ability in long-term ventilator patients with greater accuracy than conventional criteria. Since this scoring system was developed from a retrospective chart audit in a small group of long-term ventilator patients, instrument validity and reliability need to be tested with prospective trials in larger samples. Therefore, the utility of this scoring system for predicting weaning success cannot be determined.

Metabolic requirement.

Metabolic requirement, as measured by oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$), were investigated in three studies. The first study investigated 35 randomly selected, post-operative patients being weaned with continuous positive airway pressure (CPAP) following short-term MV (Kemper et al., 1987). Changes in $\dot{V}O_2$ and $\dot{V}CO_2$ during successful and unsuccessful weaning trials were determined. Both $\dot{V}O_2$ and $\dot{V}CO_2$ increased during spontaneous breathing, regardless of weaning outcome, and therefore

did not separate weaning outcomes. However, $\dot{V}e$ decreased and breathing frequency increased significantly in the unsuccessful group. The authors concluded that both $\dot{V}O_2$ and $\dot{V}CO_2$ increased during spontaneous breathing, but the changes did not separate successful from unsuccessful weaning trials.

The reliability of these $\dot{V}O_2$ and $\dot{V}CO_2$ measures are limited in the intensive care unit (ICU), since measurement requires specialized equipment to evaluate expired gas content. The gas analysis systems are prone to error due to fluctuations in the fraction of inspired oxygen (FiO_2) and metabolic rate (Marini, 1988). These potential measurement problems threaten the internal validity of the study.

A second group of researchers investigated the metabolic changes that occur with decreasing intermittent mandatory ventilation (IMV) rate. Thirty patients recovering from acute respiratory failure (ARF) were studied (Lewis et al., 1988). The sample characteristics and duration of ventilation prior to weaning were not presented. As with the previous study, $\dot{V}O_2$ increased as spontaneous ventilation increased. In contrast, however, Lewis et al. (1988) were able to separate successful and unsuccessful weaning outcomes. When $\dot{V}O_2$ increased less than 15% from baseline during MV, weaning was successful in 14 of 16 patients. Alternatively, with an increase greater than 15%, 13 of 14 failed to wean. The authors concluded that measuring changes in $\dot{V}O_2$ during weaning may play a role in assessing ventilator dependence.

The study conclusions are difficult to interpret, however, since patient characteristics were not reported. In addition, instrument reliability is questionable not only for the reasons stated above, but also because two separate gas analysis systems were used to measure $\dot{V}O_2$. No explanation was given for use of the different systems.

The final metabolic study evaluated oxygen cost of breathing (OCB) as a predictor of weaning success (Harpin, Baker, Downer, Whitwell, & Gallacher, 1987). The OCB is estimated by measuring $\dot{V}O_2$ during spontaneous breathing ($\dot{V}O_2sv$), and subtracting from this value the $\dot{V}O_2$ during controlled ventilation ($\dot{V}O_2cv$). The OCB measures changes in O_2 requirements imposed by the increased breathing work load. Twenty patients requiring MV for a variety of pulmonary, cardiovascular and neurological problems were studied. All patients had failed conventional criteria (vital capacity, negative inspiratory force, alveolar-arterial oxygen difference), and had required MV for an average of 16.4 days. CPAP was used for weaning trials.

The average OCB was 30 ± 6 ml/min. Pearson coefficient of correlation was used for statistical analysis. Time required to complete weaning was significantly correlated with the ratio of OCB/$\dot{V}O_2sv$, r = 0.84 (n=20). However, two outliers who had been ventilated for > 90 days inflated the correlations. When data were re-analyzed without these two patients, the correlations decreased although they were still significant. An OCB/$\dot{V}O_2sv$ ratio of .10 separated short- and long-term ventilation. Twelve patients with a ratio < .10 had an average weaning time of 3.3 ± 0.9 days, whereas eight patients with a ratio > .10 took an average of 36.1 ± 16 days to wean. The authors concluded that the OCB may be an important weaning predictor.

In this small group of patients with a wide variety of diagnoses, the OCB appears to be a valid indicator of weaning ability. Instrument reliability is again an issue. In addition, the correlational design prohibits generalizing beyond this sample. Further studies are needed in order to verify the utility of this indicator of weaning.

In summary, three studies investigated metabolic changes during

weaning. All found that $\dot{V}O_2$ increased as patients assumed spontaneous breathing. However, the data for predicting weaning outcome are conflicting. Two of the predictors (percent change in $\dot{V}O_2$ and the OCB as a fraction of the spontaneous $\dot{V}O_2$) warrant further exploration.

Ventilatory drive.

A group of four studies utilized the mouth occlusion pressure ($P_{0.1}$), a measure of the output from the respiratory centers, (ventilatory drive) to predict weaning. Eleven COPD patients and nine patients with other pulmonary problems were studied. (Herrera et al., 1985). A $P_{0.1}$ of 4.2 cm H_20 separated those who weaned from those who failed, with a false negative rate of 22%. However, the duration of ventilation was not reported, weaning method was not standardized and the $P_{0.1}$ measurement was performed incorrectly (Whitelaw, Derenne, & Milic-Emili, 1975). The occlusions were held throughout the inspiratory effort; they should have been released after the first 100 milliseconds. Holding the occlusion throughout inspiration would cause sensations of air hunger, altering the measurements. Therefore, measurement validity and reliability are questionable.

The accuracy of predicting weaning with the $P_{0.1}$ was validated in a study of 12 COPD patients (Sassoon, Te, Mahutte, & Light, 1987). A $P_{0.1}$ of six cm H_20 separated weaning outcomes in T-piece trials with 100% accuracy. Seven patients weaned successfully after being ventilated an average of 3.9 days. Five patients failed weaning, with a mean ventilator time of 16.4 days prior to death (n=3) or eventual weaning (n=2). The authors concluded that measuring $P_{0.1}$ in the immediate period of spontaneous breathing accurately predicts weaning ability in COPD patients. However, patient mortality is a potential threat to internal validity.

In contrast to the previous studies, the $P_{0.1}$ alone did not predict weaning in 11 subjects who had marginal conventional weaning parameters ($\dot{V}e$, NIF, and VC) (Montgomery, Holle, Neagley, Pierson, & Schoene, 1987). The subjects were primarily long-term ventilator patients (mean 58 days) who had a wide variety of diagnoses. T-piece weaning was the method used. Seven patients weaned successfully and seven failed. The $P_{0.1}$ was not different between the two groups as measured by the unpaired t test. However, an inability to augment $P_{0.1}$ in response to hypercapnic challenge (an increase in end-tidal CO_2 of 10 mmHg) did predict weaning failure. The failure group increased $P_{0.1}$ only 0.9 cm H_20, whereas the successful group increased by 3.3 cm H_20. The authors concluded that measurement of $P_{0.1}$ before and after hypercapnic challenge may accurately predict weaning in those patients who have marginal conventional weaning parameters. However, these results must be interpreted cautiously since the researchers studied three patients twice and treated them as separate cases, violating the assumption of independence.

A final study investigated the relationship between $P_{0.1}$ and muscle fatigue during weaning (Murciano et al., 1988). Sixteen intubated COPD patients were studied during 15 minute T-piece trials. Measurements were obtained after 24 hours of MV, and then at two-day intervals. The breathing pattern and $P_{0.1}$ were monitored during the weaning trials. Two groups were identified. Eleven patients weaned successfully; five required reintubation within 24-48 hours of extubation. Duration of ventilation was not different between the two groups (5-9 days). On the first day after intubation all patients exhibited a characteristic breathing pattern of low Vt and increased frequency. The diaphragmatic electromyogram (EMG) high to low ratio (H/L)

was decreased, indicating ventilatory muscle fatigue, and the $P_{0.1}$ was increased (7.1 ± 2.4 cm H_20). The evolution of the breathing pattern, however, was different for the two groups. During subsequent measurements, patients who weaned successfully increased Vt, decreased $P_{0.1}$, and no longer shifted the H/L in the direction of fatigue. In contrast, the unsuccessful group maintained the initial measurements. The authors concluded that high $P_{0.1}$ values may be useful for assessing the presence of respiratory muscle fatigue in patients during ARF, and would therefore predict weaning failure.

Even though an elevated $P_{0.1}$ was associated with fatigue in these patients, $P_{0.1}$, and therefore ventilatory drive, can be elevated for reasons other than fatigue. Alternatively, if the ventilatory muscles were fatigued it is possible that the $P_{0.1}$ could underestimate ventilatory drive, due to the inability to generate force. Therefore, the specificity of the $P_{0.1}$ as a predictor of fatigue is limited. However, the relationship between ventilatory drive and muscle fatigue is important during weaning and should therefore be assessed. For example, an elevated drive would shorten expiratory time, possibly worsening pre-existing hyperinflation in the COPD patient. With hyperinflation, weakened muscles are over-stretched, decreasing their ability to generate the pressure necessary for spontaneous breathing. Therefore, in the presence of early fatigue, the $P_{0.1}$ may be a useful indicator of weaning ability, although its utility in predicting fatigue is limited.

Despite the fact that four studies investigated the same determinant of weaning success, ventilatory drive, conclusions about the efficacy of the $P_{0.1}$ measurement are not possible. Lack of homogeneous samples, small sample sizes and the use of multiple t tests threaten internal, external and statistical conclusion validity. Further studies are needed in order to substantiate the

predictive value of $P_{0.1}$ in weaning patients from MV.

Breathing work load.

Mechanical work, a measure of breathing work load, was compared to conventional criteria (VC, NIF, $\dot{V}e$, Vt) to determine which was a better predictor of weaning outcome (Fiastro, Habib, Shon, & Campbell, 1988). Seventeen medical and surgical patients with underlying lung disease, ventilated for 22 hours to 26 days, were studied. Diagnoses were primarily COPD (n=10); the remainder had diverse pulmonary problems (n=7). Trends of values and unpaired t tests were used to analyze the data.

Two groups of patients were identified. Group I was ventilated for 22-72 hours, group II for 4-26 days. Work was calculated from plots of transpulmonary pressure versus volume. In all patients, inspiratory work of breathing per liter and per minute (Wi/L and Wi/min, respectively) separated successful and unsuccessful weaning trials. Wi/L values $\leq$ .14 kg-m, along with Wi/min values of $\leq$ 1.6 kg-m, predicted successful weaning with 100% accuracy. In contrast, the conventional criteria predicted weaning success in the group requiring short-term ventilation, but was a poor predictor in long-term patients, supporting the work of Sahn and Lakshminarayan, (1973) and Morganroth et al. (1984). Breathing frequency was the only conventional criteria that separated the short- and long-term groups. Since mechanical work predicted weaning success and failure in both long- and short-term patients, the authors recommended using mechanical work, rather than conventional criteria, to predict weaning.

Measuring mechanical work to predict weaning requires complex, specialized equipment. Potential measurement error threatens both construct and internal validity. Therefore, simplified measures to predict weaning in

long-term patients need to be developed and evaluated.

Inspiratory effort.

Inspiratory effort increases as the breathing work load increases, and may therefore be a useful substitute for mechanical work to predict weaning. (Kline, Zimnicki, Antonenko, & Bander, 1987). Relative inspiratory effort (RIE) is estimated by the ΔPt/NIF. The intrapleural pressure drop (ΔPt) is calculated from the equation of motion, which includes the two primary contributors to work load: elastance and resistance.

$$\Delta Pt = (Vt)(E) + (\dot{V})(R).$$

Where Vt is tidal volume, E is elastance, $\dot{V}$ is inspiratory flow and R is resistance. The ΔPt is then divided by the NIF to standardize the pressure drop to the patient's inspiratory muscle strength.

The efficacy of the RIE in predicting weaning was investigated in 20 medical and 30 post-surgical patients (11 had COPD) who met traditional weaning criteria ($\dot{V}e$, NIF, frequency, Vt). Duration of ventilation was 1-70 days. A RIE of .4 predicted weaning success with 96% accuracy. Twenty-seven patients with a RIE < .4 weaned, and 21 with values > .4 failed. The two false predictions underestimated weaning, with values slightly higher than .4, yet the patients weaned (false negative). The conclusion was that RIE accurately predicted weaning without the need for sophisticated equipment in long- and short-term ventilator patients who met conventional criteria. Testing of the RIE in patients who do not meet conventional weaning criteria is necessary before conclusions about the efficacy of this index of weaning can be determined.

Premorbid activity, pulmonary function, and nutritional status.

A final study investigated premorbid as well as conventional criteria to

predict weaning with T-piece (Menzies, Gibbons, & Goldberg, 1989). Data on 95 COPD patients requiring mechanical ventilation for ARF were collected. Median duration of ventilation was 20 days. Chi square and t tests were used for data analysis. The premorbid variables that separated successful and unsuccessful weaning trials included the forced expiratory volume in one second (FEV_1), activity level, dyspnea and serum albumin. The predictive ability of the conventional criteria supported the use of NIF, Vt and f. The authors concluded that premorbid activity level was the best predictor of weaning outcome, possibly because it is a good summary measure influenced by many clinical factors.

The predictive ability of the conventional criteria contrasts the work of Morganroth, et al. (1984) who found that the conventional criteria did not predict weaning in long-term ventilator patients. The difference in findings may stem from the etiologies of respiratory failure. Menzies et al. (1989) used only COPD patients, whereas Morganroth and colleagues (1984) studied patients with a wide variety of diagnoses. The use of premorbid variables to predict outcome is an interesting approach and may be helpful, if substantiated in further studies, in establishing models to determine when to withhold mechanical ventilation in the COPD patient.

In summary, the 13 studies described thus far have evaluated primarily physiological indices to predict weaning in both long- and short-term ventilator patients. The conventional criteria proposed by Sahn et al. (1976) accurately predicted weaning in short-term ventilator patients and in long-term COPD patients (Menzies et al., 1989). In an elderly population ($\geq$ 70 years of age) different criteria may need to be used (Krieger et al., 1989). In long-term patients with diverse etiologies for respiratory failure, alternative criteria that

do not require patient cooperation have been suggested (Morganroth et al., 1984). The Morganroth et al. (1984) and the Menzies et al. (1989) studies are the only ones that examined variables other than physiological parameters. Metabolic requirements (Harpin et al., 1987; Lewis et al., 1988; Kemper et al., 1987) and mechanical work (Fiastro et al., 1988) require sophisticated equipment, which limits their usefulness. Further research is needed to determine whether a critical $P_{0.1}$ value separates weaning outcomes (Sassoon et al., 1987), or whether a hypercapnic challenge is needed to make this determination (Montgomery et al., 1987). The interaction between $P_{0.1}$ and muscle fatigue in predicting weaning outcome must also be determined (Murciano et al., 1988). The relative inspiratory effort is calculated from bedside measurements, and may prove useful for predicting weaning from a physiological perspective (Kline et al., 1987). Use of premorbid variables such as lung function and activity level may also aid in predicting outcome (Menzies et al., 1989).

These determinants of weaning success have been tested primarily in small, convenience samples, in patients with varying diagnoses, utilizing inconsistent criteria to define long- and short-term ventilation. Internal validity is therefore suspect. In addition, the external validity and therefore generalizability is questionable due to convenience sampling. Further research is needed in order to substantiate the predictive ability of these criteria, especially in long-term ventilator patients.

Weaning Failure

Assessment of weaning failure was the focus of the next 12 studies. The manifestations, causes and measures of weaning failure are summarized in Table 5. Refer to Appendix C for study details. The manifestations addressed

Table 5 Assessment of Weaning Failure

Manifestations/ Causes	Measurements	Authors
clinically observable	f & regularity of breathing, $\dot{V}e$, $Vt/\dot{V}e$, HR, palpation of accessory muscle recruitment	Pardee, Winterbauer & Allen (1984)
breathing pattern	f, Vt with magnetic coils	Gilbert, Auchincloss, Peppi & Ashutosh (1974)
breathing pattern	f, Vt, $\dot{V}e$, Ti, Te, Ti/Ttot, Vt/Ti with RIP*	Tobin et al. (1986)
ventilatory muscle fatigue	EMG's, f & depth of breathing, thoracoabdominal motion, NIF	Cohen, Zagelbaum, Gross, Roussos, & Macklem (1982)
ventilatory muscle fatigue	Pdi, abdominal motion, f Pdi/Pdimax, f, Ti/Ttot	Swartz & Marino (1985); Pourriat, Lamberto, Hoang, Fournier, & Vasseur (1986)
breathing load	Indices of abnormal motion with RIP*	Tobin et al. (1987)
oxygen transport	Pulmonary artery wedge pressure, blood volumes	Lemaire et al. (1988)
	Oxyhemoglobin affinity	Agusti, Rodriguez-Roisin, Roca, Aguilar, & Agusti-Vidal (1986)
nutritional complications	Albumin	Bassili & Deitel (1981)
	Albumin, Transferrin	Larca & Greenbaum (1982)
	$\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}e$, f	van den Berg & Stam (1988)

*RIP= respiratory inductive plethysmography

clinically observable changes and changes in breathing pattern. The hypothesized causes of failure included ventilatory muscle fatigue, breathing load, defect in oxygen transport, and nutritional complications.

Clinically observable changes.

Pardee et al. (1984) investigated 112 episodes of ventilatory support in 110 patients, to determine if clinical observations would predict weaning failure. Subjects had a wide variety of medical and surgical causes of ARF. Duration of ventilation and weaning method were not specified. The variables that predicted weaning outcome by Chi square were an increased frequency; an observed irregular breathing pattern; an increased or decreased heart rate (HR); scalene and abdominal muscle recruitment; and inability to cooperate with a VC maneuver. This combination of variables predicted weaning failure with 90% accuracy. Examples of clinical problems that prevented cooperation with a VC maneuver included coma, pain and dyspnea. Pain and dyspnea were not measured. The authors encouraged testing of these clinical observations in order to formulate a bedside assessment for risk of respiratory failure.

The preceding study suggested clinically assessable criteria that may help determine when to reinstitute MV. However, instrument and/or observer reliability of the bedside estimates were not described. Lack of measurement reliability threatens the statistical conclusions. Since the weaning method and duration of ventilation prior to weaning were not reported, generalizations are not possible.

Breathing patterns.

Two studies address the changes in breathing pattern that occur during the weaning process (Gilbert, Auchincloss, Peppi, & Ashutosh, 1974; Tobin et

al., 1986). A classic article by Gilbert et al. (1974) was the first to evaluate breathing patterns following MV. The study investigated frequency, Vt, HR, arterial blood gases (ABG's) and subjective distress (as evidenced by patient requests to return to the ventilator) in 14 patients, eight with COPD and six with other pulmonary problems. Patients had received long-term MV (3-80 days). The normal changes that occurred with weaning included an immediate drop in mean Vt of 400 cc, and an increase in mean frequency of 12 breaths/min, with no significant change in $\dot{V}e$. An increased HR of 10 beats/min also occurred. Changes in ABG's were unpredictable. Subjective distress was not associated with changes in PaO_2 or $PaCO_2$. The authors concluded that knowledge of normal changes during weaning may assist clinicians in determining the need for continued MV.

The absolute values suggested by these authors must be questioned, since the changes may be a function of the pre-weaning ventilator settings. Generally, the ventilator-delivered Vt is higher (10-12 cc/kg) and the frequency is slower (8-10 breaths/min) than a normal breathing pattern; therefore, changes must be evaluated in relation to prior ventilator settings. Changes in PaO_2 and $PaCO_2$ between ventilator and spontaneous breathing were reported as significant despite small absolute changes and large variability. Statistical significance may have been due to inappropriate use of t tests to compare multiple variables. Therefore, statistical conclusion validity is questioned.

Tobin and coworkers (1986) investigated the relationship between breathing pattern and outcome of spontaneous breathing trials. Seventeen patients with a variety of etiologies for ARF were studied. The breathing pattern in the successful group changed minimally during the hour-long

weaning trial. $\dot{V}e$ and frequency increased slightly prior to extubation, but returned to normal following removal of the endotracheal tube (ET). In contrast, the changes observed in the failure group were similar to those found by Gilbert et al. (1974). Vt decreased approximately 200 cc and frequency increased by approximately 11 breaths. Shorter inspiratory (Ti) and expiratory times (Te) also separated the two groups. Ti in the successful versus unsuccessful group was 1.24 ± .07 seconds versus .81 ±.11 seconds and Te was 1.41 ± .27 seconds versus 2.48 ± .47 respectively. Duration of ventilation was longer in the failure group, an average of 42.4 days versus 2.6 days in the successful group. The authors concluded that a rapid shallow breathing pattern produced hypercapnia leading to weaning failure.

The small convenience sample limits generalizability. Further studies are needed before the utility of breathing pattern measurements during weaning can be established.

Ventilatory muscle fatigue.

The next three studies investigated the role of inspiratory muscle fatigue during weaning from MV. Diaphragm and intercostal EMG and clinical changes were investigated during spontaneous breathing trials in 12 patients with hypercapnic respiratory failure (Cohen, Zagelbaum, Gross, Roussos, & Macklem, 1982). Seven patients exhibited signs of fatigue with the H/L ratio of surface EMG's decreasing 20-60%. The patients with fatigue also exhibited, by inspection and palpation, abnormal inward movement of the abdomen during inspiration, known as "paradox" (in 6 of 7), and abnormal alternation between chest and abdominal movements, known as "alternans" (in 4 of 7). Duration of ventilation was not different between the two groups (average of 15.7 days). In addition, no abnormal motion was present in the non-fatigue

group. The authors concluded that clinical signs of paradox and alternans may be a valid diagnostic indicator of inspiratory muscle fatigue.

The conclusions of these authors are questioned for several reasons. The poor reliability of surface EMG measurements, especially in critical care units, dictates skeptical appraisal of the results. In addition, reliability of changes in observed breathing pattern was not addressed. Further studies are needed in order to define the relationship between fatigue and thoracoabdominal motion.

Swartz and Marino (1985) assessed the relationship between weaning failure and diaphragm weakness, as measured by the transdiaphragmatic pressure (Pdi). Seven patients with differing etiologies for ARF, who had failed prior weaning attempts, were studied. The average duration of ventilation was 13.3 days. The Pdi was measured during spontaneous breathing trials, but the weaning method was not specifically stated. Trials were ended if the patient exhibited clinical signs of weaning failure such as HR > 140 beats/min, frequency > 40 breaths/min, or changes in arterial blood gases. The authors found that Pdi increased rather than decreased. They concluded that unsuccessful weaning was not due to failure of the pressure-generating ability of the diaphragm, indicating the absence of fatigue. Several alternative explanations for these finding are possible. The indicators that the researchers used to define weaning failure may have been so sensitive that the patients were placed back on the ventilator before the Pdi had a chance to drop. Alternatively, the Pdi may need to be referenced to the maximal Pdi before it accurately reflects inspiratory muscle fatigue.

The Pdi/Pdimax was investigated in 40 weaning trials in 15 patients with COPD, to determine the relationship between this ratio and ability to tolerate

12 hours of spontaneous breathing (Pourriat, Lamberto, Hoang, Fournier, & Vasseur, 1986). The Pdi/Pdimax ratio was > .4 in 13 of 19 instances of weaning failure. A value < .4 was present in 16 of 18 successful trials. Duration of ventilation was not different between groups.

The findings of this study contradict the work of Swartz and Marino (1985). The difference may be the use of the Pdimax as a reference point. Even though the Pdimax may be important for accurate assessment of spontaneous breathing ability, this measurement requires patient cooperation. Therefore, measurement reliability may be questionable. The Pdi/Pdimax value is similar to the ΔPt/NIF used by Kline et al. (1987) to measure inspiratory effort. The major difference is the estimation of pleural rather than transdiaphragmatic pressure. The pleural pressure may be a more accurate indicator, since it includes all inspiratory muscles, not just one.

A secondary finding of Pourriat et al. (1986) was a negative average gastric pressure in patients who failed to wean. A negative value indicated abnormal diaphragmatic function, suggesting the presence of paradox. The successfully weaned group did not exhibit this finding, supporting the work of Cohen et al. (1982).

In contrast, the work of Tobin et al. (1987) found paradox during both successful and unsuccessful weaning trials. Respiratory movements were measured by respiratory inductive plethysmography (RIP) in the same group of 17 patients previously described (Tobin et al., 1986). Mean compartmental amplitude (MCA) divided by Vt is a measure of combined asynchrony and paradox occurring in the rib cage, abdomen or both. A MCA/Vt value > 1.18 predicted weaning failure with 100% accuracy, and a value < 1.18 predicted success with 80% accuracy. However, there was considerable overlap

between the two groups, suggesting that abnormal movements of the rib cage and abdomen do not necessarily mean the patient will fail the weaning trial. In fact, additional data from a group of normal subjects suggested that paradox occurred before the development of fatigue (Tobin et al., 1987).

These authors concluded that asynchrony and paradox are a function of the load the patient breathes against, rather than an indicator of fatigue. Abnormal movements of the chest and abdomen, as an indicator of work load, rather than fatigue, may therefore distinguish those who can and cannot wean.

Oxygen transport.

Non-pulmonary causes can also precipitate weaning failure. Two studies described O_2 transport abnormalities. Defects in oxyhemoglobin affinity and left heart function can affect the weaning process. Fifteen patients with COPD and pre-existing heart disease, who had failed prior weaning attempts despite satisfying conventional criteria, were studied (Lemaire et al., 1988). Weaning method was spontaneous breathing on a ventilator circuit. Average duration of ventilation was 3.9 weeks. During spontaneous breathing trials the pulmonary artery wedge (PAW) pressure increased from 8 to 25 mmHg, accompanied by wheezing, dyspnea and tachypnea. Significant increases in average esophageal pressure (Pes) were also observed. Patients were treated with Lasix and nutritional support. Nine patients eventually weaned, approximately one week later. Eight of these patients were studied again following weaning. The PAW was no longer elevated and blood volume was decreased. The authors concluded that movement of fluid from peripheral tissues to the central circulation during weaning is a major contributor to an unsuccessful outcome. The findings of this study emphasize

the importance of considering cardiovascular effects as possible etiologies of weaning failure.

The presentation of the data on average esophageal pressure, which equals work per liter ventilation, was confusing. When patients were changed from positive pressure ventilation to spontaneous breathing, the Pes became negative, rather than positive. The authors stated that the Pes decreased. Strictly speaking this is true; however, the relative magnitude of pressure swings increased, therefore the work load of the patient was higher.

Oxyhemoglobin affinity was investigated in 20 COPD patients with ARF, 10 receiving MV and 10 receiving conservative treatment (Agusti, Rodriguez-Roisin, Roca, Aguilar, & Agusti-Vidal, 1986). Duration of ventilation was not reported. Initially, only the ventilated group shifted the oxyhemoglobin dissociation curve to the left, indicating tighter binding of O_2 to the hemoglobin molecule. The unventilated group during the first 48 hours of treatment showed an increase in O_2 release due to acidosis. Eventually, both groups exhibited the left shifting. The authors concluded that swift correction of acidosis, with either MV or conservative treatments, may precipitate erythrocyte alkalosis and interfere with O_2 release. However, even with slow correction of acidosis in the non-ventilated group a left shift occurred after 48 hours of treatment. Further studies are needed to clarify the relationship between acid/base balance and oxyhemoglobin affinity during acute respiratory failure.

Nutritional complications.

Inadequate or excessive nutritional support can also lead to weaning failure. Three studies looked specifically at the effects of nutritional support on the weaning process. A retrospective review of 47 patients (33 surgical and

14 medical) who received MV for 3 or more days were investigated (Bassili & Deitel, 1981). Thirty-three subjects received a protein-free, isotonic intravenous replacement that provided 400 Kcal per day. Fourteen subjects received more aggressive nutritional support, with either enteral or parenteral feedings providing 2000-3000 Kcal/day. The mean length of ventilation was the same between the two nutritional support groups. However, only 18 of 33 patients in the protein-free group weaned; the rest died of multi-organ failure. In contrast, 13 of 14 patients in the aggressive support group weaned. Differences were significant with Chi square. The authors concluded that nutritional maintenance appears to significantly influence the success of weaning.

The retrospective nature of the study prohibited comparison. Other factors, rather than nutrition, may have contributed to group differences. In addition, the Chi square was inappropriate due to small cell sizes. Therefore, internal and statistical conclusion validity are questionable.

A second retrospective study evaluated the usefulness of nutritional support in treating patients who failed to wean (Larca & Greenbaum, 1982). Fourteen patients with primarily COPD and congestive heart failure (CHF) comprised the sample. Aggressive nutritional support was provided with either total parenteral nutrition or enteral feedings. Patients who eventually weaned (n=8) increased albumin and transferrin levels in response to feeding (mean duration of ventilation = 60.2 days). The group that failed weaning (n= 6) continued to decrease albumin and transferrin despite intensive nutritional support (mean duration of ventilation = 74.5 days). Total lymphocyte count and nutritional support were not different between the two groups. The authors concluded that weaning failure was due to inability to assimilate the

feedings. The retrospective nature of the study again limits the internal validity, since the two groups were not equivalent on significant variables; nor were the statistical tests described. These factors limit the conclusions inferred from the data.

A final study investigated the effects of enteral nutritional support during weaning in four patients (van den Berg & Stam, 1988). Moderate calorie feedings, 1.5 x resting energy expenditure (REE), and high calorie feedings (2 x REE) were provided. These patients were a subgroup of a larger sample who received the feedings but were not clinically stable for weaning. The diagnoses for the subgroup were not specifically stated. A modified T-piece was used in two subjects and CPAP in the other two. Duration of ventilation was not reported. $\dot{V}CO_2$ increased 18 ml/min/m^2 with moderated feedings and increased 32 ml/min/m^2 with high calorie feedings. With the moderate calorie diet, patients were able to increase $\dot{V}e$ to compensate; therefore $PaCO_2$ did not change and weaning continued. However, with the high calorie diet, patients were no longer able to augment $\dot{V}e$ to eliminate the elevated $\dot{V}CO_2$; therefore the $PaCO_2$ increased and weaning failure occurred. The authors recommended adapting caloric intake to REE. Energy expenditure is usually elevated in the critically ill. By tailoring caloric intake to REE, metabolic needs are met without excessively elevating $\dot{V}CO_2$, which interferes with weaning. The small sample size with unclear diagnoses prevents generalizing beyond this group of patients. However, the findings warrant further investigation.

In summary, research related to weaning failure investigated manifestations and causes. Manifestations included clinically observable indicators and the breathing patterns characteristic of weaning trials. Causes

of weaning failure included ventilatory muscle fatigue; or alternatively, breathing load; oxygen transport abnormalities; and nutritional complication. Clinical findings during weaning included a decreased Vt and increased breathing frequency. Whether these changes are to be expected (Gilbert et al., 1974), or indicate the likelihood of weaning failure (Tobin et al., 1986), requires further investigation. The presence of accessory muscle use and the development of abnormal movements of the chest and abdomen were also frequently seen in the weaning patient. Whether these changes indicate fatigue (Cohen et al., 1982) or stem from the increased breathing load (Tobin et al., 1987) again requires further investigation. Conflicting data about the relationship between transdiaphragmatic pressure and weaning was presented. Swartz & Marino (1985) found no decrease in Pdi despite evidence of ventilatory muscle fatigue, whereas Pourriat et al. (1986) found the Pdi/Pdimax ratio correlated with weaning success or failure. Despite the importance of cardiac function during weaning, only two studies have evaluated the factors that affect O_2 transport (Agusti et al., 1986; Lemaire et al., 1988). Further research to determine the interrelationships between pulmonary and cardiovascular factors is needed. Finally, the iatrogenic causes of weaning failure, such as excessive versus inadequate calories, require further investigation.

Treatment of Weaning Failure

The final group of five studies reported interventions used to facilitate weaning in difficult cases. The hypothesized etiologies of weaning failure and the proposed interventions are summarized in Table 6 (refer to Appendix D for study details). Interventions were aimed at treating either ventilatory muscle function or psychological etiologies, classified as either fear or anxiety.

Isocapnic hyperpnea and inspiratory resistive training were directed toward treatment of ventilatory muscle dysfunction. Biofeedback, hypnotic relaxation and progressive muscle relaxation were used in the treatment of fear and anxiety.

Table 6 Treatment of Weaning Failure

Etiology of Failure	Intervention	Authors
Ventilatory muscle dysfunction	Isocapnic hyperpnea	Belman (1981)
	Inspiratory resistive training	Aldrich, Karpel, Uhrlass, Sparapani, Eramo, Ferranti (1989)
Anxiety/Fear	Biofeedback of breathing pattern Hypnotic relaxation	LaRiccia, Katz, Peters, Atkinson, & Weiss (1985)
Anxiety/Fear	Hypnotic relaxation	Acosta (1987)
Anxiety/Fear	Biofeedback of SaO_2 Progressive muscle relaxation	Acosta (1988)

All but one of the studies are uncontrolled, and basically single-case reports, limiting internal validity and generalizability. However, the approaches used to facilitate weaning in these difficult cases can provide insights upon which to build future controlled studies.

Ventilatory muscle dysfunction.

Belman (1981) investigated isocapnic hyperpnea in two patients with ARF due to COPD. Training was started after three and five days of ventilation. Patients were successfully weaned with improvement in sustainable $\dot{V}e$, self-report of dyspnea improvement, and ability to perform self-care activities. However, the patients were ventilated only for a short time

and may have weaned easily without intervention. In addition, ventilatory muscle dysfunction was not documented, therefore the positive benefits seen with training cannot be attributed specifically to improved muscle function.

A second study evaluated the effects of inspiratory resistive training in 27 patients who had failed repeated weaning attempts (Aldrich et al., 1989). The average duration of ventilation was 12.8 weeks. Twenty of the patients had COPD, and seven had various neuromuscular diseases. Twelve of the 27 patients weaned completely, five weaned to nocturnal ventilation, and ten could never be weaned. Ventilatory muscle weakness was documented by NIF prior to initiation of therapy. The NIF and vital capacity (VC) improved in all patients, but most dramatically in those who eventually weaned. Even though NIF and VC improved, other factors could have precipitated the positive outcome, including the Hawthorne effect. Additionally, effectiveness of resistive devices to train muscles has been questioned, since patients can slow their inspiratory flow rate, thereby decreasing the effective resistance.

Psychological etiologies.

Anxiety and fear are the labels most frequently applied to weaning problems not explained by physiological causes. A patient ventilated for ARF due to multiple sclerosis (duration not reported) was treated with biofeedback and hypnotic relaxation (LaRiccia, Katz, Peters, Atkinson, & Weiss, 1985). The feedback signal was movement of her chest wall, as displayed on an oscilloscope. Verbal praise was offered for improved chest movement. Hypnotic relaxation was implemented with an eye fixation technique and the patient was asked to visualize breathing normally as she had five years before. Following eight sessions in 12 days the patient weaned successfully. Internal validity is again questioned due to the potential effects of maturation

and the increased attention from the staff.

Two patients, one with COPD and amyotrophic lateral sclerosis (ALS), the other with COPD, were treated with hypnosis-induced relaxation (Acosta, 1987). Oxygen saturation (SaO_2) by pulse oximetry and anxiety, as measured on a three point scale, were evaluated pre- and post-intervention. Twenty-three days of T-piece trials preceded intervention in the first patient. She described the reason for weaning failure as "fear of suffocation". Following eight days of intervention, she was able to breathe spontaneously during daytime hours, although she required ventilation at night. The second patient had required reintubation following a failed weaning attempt. Duration of MV was 10 days. He described the reason for weaning failure as "air hunger". Following six days of intervention he successfully weaned.

Both patients decreased subjective anxiety and increased SaO_2 from pre- to post-intervention, as shown by graphic trends of data. The author hypothesized that anxiety increased tension in the thoracic muscles and limited movement of the diaphragm, thereby prohibiting weaning in patients with limited reserve. Relaxation would prevent this from happening. Again, maturation and attention threaten internal validity and dictate that these results be interpreted carefully.

The final case was also reported by Acosta (1988). A COPD patient who had been ventilated 46 days was treated with biofeedback and progressive muscle relaxation. The patient was "afraid of suffocation". Thirty-minute intervention sessions consisted of the patient sitting in a comfortable chair with an ear oximeter within view. The patient was instructed to monitor his SaO_2 as he progressively tensed and relaxed sequential muscle groups. Following 12 sessions the patient weaned. A concern with use of progressive relaxation is

that energy expenditure increases as the muscles are tensed (Kaempfer, 1982); some patients may find the exertion too taxing. The patient in this study decreased SaO_2 during the actual intervention, indicating increased O_2 requirements. An alternative treatment would involve using a combination of mental with physical relaxation so that large increases in energy expenditure are avoided. The goal of all relaxation strategies is to teach the patient to respond more favorably to the stress of weaning.

The interventions used to treat weaning failure can be summarized as those that train the ventilatory muscles, and those that affect an undefined psychological component. The case reports presented here have used isocapnic hyperpnea (Belman, 1981), inspiratory resistance (Aldrich et al., 1989), biofeedback (LaRicca et al, 1985; Acosta, 1988), and mental and physical relaxation strategies (LaRicca et al., 1985; Acosta, 1987; 1988). Controlled studies are needed to evaluate the clinical conditions and patient characteristics which make one strategy preferable to another.

Summary

In summary, 35 studies have been included in this review of the literature related to weaning from mechanical ventilation. The studies were divided into four main categories: methods of weaning; criteria to predict weaning success; manifestations and causes of weaning failure; and treatment of weaning failure. The studies of weaning methods investigated IMV, T-piece and PSV weaning. Outcomes and physiological changes were the primary focus. The data supported none of the methods. Research is needed to evaluate weaning methods most appropriate for various clinical situations.

The criteria studies evaluated weaning determinants for both long- and short-term ventilator patients. Predictions were accurate for short-term

patients (those ventilated less than five days). However, predictions in long-term patients have not been substantiated, emphasizing the difficulty of evaluating the etiologies of weaning failure in patients who require long-term ventilation. One study suggested a measure of respiratory stress (the inspiratory effort quotient), that seems promising for predicting weaning outcome (Kline et al., 1987).

Some of the difficulty with accurate weaning predictions in long-term patients may relate to the lack of consistency in defining long-term ventilation. Patients ventilated for more than seven days were generally considered long-term patients. However, patients who were ventilated between four and seven days were not consistently classified. These inconsistencies and wide variability in duration of ventilation may contribute to the poor predictive ability of the hypothesized criteria.

The weaning failure studies investigated clinically observable signs of respiratory stress as well as the causes of failure, such as ventilatory muscle fatigue and breathing load. The clinical observations of breathing pattern and movements of the chest and abdomen may provide a means of assessing weaning failure, without the need for sophisticated equipment. However, assessment of respiratory stress as an etiology of weaning failure is still inadequate.

The final group of studies presented reports of treating difficult-to-wean patients. The interventions were aimed at ventilatory muscle dysfunction and hypothesized psychological etiologies such as anxiety and fear. The presence of psychological variables contributing to weaning failure have not been systematically described. Controlled studies evaluating the psychological etiologies of weaning failure are needed in order to improve

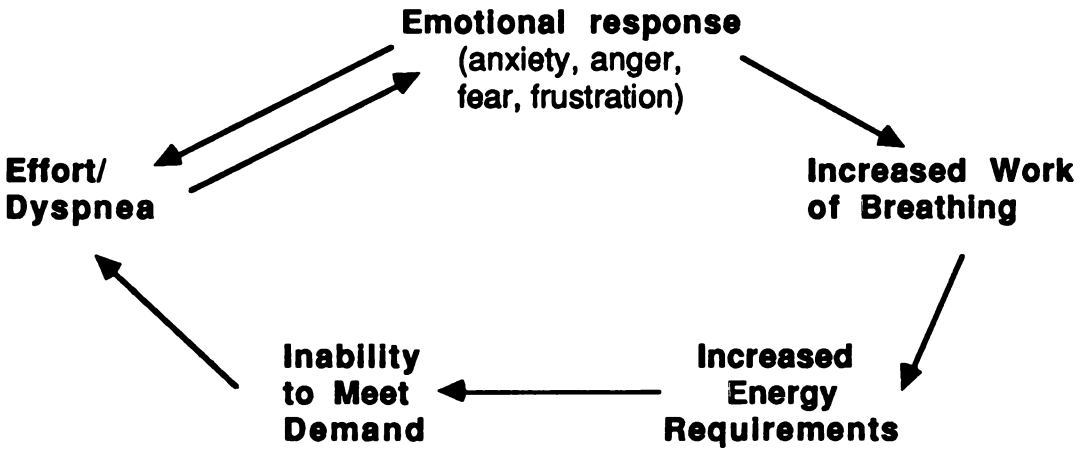
weaning outcomes in long-term patients.

The majority of weaning studies investigated criteria to predict weaning, or assessed weaning failure from a physiological perspective. Further description of the interaction between physiological and psychological causes of weaning failure would allow development of conceptually based protocols, utilizing appropriate weaning methods and incorporating nursing interventions to facilitate weaning.

Conceptual Framework

A circular model (Figure 2) proposes how physiological and psychological factors may interact, contributing to weaning failure. The

Figure 2 Conceptual relationships between physiological and psychological factors contributing to weaning failure



conceptual model suggests that negative emotions increase the work of breathing, leading to dyspnea, which can decrease the ability to breathe spontaneously (adapted from Grossbach-Landis, 1980). During mechanical

ventilation, clinical practice suggests that patients experience emotional responses such as anxiety, anger, fear, and frustration (Grossbach-Landis, 1980). These emotional responses may be precipitated by many factors in the ICU environment. For example, patients who experienced communication difficulties reported stronger feelings of anger, anxiety and frustration than patients who did not report communication problems (Riggio, Singer, Hartman, & Sneider, 1982). In addition to environmental factors, the weaning process itself may precipitate anxiety or fear (Acosta 1987; 1988).

Emotional arousal is associated with dyspnea in patients with lung disease (Janson-Bjerklie, Carrieri, & Hudes, 1986). Therefore, it is reasonable to assume that psychological distress is also associated with dyspnea in ventilator patients. The mechanism of this association has not been established. The hypothesized model suggests a physiological change in conjunction with the emotional response. For example, increased muscle tension due to anxiety (Acosta, 1987) could increase the work of breathing beyond that normally expected during weaning, thereby increasing energy demands and dyspnea. Alternatively, emotional response may have a direct effect on dyspnea.

The research proposal described in chapter 1 will allow testing of a portion of the conceptual model. The physiological responses of increased work of breathing, increased energy requirements, and the inability to meet the ventilatory demand will be measured as inspiratory effort. Emotional state will be measured as generalized psychological distress and as anxiety. The intensity of dyspnea will also be measured. By beginning to analyze the relationships between emotional state, inspiratory effort and dyspnea intensity during weaning, it may be possible to enhance understanding of the

interactions of physiological and psychological factors that can prolong the need for MV.

Assumptions

With decreasing levels of ventilator support, spontaneous work of breathing increases.

As work of breathing increases, the oxygen consumption of the ventilatory muscles will increase.

Definitions of Terms

Acute respiratory failure-- Process whereby internal and external respiration are not adequately linked, and therefore pH homeostasis is not maintained. The etiology may be due to failure of oxygenation, ventilation, gas transport, or gas utilization.

Anxiety intensity-- Quantification of perceptual intensity of one negative emotional state.

Chronic mechanical ventilation-- Requiring mechanical ventilation on a continued basis (more than 4 months), despite efforts to return to spontaneous ventilation.

Chronic respiratory failure-- Same as acute failure, except the pH has been recovered at the cost of an elevated CO_2 production.

Dyspnea intensity-- Quantification of perceptual intensity of difficult or uncomfortable breathing.

Emotional state or Mood state--A hypothetical construct or inference based upon evidence such as verbal reports about inner feelings and expressive behaviors (Plutchik, 1984).

Endotracheal tube-- A tube place either orally or nasally into the lungs used to institute ventilatory support for the treatment of respiratory failure.

Inspiratory effort-- An imbalance between energy supply to the ventilatory muscles and ventilation demands, as evidenced by breathing work load, muscle strength and inspiratory timing

Intubation-- The process of placing the endotracheal tube into the lungs.

Long-term mechanical ventilation-- Requiring mechanical ventilation for more than 3 days, but less than 4 months, due to an inability to sustain breathing without assistance.

Mechanical ventilation-- Use of machines (ventilators) to support respiration, in cases where the patient is unable to support ventilation spontaneously due to acute or chronic respiratory failure.

Psychological distress-- An emotional state with negative connotations, such as anxiety or depression.

Short-term mechanical ventilation-- Requiring mechanical ventilation for three days or less.

Spontaneous breathing-- The ability to generate the pressure required to maintain a balance between internal and external respiration, as evidenced by arterial blood gases that have a compensated pH.

Tracheostomy-- Airway access, allowing mechanical ventilation, via a tube placed in the throat into the lungs, bypassing the upper airway.

Ventilatory muscle oxygen consumption--The amount of oxygen required by the respiratory muscles to generate the pressure necessary to meet ventilation requirements. A balance between energy supply and the demand for ventilation is necessary.

Weaning from mechanical ventilation or Weaning process-- The transition from ventilator-assisted to spontaneous breathing, accompanied by a breathing pattern the patient can sustain without assist.

Weaning method-- The intervention technique used to return patients to spontaneous breathing from mechanical ventilation. For example: intermittent mandatory ventilation, T-piece and pressure support ventilation.

Weaning completion or weaning outcome-- Ability of patient to sustain spontaneous ventilation, without signs of recurrent respiratory failure, in the 12 hours following removal of the endotracheal tube or tracheostomy.

CHAPTER 3

METHODOLOGY

Research Design

A time series, randomized crossover design was used to investigate the relationships between dyspnea intensity, anxiety intensity, psychological distress, and inspiratory effort prior to and during weaning from mechanical ventilation.

Research Setting

Data were collected in an 18 bed, medical/surgical intensive care unit at a 560 bed university hospital.

Sample

A convenience sample of 21 intubated, adult ICU patients (ages 18-90) who were alert, able to communicate and clinically stable (see exclusion criteria below) were selected. Patients with diverse etiologies for acute respiratory failure were included in order to approximate clinical reality. All patients had been ventilated for ≥ 3 days, were capable of short periods of spontaneous ventilation, and had not had a weaning trial during the prior 12 hours.

Patients were excluded if they were clinically unstable and therefore unable to tolerate the added stress of spontaneous breathing during weaning. The specific exclusion criteria are listed in Table 7. Patients were excluded if they were febrile, which increases $\dot{V}CO_2$, or if they had uncontrolled pain that produces splinting. Patients were alert, oriented and English-speaking, allowing measurement of sensations and feelings. Cardiovascular, hemodynamic and pulmonary stability were essential since the weaning process added stress to the patients' system. If the patients' work load was

already close to their maximal capabilities the added stress of weaning would have been inappropriate.

Informed consent was obtained in accordance with the standards of the committee for human research at the University of California, San Francisco. (see Appendix E).

Table 7 Exclusion criteria*

General Assessment	CV / Hemodynamic	Pulmonary
Febrile > 38.5 C	Heart rate >120	Resp. rate > 40
Uncontrolled pain	B/P < 80, >180	Excessive secretions
Non-English speaking	New arrhythmias	Ve> 14 L/min
Disoriented	Hgb < 8 gm/ 100 ml	SaO_2 < 95 with FiO_2 0.5 or greater
	Hct < 26/ 100 ml	PaO_2 < 60
	Angina	CO_2 > 60 or varying more than 33% from patient's baseline
	S3 or gallop	pH < 7.3 or > 7.5
	Alveolar pulmonary edema	

(* compiled from the following sources: Browne, 1984; Brooks, 1983; Grossman, 1973; Myers, 1985; Quan & Hasan, 1980; Marini & Wheeler, 1989; Grossbach-Landis, 1980)

Data Collection Methods

The variables of interest and the instruments used to measure them are described in Table 8.

Table 8 Data Collection Methods

Variables	Instruments	Empirical Referent
Dyspnea Intensity	Visual analogue scale	Distance in millimeters
Psychological Distress	Short Profile of Mood States	Average of Likert scores
Anxiety Intensity	Anxiety visual analogue scale	Distance in millimeters
Inspiratory Effort	Pressure time index= (Pavg/Pmax) x (Ti/Ttot)	Pavg calculation from equation of motion = R * Vt/Ti + Vt/2C + AP Measures taken from recordings of: Airflow (L/sec), Volume (L) and Airway pressure (cm H_2O) versus time. Pmax: measurement of Airway pressure during maximal maneuver (cm H_2O) Ti/Ttot measurement of respiratory timing from Airflow tracing (sec)
Weaning Completion	Ability to wean within 24 hours after data collection	Endotracheal tube or tracheostomy successfully removed within the specified time frame

Variables and Instruments

Dyspnea Intensity.

Dyspnea intensity was measured by asking the patients to place a vertical mark on a printed 100 millimeter (mm) horizontal visual analogue scale in response to the question: "How short of breath are you right now?" (see Appendix F) The line has descriptors below the extreme ends. On the left is the word "none", indicating no shortness of breath. At the right is the opposite response, "extremely severe". The patients placed a vertical mark on

the line that best answered the question.

The measurement of sensations by visual analogue scale was recommended as a means for describing the "exactness of subjective experience" (Aitken, 1969). The lack of quantitative terms in the English language limits the range of descriptions; therefore, use of a horizontal line allows freedom of rating without imposition of artificial categories (Aitken, 1969). The visual analogue scale is a sensitive measure of intensity changes in response to stimulus (Joyce et al., 1975). Therefore dyspnea intensity changes in response to weaning may be charted.

Construct validity of the dyspnea VAS has been established by comparison to other measures of dyspnea (Janson-Bjerklie, Carrieri, & Hudes, 1986; Lush, Janson-Bjerklie, Carrieri, & Lovejoy, 1988), and by the correlation between the change in dyspnea intensity in response to increased physiological impairment (Gift, Plaut, & Jacox, 1986). Reliability of the VAS has been established in conditions where the stimulus intensity, and therefore sensation intensity, is not expected to change, as occurs with chronic pain (Revill, Robinson, Rosen, & Hogg, 1976). However, in situations where sensation intensity varies, as in the weaning ventilator patient, reliability is more difficult to establish (Lush et al., 1988).

Patients sometimes have difficulty understanding how to mark the VAS (Gift et al., 1986). The patients in the present study, therefore, were carefully instructed on the appropriate use of the scale. Standardized directions were read to them, and they were able to practice marking the scale prior to data collection. The feasibility of using the VAS in ventilator patients has previously been established (Lush et al., 1988).

Dyspnea intensity was evaluated on the basis of the VAS scores. For

each weaning condition, intensity was measured as the distance in millimeters from the left side of the horizontal line (corresponding to no dyspnea) to the mark placed by the patient.

Psychological distress.

A short form of the profile of mood states (POMS) was used to measure psychological distress. The short POMS is an adjective checklist with Likert scale response options. (see Appendix G) Patients were asked to respond to the question, "How do you feel today?," in response to 37 adjectives. The total mood disturbance score of the short form of the POMS correlates highly (r=.99, n=83), in cancer patients, with the original instrument (Shacham, 1983), which has established validity and reliability (Speilberger, 1972). The 37 POMS adjectives can be divided into six subscales (number of items are in parentheses): tension-anxiety (6), depression-dejection (8), anger-hostility (7), vigor-activity (6), fatigue-inertia (5), and confusion-bewilderment (5). Subscale scores were calculated by totaling the Likert responses for the subscale adjectives, and then dividing by the number of adjectives in the subscale. The internal consistency reliability for the subscales ranged from 0.80 to 0.91 for this sample. The total mood disturbance score is calculated by adding the scores for the five negative subscales, subtracting the vigor score, and dividing by 6, which is the total number of subscales. This instrument was administered prior to initiating the weaning protocols, along with the anxiety visual analogue scale.

Anxiety intensity.

The anxiety visual analogue scale (see Appendix H) asked patients to rate, "How do you feel right now?," by marking on a 100 millimeter (mm) line, with descriptors at the extreme ends reading, "not at all anxious" and

"extremely anxious". This instrument has been compared to the tension-anxiety subscale of the POMS in a study of 29 cancer patients (Sutherland, Walker, & Till, 1988). Spearman correlation coefficient between the POMS subscale and the anxiety VAS was 0.82. The anxiety visual analogue scale (VAS) was printed in large type on a separate card from the dyspnea VAS, and administered prior to and at ten minute intervals during the weaning process. The POMS and the anxiety visual analogue scales were administered prior to the weaning trial, to test construct validity of the anxiety VAS. In addition, the POMS measured the presence of other contributors to psychological distress besides anxiety. The anxiety VAS score was measured as the distance in millimeters from the left edge of the line to the mark placed by the patient. Validity and reliability of visual analogue scales is reviewed in the dyspnea intensity section (p 58).

Inspiratory effort.

Inspiratory effort was measured by the pressure time index (PTI) (see formula 1 in Table 9). The components of the PTI were obtained from analysis of waveforms of airway pressure, airflow and volume, recorded on a Hewlett Packard (HP) four-channel recorder (model number 7754B), which was calibrated with standardized signals. Airway pressure was measured utilizing a Validyne transducer (model DP 15-30, accurate ± .25% of full scale up to 88 cm H_2O) and demodulator (CD 15, output ± 10V at 10 mA). Airflow was measured with a Bionix 400 pneumotachygraph (accurate ± 2% of full scale) connected to the endotracheal tube proximal to the Y piece of the ventilator circuit. Tubing length was minimized to prevent re-breathing of carbon dioxide. The pneumotachygraph has an internal integrator, allowing volume measurement. The Bionix 400 continuously re-establishes the baseline,

Table 9 Equations Used For Calculations

# Formula	Definition of Terms
1) PTI = (Pavg/Pmax) x (Ti/Ttot)	PTI = pressure time index Pavg = average inspiratory pressure Pmax = maximal inspiratory pressure Ti/Ttot = inspiratory time as fraction of total time
2) Pavg = Vt/Ti *EstR + Vt/2EstC + AP[§]	Pavg = average inspiratory pressure or work/liter Vt = spontaneous tidal volume Ti = time of inspiration EstR = estimated inspiratory resistance EstC = estimated inspiratory compliance AP = autoPEEP
3) R = Pd - Pzf / $\dot{V}$@Pd	R = measured passive inspiratory resistance Pd = peak dynamic airway pressure Pzf = airway pressure at end inspiratory flow $\dot{V}$@Pd = flow rate at time of dynamic pressure
4) C = Vt / Pzf - PEEP	C = measured passive inspiratory compliance Vt = tidal volume, Pzf = as above PEEP = positive end expiratory pressure
5) Rslope = R1 - R2 / $\dot{V}$1 - $\dot{V}$2	Rslope = slope of resistance line R1 = measured passive resistance with high flow R2 = measured passive resistance with low flow $\dot{V}$1 = high flow rate with low tidal volume $\dot{V}$2 = low flow rate with low tidal volume
6) Cslope = C1 - C2 / Vt1 - Vt2	Cslope = slope of compliance line C1 = measured passive compliance with high volume C2 = measured passive compliance with low volume Vt1 = high ventilator delivered tidal volume at constant flow of 60 L/min Vt2 = low ventilator delivered tidal volume (constant flow)
7) EstR = Rslope * (spont$\dot{V}$ - $\dot{V}$1) + R1	EstR, Rslope, $\dot{V}$1, R1 = as above spont$\dot{V}$ = spontaneous mean inspiratory flow rate
8) EstC = Cslope * (spontVt - Vt1) + C1	EstC, Cslope, Vt1, C = as above spont Vt = measured spontaneous tidal volume
9) AP = $\dot{V}$endex * EstR	$\dot{V}$endex = flow rate at end expiration EstR = as above

§ = During PSV weaning the added pressure support was subtracted from the calculated Pavg

which prevents drift in the volume measurements, enhancing reliability of measurements even at low flow rates. The added deadspace of the experimental apparatus was approximately 100 cc, and the added resistance was 0.6 cm H_2O/L/sec. All subjects were ventilated with a Puritan-Bennett 7200 ventilator utilizing standard circuitry.

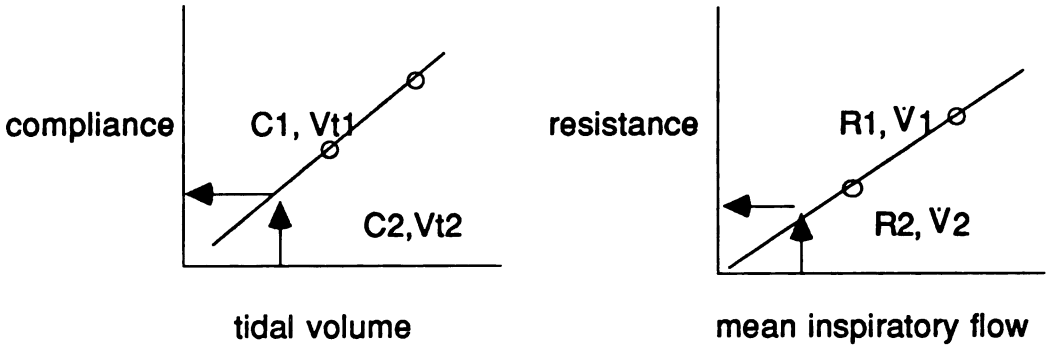
The first component of the PTI, average inspiratory pressure (Pavg) or work per liter ventilation, was calculated from the equation of motion (see formula 2, Table 9). The first element of the equation of motion, tidal volume (Vt), was measured directly from printouts from the HP recorder. The inspiratory time (Ti) was measured from the airflow versus time waveforms, utilizing the points of zero flow as the transition from inspiration to expiration. The resistance (R) and compliance (C) components of this equation were estimated from measurements of airway pressure, airflow and volume, obtained under passive conditions prior to weaning.

To obtain the passive R and C patients were briefly hyperventilated to suppress ventilatory drive. Under these conditions the ventilator, not the patients, initiated inspiration. Resistance was calculated from formula 3 in Table 9. Measurements needed for the calculation of R were obtained passively under two different conditions, high and low flow with constant tidal volume. Compliance was calculated from formula 4, Table 9, also under two conditions, high and low volume with constant flow. The measured R and C provided information about the impedance characteristics of the lung and chest wall under the two measurement conditions, and also allowed estimation of R and C during weaning.

The compliance and resistance estimates were obtained by calculating

line equations for the passive compliance and volume points, and the passive resistance and flow points. Depicted graphically, the passive points are plotted, as in Figure 3.

Figure 3 Estimating Spontaneous Compliance and Resistance from Passive Measurements



With the two known points, it is possible to calculate the line equations which join the points. First the slopes of the lines are calculated (see formulas 5 and 6 in Table 9). The slopes are then used to estimate the C and R of the spontaneous breaths, based upon formulas 7 and 8 in Table 9. The spontaneous tidal volume and mean inspiratory flow values are plugged into the line equations to estimate the spontaneous compliance and resistance.

The last element of the equation of motion, auto PEEP (AP), was calculated from formula 9 in Table 9. AP occurs when end-expiratory alveolar pressure is elevated. Situations that produce AP include: increased lung compliance and/or elevated ventilatory demand. When end-expiratory alveolar pressure is elevated, additional pressure is required to initiate a breath. Therefore, the contribution of AP to the average inspiratory pressure was estimated. Since measures of expiratory resistance were not available,

estimates of AP were obtained by assuming that inspiratory and expiratory resistance were similar. The estimated inspiratory resistance for each condition was multiplied by the end expiratory flow for six representative breaths obtained under the same conditions. The products were averaged for the six breaths, yielding a conservative estimate of AP.

Finally, in calculating the Pavg during PSV weaning, it was necessary to subtract the added pressure support from the calculated Pavg. For example, if the calculated Pavg based upon formula 2 (Table 9) equals 15 cm H_2O, and the added pressure support equals 5 cm H_2O, the actual patient work/liter ventilation (Pavg) would be 10 cm H_2O. No such correction was necessary for the IMV weaning protocol.

After the first component of the PTI (Pavg) was calculated, the second component (the maximal inspiratory pressure or Pmax) was measured directly from the airway pressure waveform. Prior to the start of weaning, patients were asked to perform maximal inspiratory efforts against a one-way valve. The one-way valve allowed expiration but prevented inspiration. Therefore, the patients' ventilatory drive was stimulated and the maximal inspiratory pressure was standardized at residual volume (Marini, Smith, & Lamb, 1986). In order to ensure maximal efforts, subjects breathed against the one-way valve for approximately 15 seconds as the researcher encouraged subjects to make the strongest efforts possible. The one-way valve was removed from the endotracheal tube after the airway pressure reached a maximal value (Pmax) and then began to decline. A rest period was provided following the exertion.

Looking only at the first ratio of the PTI, a Pavg/Pmax of < 0.4 was shown to correlate with ventilatory muscle fatigue (Bellemare & Grassino, 1982). Taking this ratio one step further and multiplying by the inspiratory duty cycle

calculates the pressure time index. The PTI is thought to better represent a fatigue threshold since it includes the timing component as well as the work/strength component.

The inspiratory duty cycle (Ti/Ttot) was calculated from the airflow waveforms. The inspiratory time (Ti) was measured from the point of end-expiratory zero flow for the preceding breath, to the point where the flow tracing again crosses the zero flow point, indicating end inspiration. The total cycle time (Ttot) is measured from the beginning of one breath to the beginning of the next breath, again using the zero flow points.

Therefore the PTI equals (Pavg/Pmax) x (Ti/Ttot). The measurements used to calculate the PTI were obtained after ten minutes accommodation to a ventilator change, as described below. Reported values are the mean for six breaths.

In addition to calculating the pressure time index, the strip chart recordings of airway pressure, airflow and volume were used to describe pulmonary function prior to and during weaning. The other pulmonary function variables included: the breathing pattern composed of tidal volume (Vt); mean inspiratory flow (Vt/Ti); breathing frequency (f); and the minute ventilation ($\dot{V}e$).

Procedure

The study procedure described below is diagramed in Appendix I. Subject eligibility was based upon the previously stated criteria. Consent for participation was obtained from the patient (see Appendix E). At the time consent was obtained, the patient was taught how to mark the VAS's. Collected demographic data included: age, sex, diagnosis, reason for ventilation, prior ventilator experience, size of ET tube, pre-weaning

hemoglobin, hematocrit, time and dose of sedative medications in the six hours preceding the weaning trial and duration of intubation (see Appendix J).

The pre-weaning measurements of psychological distress, anxiety intensity, and dyspnea intensity were collected prior to initiating physiological measurements, in order to prevent contamination of baseline subjective measures with the physiological instrumentation. With patients sitting at least 45 degrees upright, the airway pressure monitoring equipment and pneumotachygraph were then connected to the endotracheal tube.

After the equipment was properly placed, patients were asked to perform the maximal inspiratory pressure maneuver against the one-way valve. The subjects then recovered from the exertion, breathing with assist-control ventilation. The resting $\dot{V}e$ was recorded. Passive, machine-controlled breaths (where the patient did not initiate inspiration) were obtained by hyperventilation by increasing the breathing frequency in order to suppress patient triggering of the ventilator. These passive breaths were necessary for calculating the passive resistance and compliance, as previously described.

The patients were weaned using two protocols, pressure support ventilation (PSV) and intermittent mandatory ventilation (IMV). All patients experienced both protocols. Half of the patients received the IMV protocol first, while the others received the PSV protocol first. The order of presentation was randomized based upon a table of random numbers. A one- to three- hour rest preceded the start of the second protocol. Care was taken to ensure that patients felt ready to begin a second protocol. All patients started at a level of ventilation to achieve full support. This meant that for the pressure support group, the level of added pressure support was adjusted until the patient achieved a tidal volume equal to 10 cc/kg. The level of

support that achieved this volume varied from subject to subject, depending upon the individuals' intrinsic impedance to chest inflation. The applied pressure support level was then decreased from this 100% support level in 20% decrements to 80%, 60%, 40%, then 20%, until the patient breathed spontaneously, with no assistance from the machine (0%). For example, the patient may have started at 20 cm H_2O pressure support to achieve a tidal volume of 10 cc/kg. This support level was decreased by 4 cm H_2O decrements. Therefore, 16 cm H_2O support was 80% support; 12 cm H_2O was 60%; 8 cm H_2O was 40%; 4 cm H_2O was 20%; and 0 cm H_2O pressure support, with 5 cm H_2O continuous positive airway pressure (CPAP), was 0% support. At 0% support spontaneous breathing occurs.

For the IMV protocol, the ventilator-delivered tidal volume was set to achieve a volume equal to 10 cc/kg. The ventilator-breath frequency was then adjusted to achieve a $\dot{V}e$ equal to that set by the patient when breathing with assist-control ventilation. During this weaning protocol the ventilator-delivered breathing frequency was decreased in the same manner as previously described in order to achieve 80%, 60%, 40%, 20% and 0% ventilator support. For example, if the patient weighed 70 kg, the ventilator-delivered tidal volume was 840 ml or .84 L. Therefore, if their baseline $\dot{V}e$ on assist-control ventilation was 10 L/min, the ventilator frequency was set at 12 breaths per minute ([10 L/min] / [0.84 L] = 12 breaths/min). The ventilator rate was then decreased from 12 to 9, 7, 5, 3, then 0 breaths per minute. Again, at 0 breaths per minute with 5 cm H_2O CPAP the patient breathed spontaneously.

Five cm H_2O CPAP was used during both spontaneous breathing trials for several reasons. Low levels of CPAP are routinely used to counter-

balance the loss of end-expiratory lung volume that occurs when patients are lying in a semi-recumbent position. In patients who have dynamic hyperinflation, such as emphysema patients, low CPAP levels can also prevent dynamic airway collapse thereby offsetting elevated end-expiratory alveolar pressure (the auto-PEEP phenomenon) (Smith & Marini, 1988).

During both protocols, measurements of airway pressure, airflow, and volume were obtained after 10 minutes accommodation to each new ventilator setting. The dyspnea intensity and anxiety intensity visual analogue scales were then obtained. The order of presentation of the visual analogue scales was also randomized to prevent order effects. Data collection at each ventilator setting took approximately three to five minutes. Therefore, the patients breathed for approximately 10-15 minutes at each level of support. Each weaning protocol lasted approximately two hours. The two protocols were separated by a rest period of approximately two hours. Therefore, data collection lasted for roughly six hours. Refer to Appendix I for detailed illustration of the sequence.

Patients were monitored closely as the level of ventilatory support was decreased. Patients were placed back on full ventilator support if they developed any of the exclusion criteria (p. 57), if oxygen saturation decreased to less than 90% (Nelcor N200 pulse oximeter), or if they requested increased ventilation due to severe dyspnea or anxiety. Subjects were followed for 24 hours following data collection to see if weaning was completed within that time frame. Weaning completion was defined as successful removal of the endotracheal tube, without need for reintubation in the subsequent 12 hours.

Data Analysis

Table 10 describes the data analysis techniques corresponding to the questions of interest in the study. Descriptive statistics were used to summarize sample characteristics. Pearson coefficient of correlation evaluated the associations between the pre-weaning variables. Pearson correlation coefficients also assessed the relationships between the pre-weaning and weaning process variables. Mann Whitney U was used to evaluate the differences in dyspnea intensity, anxiety intensity and mood, between those who did and those who did not wean within 24 hours of data collection. Point-biserial correlation coefficients and Chi Square analysis compared the relationships between all study variables and the subjects' ability to wean within 24 hours of data collection. A two-way repeated measures analysis of variance evaluated the differences in dyspnea intensity, anxiety intensity and inspiratory effort between the two weaning methods. Level of significance was set at $p < 0.05$ for all statistical tests.

Table 10 Data Analysis

Question	Variable	Analysis
What are the sample characteristics?	Age, sex, diagnoses, Pre-weaning: mood state, dyspnea intensity and anxiety intensity VAS scores, and pulmonary function	Frequencies, means, standard deviations
Is there a relationship between pre-weaning mood state and baseline dyspnea and anxiety intensities, prior to the start of weaning?	Pre-weaning total POMS, dyspnea intensity and anxiety intensity VAS scores	Pearson Correlation Coefficients
Is there a difference in the pre-weaning variables between those who did and those who did not wean within 24 hours of study?	Pre-weaning: Total POMS, dyspnea intensity, anxiety intensity and ability to successfully remove ET or trach within 24 hours of data collection	Mann Whitney U
Is there a relationship between the pre-weaning variables and dyspnea and anxiety intensities and inspiratory effort measured at the end of the weaning trial?	Total POMS, dyspnea intensity and anxiety intensity VAS scores prior to weaning and PTI & VAS scores at the lowest support level subjects completed with both methods	Pearson Correlation Coefficients
Is there a relationship between pre-weaning variables and weaning completion? Is there a relationship between end-weaning variables and weaning completion? Is there a relationship between weaning method and weaning completion?	Pre-weaning: Total POMS, dyspnea intensity and anxiety intensity VAS scores prior to weaning. End weaning: PTI, dyspnea and anxiety VAS scores. Ability to complete CPAP (0%) level following both weaning methods. Weaning completion: Ability to complete weaning within 24 hours.	Point-biserial Correlations and Chi Square
Are there differences in dyspnea and anxiety intensities and inspiratory effort at decreasing levels of ventilatory support in response to the two weaning methods?	Dyspnea intensity and anxiety intensity VAS scores and PTI measured at each level of decreased support with both methods	Two-way repeated measures ANOVA

CHAPTER 4

RESULTS

Preliminary Analyses

Sample Characteristics

The convenience sample included 21 adult subjects, 10 males and 11 females, with a mean age of 52 ± 21.7 years. All subjects were mechanically ventilated for respiratory failure for three or more days in one intensive care unit. The mean number of days ventilated was 10.4 ± 12.4, characterizing the sample as difficult-to-wean. As shown in Table 11, the etiology of respiratory failure varied considerably among patients. Eleven of the 21 subjects had at least one prior ventilator experience.

Table 11 Sample Characteristics (N = 21)

VARIABLES	n =	VARIABLES	Mean ± SD
Gender		**Age**	52 ± 21.7
male	10		
female	11	**Days Ventilated**	10.4 ± 12.4
Diagnosis		**Pre-Wean**	
ARDS	3	**Dyspnea~**	32.2 ± 22.6
COPD	6		
Neuromuscular	2	**Pre-Wean**	
Pneumonia	3	**Anxiety≈**	43.1 ± 31.4
Post-Op Surgical	5		
Asthma	1		
Other	1		

ARDS = adult respiratory distress syndrome,
COPD = chronic obstructive pulmonary disease,
Other = questionable etiology, possibly partial diaphragmatic paralysis
~Dyspnea intensity = score on 100 mm horizontal visual analogue scale
≈Anxiety intensity = score on 100 mm horizontal visual analogue scale

Despite resting on "full" ventilator support (an intermittent mandatory ventilation rate of ≥ 6 breaths/minute) for at least 12 hours prior to weaning, patients reported pre-weaning dyspnea ($\bar{X}$ = 32.2 ± 22.6) on a 0-100 mm scale. The anxiety score prior to weaning was also elevated ($\bar{X}$ = 43.1 ± 31.4) on a 0-100 mm scale.

Pre-weaning Pulmonary Function

Table 12 provides detailed information about subjects' respiratory muscle strength (Pmax), minute ventilation requirement ($\dot{V}e$), and several variables that contribute to work of breathing during weaning (i.e. compliance, resistance and endotracheal tube size). The mean Pmax exceeded the standard criteria of 30 cm H_2O, used to predict successful weaning (46.1 ± 18.7 cm H_2O). All subjects had a minute ventilation of less than 14 L/min, with a mean also in the weaning range of approximately 10 L/min.

The measured compliance and resistance under passive conditions provided information about the impedance characteristics of the lung and chest wall. As shown in Table 12, the compliance under low tidal volume conditions is in the range previously reported for ventilated patients ($\bar{X}$ = .053 ± .02) (Marini, Smith, & Lamb, 1988). However, many of the resistance values were elevated, with a mean of 23.1 ± 6.4 cm H_2O/L/sec. All patients, except one who had a tracheostomy, had endotracheal tubes ranging in size from 7 to 8 mm.

Pre-weaning Mood State

Despite using the shortened version of the profile of mood states (POMS), two subjects were unable to complete the instrument, due to an inability to concentrate for extended periods. Therefore, data on 19 subjects are presented. Overall, the ventilated subjects in this study assigned higher

Table 12 Description of Pre-weaning Pulmonary Function

Diagnosis	Pmax (cm H2O)	Ve (L)	C (High Vt) (L/cm H2O)	High Vt (L)	C (Low Vt) (L/cm H2O)	Low Vt (L)	Size Et (mm)	R (High flow) (cm H2O/L/sec)	High Flow (L/sec)	R (Low flow) (cm H2O/L/sec)	Low Flow (L/sec)
1 Post-Op	48.00	14.00	0.088	1.04	0.053	0.55	8.00	25.97	0.63	24.14	0.28
1 Post-Op	50.00	10.20	0.03	0.70	0.04	0.52	7.50	22.08	0.84	19.48	0.45
1 Post-Op	41.00	10.00	0.069	1.00	0.051	0.79	8.00	22.11	0.86	19.68	0.56
4 ARDS	77.00	14.00	0.063	1.00	0.057	0.70	7.50	21.96	1.14	30.13	0.50
5 ARDS	25.00	12.90	0.079	0.89	0.043	0.76	7.50	36.30	1.11	36.95	0.84
6 NeuroMusc	12.00	5.00	0.045	0.49	0.044	0.39	6*	18.90	0.86	19.38	0.57
7 Asthma	40.00	9.00	0.046	1.10	0.044	1.00	7.50	26.41	0.84	30.72	0.56
8 Pneumonia	82.00	14.00	0.076	0.84	0.071	0.72	8.00	20.26	1.00	23.63	0.53
9 COPD	77.00	14.00	0.047	1.13	0.04	0.90	8.00	18.30	1.10	27.38	0.80
10 Other	15.00	6.50	0.06	0.74	0.052	0.51	7.00	26.19	1.00	23.13	0.71
11 ARDS	36.00	12.00	0.029	0.52	0.041	0.35	8.00	14.51	1.15	13.97	0.94
12 Pneumonia	67.00	14.00	0.043	0.86	0.049	0.70	7.50	24.90	1.01	33.57	0.65
13 COPD	37.50	8.00	0.062	0.78	0.071	0.58	8.00	18.41	1.29	16.76	1.02
14 COPD	54.50	10.90	0.041	0.90	0.043	0.73	8.00	25.20	1.20	26.16	0.85
1 Post-Op	45.00	12.00	0.055	1.64	0.044	1.16	7.50	24.31	0.94	27.49	0.66
1 Post-Op	33.00	9.80	0.085	0.97	0.13	0.69	7.50	8.18	0.76	11.12	0.46
17 COPD	60.00	14.00	0.065	1.20	0.062	0.72	8.00	20.52	1.02	19.73	0.75
18 COPD	41.50	7.80	0.051	1.20	0.045	0.93	7.50	21.46	1.10	21.02	0.76
19 Pneumonia	36.50	12.00	0.04	0.95	0.045	0.72	7.00	24.32	0.79	24.18	0.45
20 COPD	43.50	9.60	0.041	0.94	0.043	0.65	8.00	20.76	0.94	16.83	0.60
21 NeuroMusc	46.00	8.00	0.061	0.90	0.053	0.81	7.00	24.38	1.10	20.17	0.80
Total Sample											
Mean	46.10	10.84	0.056	0.94	0.053	0.71	7.50	22.20	0.99	23.10	0.65
SD	18.70	2.77	0.017	0.25	0.02	0.19	0.50	5.40	0.16	6.40	0.19

Pmax=maximal inspiratory pressure; Ve=minute ventilation; C=measured compliance, passive conditions; Vt=tidal volume; Et=endotracheal tube; R=passive measured resistance; NeuroMusc=neuromuscular disorder; other=probably partial diaphragmatic paralysis; 6*=tracheostomy

numbers to the fatigue/inertia and tension/anxiety subscale adjectives, when compared to the other adjectives. This same trend was noted in the sample of cancer patients upon which this shortened instrument was first standardized (Shacham, 1983). Refer to Table 13 for a comparison of the two patient groups. The depression/dejection subscale scores were also very similar. However, in contrast to the cancer patients, the ventilated patients in this study reported higher values on the anger/hostility subscale, and lower values on the vigor/activity subscale. The total score could not be compared because of discrepancies in the calculations used for the cancer patients.

Table 13 Comparison of Mean POMS Scores Between Two Patient Groups

	Cancer Patients*	Ventilator Patients**
Tension/Anxiety	1.44	1.69
Depression/Dejection	1.19	1.16
Anger/Hostility	0.65	1.05
Vigor/Activity	1.25	1.04
Fatigue/Inertia	1.73	1.96
Confusion/Bewilderment	0.99	1.27
Total Mood Disturbance		1.16

* Shacham, 1983, N = 83; ** N = 19

Responses to Weaning

Response to method.

All 21 subjects crossed over to both weaning methods. Eleven received IMV first, while ten had PSV first. Breathing pattern changes during weaning with the two methods are shown in Table 14. The mean total $\dot{V}e$ at each support level is comparable between the two methods. During IMV weaning,

Table 14 Ventilator Settings and Breathing Pattern (N = 21)

IMV Support level		f~ (breaths/min)	Ve~ (L/min)	PSV Support level		Pressure (cmH2O)	f (breaths/min)	Vt (L)	Ve (L/min)
100%	Mean ± SD	14.4 ± 7.2	15.09 ± 6.08	100%	Mean ± SD	22 ± 7.1~	17.2 ± 6.6	.77 ± .19	12.58 ± 3.73
	range	6 - 35	7.28 - 32.3		range	10 - 35	8 - 29	.49 - 1.25	5.83 - 19.23
80%	Mean ± SD	11.6 ± 5.7	13.16 ± 4.72	80%	Mean ± SD	17.7 ± 5.6	20.4 ± 9.2	.64 ± .18	11.95 ± 3.54
	range	5 - 28	7.64 - 25.13		range	8 - 28	9 - 44	.33 - 1.1	6.68 - 20.89
60%	Mean ± SD	8.7 ± 4.2	13.83 ± 3.96	60%	Mean ± SD	13.5 ± 4.2	23.1 ± 8.7	.56 ± .15	12.01 ± 3.20
	range	4 - 21	6.67 - 21.53		range	6 - 21	10 - 43	.35 - .93	6.08 - 18.14
40%*	Mean ± SD	5.6 ± 2.7	13.35 ± 3.52	40%	Mean ± SD	9.2 ± 2.8	24.6 ± 8.6	.52 ± .19	11.78 ± 3.43
	range	3 - 14	8.56 - 23.1		range	4 - 14	8 - 42	.27 - 1.05	5.94 - 19.72
20%**	Mean ± SD	2.9 ± 1.5	11.82 ± 3.31	20%*	Mean ± SD	5.1 ± 1.4	26.8 ± 8.6	.48 ± .19	11.99 ± 4.39
	range	1 - 7	7.28 - 19.25		range	2 - 7	10 - 43	.19 - .96	5.38 - 25.04

~f = machine delivered breathing frequency determined from initial Ve, prior to weaning, and Vt of 10cc/kg body weight. Mean machine tidal volume .85 ± .2 L; Range = .42-1.2 L, ~ Ve=total minute ventilation, spontaneous plus machine delivered. Flow rate at least 60 L/min with square wave form. *N=19; **N=16 subjects able to complete level.

Pressure = machine delivered pressure support; f = breathing frequency; Vt = tidal volume; ~100% pressure support = amount of pressure required to achieve Vt of 10 cc/kg;
* N = 19 subjects able to complete this level of support

machine tidal volume remained unchanged, with a mean of .85 ± .2 L, and the frequency of ventilator-delivered breaths was gradually decreased ($\bar{X}$ = 14.4 ± 7.2 to 2.9 ± 1.5). With the decrease in machine support, the spontaneous frequency and Vt increased to meet the $\dot{V}e$ requirement.

With PSV, in contrast to IMV, every breath was supported by the ventilator. Tidal volume and breathing frequency varied, depending upon the level of applied pressure and the impedance characteristics of the patient. The right hand panel of Table 14 shows that as the level of applied pressure decreased, the tidal volume decreased and the breathing frequency increased. This increase in f was necessary to fulfill the $\dot{V}e$ requirement since the Vt decreased.

It is interesting to note that the mean Vt on 20% PSV is .48 ± .16, which is not different than the mean Vt during spontaneous breathing with 5 cm H_2O continuous positive airway pressure (CPAP). Mean CPAP Vt following PSV weaning equals .46 ± .16, and mean CPAP Vt following IMV weaning equals .47 ± .15. This finding is consistent with the work of Fiastro, Habib and Quan (1988), who suggested that low levels of PS (in this case a mean of 5 cm H_2O) does not augment Vt, but is probably dissipated in overcoming the additional work of breathing associated with the ET tube and ventilator circuitry. Finally, in Table 14, it is important to note that not all subjects were able to continue the weaning protocol at the lower support levels.

Table 15 describes the protocol patients received first, the lowest support levels they reached, and whether they completed weaning (endotracheal tube successfully removed) within 24 hours of study. More subjects completed the lowest level of support (spontaneous breathing with continuous positive airway pressure or CPAP), following the PSV protocol (N

= 18), compared to the IMV protocol (N = 13). The ability to complete the CPAP support level was not dependent upon which protocol came first (Chi Square analysis). Even though more subjects completed the PSV protocol, completing it did not relate to ability to wean within 24 hours of study.

Table 15 Weaning Protocol, Lowest Support Levels and Ability to Wean Within 24 Hours of Study

Subject #	First Protocol	Last IMV Support Level	Last PSV Support Level	Weaned ≤ 24 Hours
1	IMV	CPAP	20%	No
2	PSV	CPAP	20%	Yes
3	IMV	CPAP	CPAP	Yes
4	PSV	20%	CPAP	Yes
5	PSV	60%	40%	No
6	PSV	40%	40%	No
7	IMV	CPAP	CPAP	Yes
8	PSV	60%	CPAP	No
9	IMV	CPAP	CPAP	Yes
10	IMV	CPAP	CPAP	No
11	PSV	CPAP	CPAP	No
12	IMV	40%	20%	No
13	PSV	CPAP	CPAP	Yes
14	IMV	CPAP	CPAP	Yes
15	IMV	20%	CPAP	No
16	IMV	CPAP	CPAP	Yes
17	IMV	20%	CPAP	No
18	PSV	CPAP	CPAP	Yes
19	IMV	CPAP	CPAP	Yes
20	PSV	CPAP	CPAP	No
21	PSV	40%	CPAP	No

Last IMV support level = lowest level of support subjects reached during weaning with intermittent mandatory ventilation; Last PSV support level = lowest level of support subjects reached during weaning with pressure support ventilation; CPAP = spontaneous breathing with 5 cm H_2O continuous positive airway pressure. Subjects who could breathe for 10 minutes on CPAP, but did not complete weaning within 24 hours did not have the endurance necessary to sustain spontaneous ventilation for extended periods.

However, completion of the IMV protocol was associated with weaning outcome ($X_2 = 4.32$, $p = .04$).

Physiological responses.

Average pulmonary function values describing breathing pattern, impedance characteristics, and work of breathing during IMV and PSV weaning are presented in Tables 16 a and b. The mean spontaneous $\dot{V}e$ during IMV weaning increased from 8.24 to 13.17 L/min. This increase in $\dot{V}e$ was achieved by increasing spontaneous Vt ($\bar{X}$ = .29 to .47 L) and spontaneous breathing frequency ($\bar{X}$ = 19 to 29 breaths/min).

It is not possible with PSV to separate the spontaneous $\dot{V}e$ from the total $\dot{V}e$, since every breath is supported. As stated previously, the total $\dot{V}e$ changed little as the pressure support level decreased, remaining close to the initial value of 12 L/min. Even though total $\dot{V}e$ remained unchanged, tidal volume progressively decreased as the level of pressure support was decreased ($\bar{X}$ = .75 to .46 L). The consequence of maintaining $\dot{V}e$ with decreased Vt was a mean increase in f from 18 to 28 breaths/ minute. Therefore, breathing pattern changes during weaning with both methods were similar for f, but different for Vt. Despite differences in the progression of Vt during weaning, the mean Vt and f were not different at the lowest support levels. On 20% support, the mean IMV Vt was .47 ± .15 and the mean PSV Vt was .49 ± .20. The mean frequency on 20% support for both IMV and PSV was 27 ± 9. These similarities held true for the lowest support level, CPAP.

Tables 16 a and b compare the impedance characteristics between the two methods. Low levels of autoPEEP (less than 2 cm H_2O) were present throughout weaning with both IMV and PSV. No significant differences were noted between the two methods. The level of AP did increase slightly as

Table 16a Pulmonary Function During IMV Weaning*

Support Level		Ve (L/min)	Vt (L)	V (L/sec)	f (breaths/min)	Ti/Ttot	AP (cmH2O)	Estimated C (L/cm H2O)	Estimated R (cm H2O/L/sec)	Pavg (cmH2O)	Pavg/Pmax
IMV											
100%	N = 9										
	Mean	8.24	0.29	0.40	19	0.38	0.70	0.042	18.38	13.97	0.37
	SD	4.44	0.14	0.24	9	0.09	1.04	0.025	4.36	7.71	0.18
80%	N = 13										
	Mean	7.67	0.29	0.39	20	0.35	0.77	0.045	20.30	13.10	0.35
	SD	3.89	0.12	0.19	9	0.11	1.04	0.02	7.90	6.80	0.20
60%	N = 18										
	Mean	9.77	0.35	0.44	25	0.40	0.82	0.045	21.75	15.60	0.34
	SD	5.40	0.17	0.22	8	0.09	1.28	0.017	6.51	8.12	0.17
40%	N = 18										
	Mean	10.86	0.41	0.50	28	0.38	1.28	0.044	22.15	18.10	0.42
	SD	4.40	0.17	0.17	9	0.08	1.83	0.016	6.35	8.25	0.18
20%	N = 14										
	Mean	12.02	0.47	0.52	27	0.39	1.06	0.044	22.53	18.79	0.41
	SD	4.21	0.15	0.15	9	0.08	0.98	0.013	5.98	8.03	0.12
CPAP	N = 12										
	Mean	13.17	0.47	0.55	29	0.41	1.33	0.044	21.31	19.15	0.42
	SD	5.14	0.15	0.22	9	0.06	0.99	0.012	5.27	8.41	0.15

*Subjects 5 and 16 deleted due to inaccurate Pavg values. IMV = intermittent mandatory ventilation
Ve = minute ventilation, Vt = Tidal volume, V = mean inspiratory flow rate, f = breathing frequency, Ti/Ttot = fraction of a breathing cycle spent in inspiration, AP = autoPEEP, Estimated C = spontaneous compliance estimated from passive conditions,
Estimated R = spontaneous resistance estimated from passive conditions, Pavg = average inspiratory pressure calculated from the equation of motion using estimated R & C values. Pavg/Pmax = work/liter ventilation as a fraction of the maximal inspiratory pressure. Average Pmax across all subjects = 46.1. CPAP = continuous positive airway pressure.

Table 16b Pulmonary Function During PSV Weaning*

Support Level		Ve (L/min)	Vt (L)	V (L/sec)	f (breaths/min)	Ti/Ttot	AP (cmH2O)	Estimated C (L/cm H2O)	Estimated R (cm H2O/L/sec)	Pavg (cmH2O)	Pavg/Pmax
PSV											
100%	N = 12										
	Mean	12.65	0.75	0.68	18	0.32	0.59	0.049	22.46	4.49	0.11
	SD	3.87	0.19	0.17	7	0.08	0.88	0.013	5.19	3.45	0.07
80%	13										
	Mean	12.17	0.63	0.62	21	0.34	0.87	0.048	22.28	5.92	0.13
	SD	3.66	0.18	0.15	9	0.09	1.65	0.011	5.31	4.34	0.07
60%	N = 19										
	Mean	12.19	0.56	0.61	23	0.34	0.88	0.047	22.66	7.30	0.16
	SD	3.31	0.15	0.14	9	0.07	2.04	0.01	5.44	5.15	0.10
40%	18										
	Mean	11.88	0.52	0.57	25	0.36	1.12	0.046	22.20	11.28	0.24
	SD	3.60	0.20	0.16	9	0.08	2.00	0.011	5.63	7.03	0.15
20%	N = 18										
	Mean	12.17	0.49	0.55	27	0.37	1.31	0.045	21.90	14.80	0.29
	SD	4.44	0.20	0.17	9	0.07	1.64	0.014	5.80	8.70	0.15
CPAP	N = 17										
	Mean	11.95	0.46	0.51	28	0.39	1.44	0.045	21.71	18.80	0.40
	SD	3.63	0.16	0.15	9	0.06	1.10	0.014	6.16	7.95	0.15

*Subjects 5 and 16 deleted due to inaccurate Pavg values. PSV = pressure support ventilation
Ve = minute ventilation, Vt = Tidal volume, V = mean inspiratory flow rate, f = breathing frequency, Ti/Ttot = fraction of a breathing cycle spent in inspiration, AP = autoPEEP, Estimated C = spontaneous compliance estimated from passive conditions,
Estimated R = spontaneous resistance estimated from passive conditions, Pavg = average inspiratory pressure calculated from the equation of motion using estimated R & C values. Pavg/Pmax = work/liter ventilation as a fraction of the maximal inspiratory pressure. Average Pmax across all subjects = 46.1. CPAP = continuous positive airway pressure.

ventilator support was withdrawn, possibly due to increased f and decreased expiratory time. However, even at the lowest support levels, the additional pressure investment needed to overcome the AP was negligible.

The compliance and resistance estimates presented in these tables were similar between the two weaning methods, and were consistent throughout the study. Mean C during IMV weaning ranged from .042 L/cm H_2O on 100% support to .044 L/cm H_2O on CPAP. During PSV weaning, mean C at 100% support was .049 L/cm H_2O, and on CPAP was .045 L/cm H_2O. Resistance values averaged 21.07 cm H_2O/L/sec during IMV weaning, and 22.2 cm H_2O/L/sec during PSV weaning. The estimated values for C are again consistent with prior work in ventilated patients (Marini, Smith, & Lamb, 1988). However, the R estimates are two times higher than those previously reported.

The work/liter ventilation or average inspiratory pressure (Pavg) gradually increased with both weaning methods as ventilator support was withdrawn. However, the Pavg was consistently lower during PSV weaning compared to IMV weaning, except at the end of the protocols, where the numbers were very similar. Mean values during IMV weaning ranged from 13.97 ± 7.71 cm H_2O on 100% support to 19.15 ± 8.41 cm H_2O on CPAP. During PSV weaning the mean Pavg on 100% support was 4.49 ± 3.45 cm H_2O, and on CPAP was 18.8 ± 7.89 cm H_2O. Therefore, the Pavg increased more dramatically during PSV weaning. At the end of weaning, the spontaneous work/liter ventilation was almost identical between the two methods (19.15 versus 18.8 cm H_2O). The estimated values for Pavg at IMV support levels 60% or less are consistent with measured values previously reported (Marini, Smith, & Lamb, 1988). However, the estimates of Pavg at

the highest IMV levels (100% and 80%) were higher than those reported by Marini and colleagues.

Finally, the Pavg/Pmax ratio was computed. Referring again to Tables 16 a and b, the average values for each support level during weaning are presented. Previous work revealed that a Pavg/Pmax ratio of > 0.4 correlated with ventilatory muscle fatigue (Roussos & Macklem, 1977). In the present study, during IMV weaning, subjects breathed close to the fatigue value throughout the weaning trial, whereas with the PSV method, subjects approached the critical value only during the CPAP trial. In contrast to previous work (Kline et al., 1987), the Pavg/Pmax ratio was not different between those who did and those who did not wean within 24 hours.

The pressure time index (PTI), an index of inspiratory effort, was derived from the Pavg/Pmax ratio (formula 1, Table 9, Chapter 3). The PTI defines a fatigue threshold value of .15 where work load can no longer be sustained (Bellemare & Grassino, 1982). This index of effort increased as the amount of ventilator support decreased, with one exception (see Table 17): in decreasing support from 100% to 80% IMV the PTI unexpectedly decreased. In evaluating the individual cases, it appears that two subjects, 11 and 20, altered their breathing patterns (decreasing Vt) as they changed between these two levels. When these subjects were deleted from the analysis the mean PTI for 100% IMV decreased from .13 to .11, and the value for 80% support remained the same, .11. The progression in the PTI excluding these subjects is more as expected: a gradual increase in PTI as the subject does more of the work of breathing.

Comparing mean PTI between the two weaning methods, Table 17 shows that PTI was higher throughout IMV weaning than with PSV weaning.

Table 17 Mean Dyspnea Intensity, Anxiety Intensity, and Inspiratory Effort During Weaning*

Support Level		Dyspnea (mm)	Anxiety (mm)	PTI	Support Level		Dyspnea (mm)	Anxiety (mm)	PTI
IMV					PSV				
100%	N = 9				100%	N = 12			
	Mean	33.00	29.83	0.13		Mean	28.08	45.96	0.03
	SD	35.09	30.85	0.06		SD	22.56	26.51	0.02
80%	N = 14				80%	N = 12			
	Mean	30.93	32.21	0.11		Mean	47.13	46.13	0.05
	SD	30.05	23.49	0.05		SD	30.26	27.55	0.02
60%	N = 18				60%	N = 19			
	Mean	38.97	37.39	0.13		Mean	40.53	45.87	0.05
	SD	30.23	26.28	0.06		SD	32.02	27.93	0.03
40%	N = 18				40%	N = 17			
	Mean	52.00	52.44	0.15		Mean	43.00	46.91	0.08
	SD	33.63	29.35	0.05		SD	33.95	30.84	0.04
20%	N = 14				20%	N = 17			
	Mean	50.25	43.85	0.15		Mean	43.71	50.27	0.11
	SD	33.33	33.69	0.04		SD	31.75	30.28	0.04
CPAP	N = 12				CPAP	N = 15			
	Mean	43.50	48.79	0.18		Mean	45.57	47.63	0.15
	SD	36.18	28.46	0.04		SD	24.92	26.97	0.05

*Subjects 5 and 16 deleted due to inaccurate PTI values
Dyspnea= intensity scored on 100 mm horizontal visual analogue scale, Anxiety= intensity scored on 100 mm horizontal visual analogue scale, PTI = pressure time index, IMV = intermittent mandatory ventilation, PSV = pressure support ventilation, CPAP = continuous positive airway pressure.

At 40% and 20% IMV support, the mean PTI values reached the fatigue threshold of .15. During IMV CPAP, the mean PTI exceeded the fatigue threshold, increasing to .18. In contrast, during PSV weaning the fatigue threshold of .15 was reached only during the CPAP trial.

Subjective responses.

Generally, during IMV weaning mean dyspnea and anxiety intensities (left panel, Table 17) remained stable on the higher levels of support. There were, however, small increases of 13 and 15 mm, respectively, between 60% and 40% support. The mean PTI reached the fatigue threshold value of .15 at this same time. As the support level was further reduced, the mean dyspnea and anxiety intensity scores did not change much, despite further increases in the PTI. It appears therefore that mean dyspnea and anxiety intensities do not vary with inspiratory effort in this sample of ventilator patients.

The dyspnea and anxiety intensity scores were stable during PSV weaning as well (right panel, Table 17). Despite consistent increases in the PTI value ($\bar{X}$ = .03 on 100% support to $\bar{X}$ = .15 on CPAP), mean dyspnea and anxiety intensities did not change much. The maximal difference in mean anxiety intensity scores was a change of 15.6 mm. The only noteworthy change in mean dyspnea intensity was an increase of 21.5 mm, which occurred when pressure support was reduced from 100% to 80%. During the other five support levels, 80% to CPAP, the maximal mean difference was only 6.6 mm. The mean value for PTI did not reach the fatigue threshold value of .15 until the CPAP support level. A question arises: would the dyspnea and anxiety intensity scores on 80% through CPAP have changed if the fatigue threshold value had been reached earlier?

A final consideration regarding Table 17 is that the sample size is

smaller when the group comprises only those who completed all levels of support. The missing data at the lower support levels were obviously due to the inability of subjects to maintain the work of breathing. At the higher levels of support, the work of breathing was often supported totally by the ventilator. Therefore, there was no measurable spontaneous work load, hence the missing data at the highest support levels.

Analysis Of Research Questions

Is there a relationship between pre-weaning mood state and pre-weaning dyspnea and anxiety intensities?

The negative mood state subscales had small to moderate positive correlations with pre-weaning dyspnea intensity, with r values ranging from .13 to .31 (N=19). However, none of these correlations were statistically significant. The vigor subscale had a negative correlation with pre-weaning dyspnea intensity ($r = -.38$, $p < .10$). Table 18 describes the correlations between the POMS subscales and the pre-weaning dyspnea and anxiety intensities.

Pre-weaning anxiety intensity did not correlate with any of the POMS subscales, including the tension subscale. This unexpected finding is in contrast with the findings of Sutherland et al. (1988) who found a correlation of .82 (N = 29) between the tension subscale of the POMS and the anxiety VAS in a group of cancer patients. The negative subscales of the POMS had significant inter-correlations, ranging from .63 to .95. (refer to Table 18).

Table 18 Correlations Between Pre-weaning Mood State and Pre-weaning Dyspnea and Anxiety Intensities*

	Total Mood	Tension	Anger	Fatigue	Depression	Vigor	Confusion	Pre-weaning Dyspnea	Pre-weaning Anxiety
Total Mood	1								
Tension	0.85	1							
Anger	0.90	0.79	1						
Fatigue	0.83	0.70	0.75	1					
Depression	0.90	0.82	0.84	0.66	1				
Vigor	-0.46	-0.23	-0.22	-0.23	-0.19	1			
Confusion	0.88	0.63	0.76	0.66	0.83	-0.35	1		
Pre Dyspnea	0.31	0.22	0.28	0.14	0.22	-0.38	0.27	1	
Pre Anxiety	-0.006	0.16	0.11	0.01	0.02	0.08	-0.20	0.13	1

* N = 19

Is there a relationship between pre-weaning mood state and ability to wean within 24 hours of study?

In Table 19, the total mood disturbance score and the individual subscales are separated for those who did and those who did not wean within 24 hours of study. There were no differences in mood between the two groups of subjects (Mann Whitney U, $p < .05$). Mood state, therefore, did not separate successful from unsuccessful weaning trials.

Is there a relationship between the pre-weaning variables and dyspnea, anxiety, and inspiratory effort, measured at the lowest level of ventilatory support subjects achieved?

Table 20 is the correlation matrix describing the relationships of interest. The correlations between pre-weaning mood and end-weaning variables were weak, and frequently negative. Pre-weaning dyspnea and anxiety intensities had inconsistent correlations with the end-weaning variables. Some correlations were moderately positive, while others were moderately negative. However, none of the correlations between the pre-weaning and end-weaning variables were significant.

The end-weaning dyspnea and anxiety intensities were significantly correlated with each other ($r = .35$ to $.72$). However, only dyspnea and anxiety intensities measured at the end of PSV, not IMV weaning, correlated ($r = .17$ to $.27$) with PTI. Of the variables measured at the end of weaning, only dyspnea intensity correlated with ability to wean ($r = .27$ during PSV weaning and $r = .45$ during IMV weaning).

The reliability of the dyspnea and anxiety intensity visual analogue scales was also demonstrated by this correlation matrix. The correlation between dyspnea intensity, measured at the end of IMV weaning, and

Table 19 Description of Pre-weaning Profile of Mood States

Subjects		Total Mood Score	Mood Subscale Scores~ 1	2	3	4	5	6
Weaned ≤ 24 hours of study	(n = 8)							
	Mean	1.19	1.67	1.28	1.12	0.65	2.10	1.57
	SD	0.64	0.55	0.94	0.88	0.74	0.82	0.97
Weaned > 24 hours of study	(n = 11)							
	Mean	0.88	1.71	1.07	0.95	1.33	1.85	1.05
	SD	0.70	0.72	0.95	0.79	0.82	0.98	0.85
Total Sample	(n = 19*)							
	Mean	1.01	1.69	1.16	1.05	1.04	1.96	1.27
	SD	0.68	0.64	0.93	0.82	0.84	0.90	0.91

~1= Tension/Anxiety, 2= Depression/Dejection, 3= Anger/Hostility, 4= Vigor/Activity, 5= Fatigue/Inertia, 6= Confusion/Bewilderment

* Two subjects were unable to complete the Profile of Mood States

There were no differences in mood state between those who did and did not wean within 24 hours of study (Mann Whitney U, $p < .05$).

Table 20 Correlation Matrix For Pre-weaning and End Weaning Variables N = 17*

	PreWean Mood	PreWean Dyspnea	PreWean Anxiety	Last PS Dyspnea	Last PS Anxiety	Last PS PTI	Last IM Dyspnea	Last IM Anxiety	Last IM PTI	Weaned ≤ 24 hrs.
PreWean Mood	1.00									
PreWean Dyspnea	0.25	1.00								
PreWean Anxiety	-0.04	0.12	1.00							
Last PS Dyspnea	-0.08	0.18	-0.21	1.00						
Last PS Anxiety	-0.14	0.26	0.07	0.66	1.00					
Last PS PTI	0.19	0.21	-0.41	0.20	0.27	1.00				
Last IM Dyspnea	-0.01	0.21	0.18	0.77	0.35	0.02	1.00			
Last IM Anxiety	0.13	0.22	0.26	0.47	0.72	0.16	0.41	1.00		
Last IM PTI	-0.17	-0.31	-0.33	0.26	0.17	0.43	-0.06	-0.14	1.00	
Weaned ≤ 24 hours	-0.32	-0.43	0.23	0.27	0.03	-0.32	0.45	-0.07	0.10	1.00

PreWean mood= preweaning total profile of mood states; PreWean dyspnea= intensity scored on 100 mm horizontal visual analogue scale, measured prior to weaning; PreWean anxiety= intensity scored on 100 mm horizontal visual analogue scale, measured prior to weaning; Last PS Dyspnea and Anxiety = dyspnea and anxiety intensities (measured as previously described) during lowest pressure support level the patient could tolerate or, if the patient was strong enough, during spontaneous breathing at the end of the pressure support trial; Last PS PTI = Pressure time index (an indicator of inspiratory effort) measured at the same time point described above; Last IM Dyspnea, Anxiety, & PTI = measured at the lowest level of ventilator support the patient could tolerate during the IMV weaning trial; Weaned ≤ 24 hours = ability of patient to wean within 24 hours of study. *Subjects 13 & 14 unable to complete POMS, Subjects 5 & 16 deleted due to inaccurate PTI.

dyspnea intensity, measured at the end of PSV weaning, was .77. The correlation between anxiety intensity scores measured at the same two time points was .72. This finding indicates that the VAS's are reliable over time.

What is the relationship between dyspnea intensity, anxiety intensity, and inspiratory effort during weaning with pressure support ventilation and intermittent mandatory ventilation?

The overall correlation between dyspnea intensity and PTI during IMV weaning was r = .15 (N = 90), and during PSV weaning was r = .21 (N = 100). Anxiety intensity and PTI had smaller correlations. During IMV weaning, the correlation between anxiety intensity and PTI was r = .03, and during PSV weaning r = .12. The correlations between the subjective measures were stronger than the correlations between subjective measures and inspiratory effort. Dyspnea intensity correlated with anxiety intensity during IMV weaning (r = .55) and during PSV weaning (r = .61).

In order to better understand the relationships between dyspnea intensity, anxiety intensity and PTI, the correlations between these three variables were evaluated for each support level for the two methods (refer to Tables 21 a and b). The moderate-to-high correlation between the dyspnea and anxiety intensity visual analogue scales persists for all support levels during both weaning methods. Correlation coefficients range from r = .45 to r = .74 for PSV weaning and from r = .37 to .68 for IMV weaning.

The relationship between anxiety intensity and PTI is similar for both weaning methods. At the highest support levels there are unexpected negative correlations between anxiety intensity and fatigue threshold. Some subjects had low anxiety and relatively high PTI values - for example, a subject with neuromuscular weakness who was optimistic about the possibility

Table 21a Correlation Coefficients For Dyspnea Intensity, Anxiety Intensity, and Inspiratory Effort at Each PSV Support Level*

	100% PSV (n = 12)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.45	-0.37
Anxiety	0.45	1.00	-0.07
PTI	-0.37	-0.58	1.00

	80% PSV (n = 12)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.48	-0.13
Anxiety	0.48	1.00	-0.34
PTI	-0.13	-0.34	1.00

	60% PSV (n = 19)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.74	0.27
Anxiety	0.74	1.00	0.13
PTI	0.27	0.13	1.00

	40% PSV (n = 17)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.56	0.43
Anxiety	0.56	1.00	0.53
PTI	0.43	0.53	1.00

	20% PSV (n = 17)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.75	0.43
Anxiety	0.74	1.00	0.21
PTI	0.43	0.21	1.00

	CPAP PSV (n = 15)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.62	0.06
Anxiety	0.62	1.00	0.35
PTI	0.06	0.35	1.00

*Subjects 5 & 16 deleted. Some patients had no spontaneous work on the high support levels. Some patients unable to complete lower levels.

Table 21b Correlation Coefficients For Dyspnea Intensity, Anxiety Intensity, and Inspiratory Effort at Each IMV Support Level*

	100% IMV (n = 9)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.46	0.04
Anxiety	0.46	1.00	-0.36
PTI	0.04	-0.36	1.00

	80% IMV (n = 14)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.64	-0.17
Anxiety	0.64	1.00	-0.38
PTI	-0.17	-0.38	1.00

	60% IMV (n = 18)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.68	0.15
Anxiety	0.68	1.00	-0.12
PTI	0.15	-0.12	1.00

	40% IMV (n = 18)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.52	0.11
Anxiety	0.52	1.00	0.19
PTI	0.11	0.19	1.00

	20% IMV (n = 14)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.37	0.28
Anxiety	0.37	1.00	0.43
PTI	0.28	0.43	1.00

	CPAP IMV (n = 12)		
	Dyspnea	Anxiety	PTI
Dyspnea	1.00	0.49	0.37
Anxiety	0.49	1.00	-0.06
PTI	0.37	-0.06	1.00

*Subjects 5 & 16 deleted. Some patients had no spontaneous work on the high support levels. Some patients unable to complete lower levels.

of weaning success. Other patients had high anxiety intensity scores associated with lower PTI values, an example being a post-operative patient who had never been ventilated before, and who had resolving pulmonary edema. Therefore, on full ventilator support, high anxiety intensity has an inverse relationship with PTI.

The trend in the correlation between anxiety intensity and PTI also proved interesting. As the support level was decreased, the correlations became smaller and then turned positive, ending with moderately positive correlations on the lowest levels of support, except during PSV CPAP. This finding suggests that anxiety intensity and inspiratory effort are related when breathing work load is elevated. The one exception to this trend occurred at the change between IMV 20% and CPAP. Evaluating the individual cases demonstrated that the most anxious subjects, such as the post-operative patient described above, had relatively low PTI values.

The same trend in the correlation between dyspnea intensity and PTI (as described above) was present only during pressure support (Table 21 a), but not IMV weaning (Table 21 b). On high levels of pressure support, subjects were often dyspneic, even though the PTI was low. As the level of pressure support decreased, the correlation between dyspnea intensity and PTI became positive and stronger, suggesting that dyspnea intensity and inspiratory effort have a moderately positive association only when breathing work load is elevated.

The one exception is at the lowest PSV level, where the correlation between dyspnea intensity and PTI unexpectedly falls. When subject 10 was deleted from the analysis, the correlation improved from .06 to .59, which would have been the expected trend. One possible explanation is that the

respiratory muscles were truly fatigued, and could no longer generate the pressure necessary for ventilation. In this instance, the PTI will underestimate inspiratory effort. Subject 10 had demonstrated carbon dioxide retention by blood gas analysis during this CPAP trial. The CO_2 retention suggested that the ventilatory muscles were failing, and so the patient could no longer generate the pressures necessary for ventilation. In this instance, the PTI was underestimated, since the patient could no longer generate his ventilation requirement; yet as he failed, his dyspnea intensity continued to increase.

The trend in correlation between dyspnea intensity and PTI during PSV weaning was not present during IMV weaning (Table 21 b). Dyspnea intensity and PTI had weak positive correlations at the highest levels of support, rather than moderate negative correlations. As the support level decreased, the correlations became stronger, ending with a moderate correlation ($r = .37$).

Are there differences between the IMV and PSV weaning methods, in terms of dyspnea and anxiety intensity, and inspiratory effort?

Repeated measures analysis of variance was used to determine whether the pressure support weaning method was more "comfortable" for patients. Comfort was measured via two variables: anxiety and dyspnea intensity. Table 22 depicts the differences in anxiety intensity between the two weaning methods, for those subjects who had complete data across all levels of support. The ANOVA was based upon 10 subjects, with 6 repeated measures and therefore 60 observations. Anxiety intensity was not different between the two weaning methods, nor across the six levels of support.

Table 22 Two-way Repeated Measures ANOVA for Anxiety Intensity Across Two Methods And Six Support Levels

Source of Variation	df	SS	MS	F	p	%*
Between Subjects	9	25393.79				
Within Subjects	110	52904.05				
2 Methods	1	262.85	262.85	0.537	0.48	0.5
Residual (Methods)	9	4407.73	489.75			
6 Support Levels	5	2074.8	414.96	0.796	0.39	3.9
Residual (Levels)	45	23464.65	521.44			
Interaction Method x Level	5	409.28	81.86	0.17	0.69	0.77
Residual (interaction)	45	22284.72	495.21			

df = Degrees of freedom; SS = Sum of Squares; MS = Mean Square; %* = percent of within subjects variance that is explained

The second component of comfort was dyspnea intensity. In Table 23, the same relationship is revealed. There was no difference in dyspnea intensity between the two weaning methods, nor across the six levels of support.

Approaching the question in a slightly different way, the 60% support level (the highest support level that included the majority of subjects) was compared to the lowest level of support subjects completed (see Table 24).

Table 23 Two-way Repeated Measures ANOVA for Dyspnea Intensity Across Two Methods And Six Support Levels

Source of Variation	df	SS	MS	F	p	%*
Between Subjects	9	43867.11				
Within Subjects	110	40718.11				
2 Methods	1	123.02	123.02	0.199	0.666	0.3
Residual (Methods)	9	5557.5	617.5			
6 Support Levels	5	1136.96	227.39	0.459	0.52	2.80
Residual (Levels)	45	22313.81	495.86			
Interaction Method x Level	5	654.79	130.96	0.54	0.48	0.61
Residual (interaction)	45	10932.06	242.93			

df = Degrees of freedom; SS = Sum of Squares; MS = Mean Square; %* = percent of within subjects variance that is explained

Using a repeated measures ANOVA, and looking at differences between 19 subjects at two levels (38 observations), there were still no differences in anxiety or dyspnea intensities between the two weaning methods.

The same repeated measures ANOVA was used to evaluate the differences in PTI between the two weaning methods, across the six levels. The sample size was smaller in this instance, due to missing values at the highest support levels, when there was no measurable work, as well as the lowest levels of support. Ten subjects were unable to complete the lower support levels (i.e. less than 40%). The reasons for ending the weaning trial before the lowest support levels were reached included: tachycardia > 120 beats/min, tachypnea > 40 breaths/min, fall in SaO_2 < 90%, patient appearance of labored breathing, requests for increased ventilation due to severe dyspnea or anxiety, and/or deterioration of arterial blood gases.

Table 24 Mean Dyspnea and Anxiety Intensities and Associated ANOVA for Comparing 60% and Last Support Levels*

Mean Scores for Anxiety (N=19)

	60%	Last
IMV	37.2	51.2
PSV	45.9	51.3

Mean Scores for Dyspnea (N=19)

	60%	Last
IMV	39.1	50.1
PSV	40.5	46.1

Anxiety ANOVA

Source	df	SS	MS	F	p
Between	18	27861.2			
Within	57	28863.8			
Method	1	367.4	367.4	1.37	0.26
Residual	18	4842.08	269		
Level	1	1810.09	1810.1	2.02	0.17
Residual	18	16127.4	895.9		
M x L	1	353.46	353.46	1.19	0.29
Residual	18	5363.31	297.9		

Dyspnea ANOVA

Source	df	SS	MS	F	p
Between	18	45211.6			
Within	57	25126.3			
Method	1	31.6	31.59	0.116	0.74
Residual	18	4912.3	272.9		
Level	1	1305.6	1305.6	1.75	0.20
Residual	18	13469	748.3		
M x L	1	136.9	136.9	0.47	0.50
Residual	18	5271	292.8		

*Comparison of the highest support level that included the majority of subjects to the last support level they completed

Based upon an N of 6 with 6 levels (i.e. 36 observations), there were significant differences in fatigue threshold between the two weaning methods, as well as between the six levels of support. However, there was no interaction effect between weaning method and support level (Table 25).

Table 25 Two-way Repeated Measures ANOVA for PTI Across Two Methods And Six Support Levels

Source of Variation	df	SS	MS	F	p	%*
Between Subjects	5	0.067				
Within Subjects	66	0.212				
2 Methods	1	0.06	0.06	29.96	0.003	28.3
Residual (Methods)	5	0.01	0.002			
6 Support Levels	5	0.054	0.011	7.48	0.04	25.5
Residual (Levels)	25	0.036	0.001			
Interaction Method x Level	5	0.006	0.001	0.612	0.469	2.6
Residual (interaction)	25	0.046	0.002			

df = Degrees of freedom; SS = Sum of Squares; MS = Mean Square; %* = percent of within subjects variance that is explained

When the 60% level is compared to the last level of support that 19 subjects completed, the same effects are seen. As seen in Table 26, there are significant differences between the two methods of weaning, and between the two support levels. In this instance there is also an interaction effect between weaning method and support level. The IMV PTI increased between the 60% support level and the lowest support level, whereas the PSV PTI remained unchanged.

Table 26 Mean PTI and ANOVA Comparing 60% Level and Last Support Level

Mean PTI Values (N=19)

	60%	Last
IMV	0.11	0.15
PSV	0.15	0.15

PTI ANOVA

Source	df	SS	MS	F	p
Between	18	0.087			
Within	57	0.251			
Method	1	0.022	0.022	12.16	0.003
Residual	18	0.033	0.002		
Level	1	0.117	0.117	57.94	0.00
Residual	18	0.036	0.002		
M x L	1	0.012	0.012	7.08	0.016
Residual	18	0.031	0.002		

df = Degrees of freedom; SS = Sum of Squares; MS = Mean Square; %* = percent of within subjects variance that is explained

Other Findings

The effect of pre-weaning, during weaning, and end-weaning variables on ability to complete weaning within 24 hours of study was evaluated by means of the Mann Whitney U and Chi Square tests. None of the pre-weaning variables was different between those who did and those who did not wean.

During pressure support weaning, the tidal volume was significantly

different at 40% support between those who did and did not wean (Mann Whitney U, $p < .05$). In fact, the tidal volumes throughout the pressure support weaning trial approached significant differences between a positive and negative weaning outcome.

The end-weaning variables that separated the successful and unsuccessful weaning trials were: breathing frequency during IMV CPAP, and dyspnea intensity at the lowest level of IMV support (Mann Whitney U, $p < .05$). By Chi Square analysis, the ability to complete the IMV CPAP trial was also associated with ability to wean within 24 hours of study ($p < .05$). Therefore, the variables associated with weaning outcome were PSV Vt; frequency and dyspnea at low IMV levels; and the ability to complete the IMV weaning trial.

Since the age range of the sample was large (18-90 years of age), the subjects were divided into a young ($\leq$ 60 years) and older category (> 60), to see if there were differences based on age. In general, mood state was not different between the 2 subgroups; however, the older group had significantly higher depression subscale scores, by Mann Whitney U ($p < .05$). There were no consistent age differences in the pulmonary physiological variables.

The effect of prior ventilator experience was also evaluated. None of the mood state, end weaning, nor weaning ability variables were different between those ventilated before versus those ventilated for the first time.

CHAPTER 5

DISCUSSION

Major Findings in Relation to Hypotheses

The research hypotheses proposed in Chapter 1 will be examined in light of the research findings. Each block in Figure 1, which graphically depicts the relationships among the variables, will be discussed. This discussion examines the pre-weaning and weaning process variables, the relationship of these variables to weaning completion, and the effect of weaning method on the weaning process.

Pre-weaning

Psychological distress.

It was hypothesized that pre-weaning psychological distress, as measured by the profile of mood states (POMS), would be associated with the weaning process variables (dyspnea and anxiety intensities and inspiratory effort). It was also postulated that pre-weaning psychological distress would be associated with weaning outcome (ability to complete weaning within 24 hours of study). Neither of these hypotheses was substantiated. Although subjects reported feeling distressed, with significant levels of subjective fatigue/inertia and tension/anxiety, this increased pre-weaning distress was not associated with increased dyspnea or anxiety intensity, nor with elevated inspiratory effort during weaning. Additionally, subjects who felt distressed did not take longer to complete the weaning process. If these findings are substantiated in further studies, it would appear that the presence of generalized psychological distress prior to weaning does not deter the weaning process, nor contribute to weaning outcome.

The possibility that the POMS is not a useful measure of mood in the

ventilator population must be considered. Even though a shortened form of the POMS, with established validity, reliability, and utility in ill populations was used, it had not previously been tested in the ventilator population. The 37 items were difficult for subjects to complete, requiring a significant degree of concentration. Several rest periods were often necessary before the instrument could be completed. Therefore, the utility of the POMS in the ventilator population requires further investigation. However, the information provided by the instrument, in relation to the difficulty with administration, may not warrant further work.

Dyspnea and anxiety intensities.

It was hypothesized that pre-weaning dyspnea and anxiety intensities would be associated with the weaning process variables (dyspnea intensity, anxiety intensity and inspiratory effort) and with weaning outcome (ability to complete weaning within 24 hours of data collection). Even though subjects reported feeling anxious and dyspneic prior to weaning, these variables did not correlate with the weaning process nor weaning outcome variables.

A possible explanation for the lack of correlation between these pre-weaning variables and the weaning process variables is that the dyspnea and anxiety intensity measures are situation dependent. If this explanation were true, the subjective measurements would not generalize beyond the immediate circumstances. Therefore, the measurements obtained under one set of conditions (pre-weaning) could not be used to make inferences about other conditions (weaning process). Additionally, the weak correlations between the pre-weaning dyspnea and anxiety intensities, and weaning outcome, as with the POMS, suggests that predicting weaning outcome from the pre-weaning measures could be misleading.

Methodology problems with using visual analogue scales (VAS) in ventilator patients may provide an alternative explanation for the lack of correlation between the pre-weaning dyspnea and anxiety intensities and the weaning process and outcome variables. Early in the data collection process, two subjects appeared to reverse the ends of the VAS, forgetting which end of the scale represented more of the sensation. This reversing occurred more frequently when subjects worked harder to breathe. After this potential problem was identified, attempts were made to re-orient subjects to the proper use of the scale with each presentation.

Additional methodological problems occurred when subjects worked hard to breathe. Some subjects simply refused to mark the scale, not wanting to be bothered by the exertion. Other subjects, at high work loads, used their arms to stabilize their chest wall, and could no longer mark the scales themselves. Attempts were made to use a consistent method of marking throughout the study. However, in these patients the researcher traced the line, and subjects nodded their heads at the point where the researcher was to place the mark. The effect of different marking methods on VAS data has not been studied.

There were also several methodological issues related specifically to the anxiety visual analogue scale. The weak correlations between anxiety intensity and the weaning process and outcome variables may have been due to a lack of construct validity of the anxiety VAS. That is, the VAS may not accurately measure a phenomenon as complex as anxiety.

Construct validity of the anxiety VAS has been established in ill subjects; however, this instrument had not been tested previously in the ventilator population. The small correlations between the anxiety VAS and the

tension/anxiety subscale of the POMS, as found in this study, suggests that these instruments do not measure the same construct.

The tension/anxiety subscale and the anxiety VAS may measure different dimensions of psychological distress. The tension/anxiety subscale of the POMS asks subjects to rate, with a five point Likert scale, six adjectives thought to describe the global feeling of tension/anxiety. Some of the adjectives are: restless, uneasy, on edge, and nervous. In contrast, the anxiety VAS lets subjects define anxiety in their own terms. "How do you feel right now?" The scale ranges from "not at all anxious" to "extremely anxious". Therefore, with the anxiety VAS there is no standardization of the anxiety definition. This difference in approach may have measured two different dimensions: global feelings of anxiety compared to more subjective or personal feelings.

A final instrument issue that may have contributed to the lack of correlation between the anxiety VAS and the tension/anxiety subscale of the POMS relates to the questions that the two scales ask. The POMS asks subjects to describe how they "feel today," in contrast to the VAS, which asks subjects to describe how they "feel right now". The temporal differences in the questions may result in measuring more stable or persistent anxiety with the POMS, as opposed to measuring situation specific anxiety (at single point in time) with the VAS. In the complex intensive care environment, the point-in-time measure could be easily influenced by many factors that would not affect the more stable measure.

Weaning Process

Work load during weaning.

It was hypothesized that work of breathing would be less with the PSV

method, as compared to the IMV method. As expected, subjects breathed against lower work loads during PSV weaning as compared to IMV weaning. This finding suggests the importance of using adequate IMV rates to rest patients who are not actively weaning.

Adding low levels of pressure support to spontaneous breaths may reduce the excess work load related to the endotracheal tube (ET) tube during IMV weaning. In the current study, when a mean of 5 cm H_2O pressure support was added, tidal volume was not augmented. Therefore, this small level of added pressure did not support ventilation, but provided extra pressure needed to overcome the work of breathing due to the ET tube (Fiastro, Habib, & Quan, 1988). The ability of PSV to overcome the work associated with the ET tube may be one explanation why more subjects completed the PSV protocol as compared to the IMV protocol.

The importance of the work load associated with the ET was demonstrated by the high pulmonary resistances (R) subjects experienced in this study. The elevated R could not be explained on the basis of the experimental apparatus, and was probably due to the ET. Wright and colleagues (1989) demonstrated that in vivo ET tubes produce substantial additional resistance, higher than the added R of the ET tube alone. Therefore, low levels of PSV in conjunction with IMV may be particularly important for reducing the additional work load associated with the ET, preventing muscle fatigue prior to the weaning trial. However, care must be taken to not reduce the work load too much with PSV and then expect patients to tolerate the sudden addition of work during weaning. This sudden transition could be uncomfortable and frightening for patients, especially if muscle atrophy has occurred.

The higher work loads during IMV weaning could also result from the methodology used to estimate work from the equation of motion. To calculate Pavg or work/liter ventilation, passive measurements of resistance (R) and compliance (C) were used to estimate R and C during spontaneous breathing. Obtaining the passive measurements was often difficult, necessitating use of higher tidal volumes and flow rates to suppress the ventilatory drive. If the spontaneous Vt and flow rates were lower than the measured range (as occurs at higher IMV rates), the estimates of spontaneous R and C may not have been accurate. With inaccurate predictions of R and C, the work estimates would obviously not be accurate either. At lower IMV rates, where the Vt and flow were within the measured range, the estimates should have been accurate.

The fact that subjects were briefly hyperventilated prior to the start of weaning may have also contributed to the elevated pulmonary resistances seen in this study. The period of hyperventilation suppressed the ventilatory drive so that passive measurements of resistance and compliance could be obtained. The resulting decrease in carbon dioxide may have precipitated broncho-constriction and therefore contributed to the elevated resistances.

Not only were there differences in the magnitude of work between the two weaning methods, but there were also differences in how the two methods transferred the work load to the subjects. With IMV, work load remained high and fairly constant throughout the weaning trial. In contrast, there were large increases in work of breathing as the level of PSV decreased. The larger increments in work during PSV weaning may have resulted in "dumping" of the work load on to the patient at the end of weaning.

An alternative explanation for the large increases in work load during

PSV weaning may be related to the research design used in this study. The initial pressure support level (100%) was set so that subjects achieved a tidal volume (Vt) equal to 10 cc/kg. The same 10 cc/kg Vt was used throughout the IMV protocol. This starting volume for PSV was larger than is generally used in clinical situations. Normally the initial pressure support level is set to achieve a Vt of 450-500 cc. The initial pressure support levels in this study produced volumes in the range of 750 cc. These higher starting pressures at 100% PSV resulted in lower work loads than would normally be seen. Therefore, in clinical practice, if the starting pressure support level is set in the usual clinical range, these relatively large increases in breathing work load between 100% support and CPAP may not occur.

Likewise, the work loads measured during the IMV protocol may have been affected by the study design. A 10 cc/kg Vt used during the IMV protocol may have under-ventilated some subjects. Additionally, Vt and breathing frequency were estimated from the resting $\dot{V}e$. The IMV mode was then used to deliver the calculated settings, however, the settings did not completely support all patients. Therefore, in the present study 100% IMV support did not actually deliver 100% of the $\dot{V}e$ requirement for some subjects. Unexpectedly, measurable work loads at the highest support levels resulted.

Even though higher levels of PSV (which do not approximate clinical reality) were used in the current study, the work estimates do appear accurate. The estimated work measurements in this study (at comparable pressure support levels) were similar to the values reported by Brochard et al.(1989).

In contrast, the work loads measured during 100% IMV were higher than previously reported by Marini and co-workers, who studied ventilator-dependent patients in a more acute phase of their illness (Marini, Smith, &

Lamb, 1988). These researchers used a different method for delivering 100% IMV, (assist-control ventilation) which did not allow unassisted breaths to occur, perhaps explaining the differences. However, the measured work loads on 60% through CPAP were comparable between the two studies.

A final consideration when comparing the way in which the two ventilator modes transfer the work load to patients: the decrements in ventilator support with PSV may not be equivalent to the decrements with IMV. The goal of this study was to reduce ventilator support by 20% with each ventilator change. With IMV, as the breathing frequency was reduced there was an actual 20% reduction in the work supported by the ventilator. With PSV, since every breath is supported, it is harder to separate the ventilator work from the patient work. This separation of the work load was necessary in order to ensure that a 20% reduction in ventilator support actually occurred.

The machine component of the work load during PSV weaning can be estimated by multiplying the level of applied pressure support times the minute ventilation ($\dot{V}e$). For example, if the applied pressure is reduced by 20% (i.e. changing from 20 cm H_2O to 16 cm H_2O), yet the minute ventilation ($\dot{V}e$) increased in equal proportion (by changing the breathing pattern), the decrease in applied pressure would result in no net change in the work/min provided by the machine.

In the present study, the mean $\dot{V}e$ remained fairly constant throughout the PSV protocol, indicating that the 20% reductions in applied pressure may have actually resulted in a 20% reduction in the work provided by the machine. The difference between the expected and actual machine work substantiated this finding. The 20% reduction in applied pressure usually resulted in a 20% reduction in machine work (within 3 joules/min). However,

there were some instances when decreasing the applied pressure support did not reduce the machine work. The most startling difference was in the change from 100% to 80% PSV. Even though the applied pressure was reduced 20%, the ventilator supplied work load did not decrease. In fact, the ventilator supplied a mean of 5 joules/min more than would be expected based upon the 20% reduction in applied pressure. The reverse situation also occurred. There were a few instances when the 20% reduction in applied pressure resulted in more than a 20% decrease in machine-supported work. Therefore, when comparing the IMV and PSV levels it is important to consider that the reductions in applied pressure during PSV weaning may not be linear, and therefore may not be comparable to equivalent reductions in machine support during IMV weaning.

Dyspnea and anxiety intensities during weaning.

Even with the ventilator supporting a large proportion of the breathing work load, subjects reported a substantial degree of dyspnea intensity and anxiety intensity (at least 30 mm) during weaning with both methods. One possible explanation may be the relationship between dyspnea intensity and anxiety intensity. The hypothesis that dyspnea and anxiety intensities would have a positive correlation with each other was supported at all levels of support, with both weaning methods. A question arises as to whether this relationship is conceptually true, or whether it is a function of using two visual analogue scales.

The visual analogue scales were used because of the ease of marking. The goal was to prevent adding a burden to the patient during a stressful weaning trial. Attempts were made to ensure that patients dissociated the two instruments. The visual analogue scales were printed on individual cards, so

that the subjects had to think about the questions separately. Additionally, with the scales on separate cards subjects could not just mark through both scales at the same point, and they could not see their previous ratings. The cards were presented randomly to prevent order effects. Despite attempts to separate the two subjective measurements, it is not possible to know from the data in this study the effect of using visual analogue scales to measure both dyspnea and anxiety intensities.

The high levels of reported dyspnea and anxiety intensities were also fairly stable throughout the weaning trials. The lack of variance in the subjective measures may have several possible explanations. If the visual analogue scales were not sensitive to changes in sensation intensity as work load increased, then the VAS scores would remain stable during weaning. However, this is unlikely since one of the strengths of the VAS is its sensitivity (Gift, 1989). Another possible explanation for the stability may be that the subjects adapted to the gradual changes in ventilator support and therefore felt no real change in dyspnea or anxiety intensity. A third potential explanation may have been the continual presence of the researcher at the bedside during the weaning trials. Knowing they were closely monitored may have had a calming effect, resulting in little change in dyspnea or anxiety intensity as ventilator support was withdrawn.

Dyspnea intensity and inspiratory effort during weaning.

The hypothesis that high levels of dyspnea intensity would be associated with greater inspiratory effort was demonstrated during PSV weaning. However, the hypothesis was true only at high work loads in subjects who did not have demonstrated ventilatory muscle fatigue (which produces artificially low PTI values). In contrast, during IMV weaning the hypothesis that

increased dyspnea intensity would be associated with elevated inspiratory effort tended to be supported. However, the correlations did not reach statistical significance. The lack of variance in work load during IMV weaning produced a flat relationship between the two variables, and therefore, the weaker correlations.

The correlations between dyspnea intensity and PTI were also affected by breathing pattern changes (decreased Vt, or increased Te). For example, if the subject decreased tidal volume by changing the timing of the breathing cycle, it is conceivable that the ventilatory muscles would generate less pressure in order to fulfill the $\dot{V}e$ requirement. Hence, the PTI would change little despite decreases in ventilator support. Therefore, changes in dyspnea would correspond to small changes in PTI, producing the weaker correlations.

Anxiety intensity and inspiratory effort during weaning.

The hypothesized positive relationship between greater anxiety intensity and elevated PTI was not supported. The correlations between anxiety intensity and PTI were inconsistent- sometimes anxiety was related to work load and at other times it was not. This finding contradicts the theory proposed by Grossbach-Landis (1980) as presented in adapted form in Chapter 2 (figure 2). The theory hypothesized that increased anxiety would lead to tightening of the chest wall muscles, which would then increase the work of breathing. If the patient was not able to meet the resulting energy requirements, dyspnea and anxiety would increase, leading to further increases in psychological distress. A circular pattern would result. Occasionally, with elevated work loads, the theory was supported. Frequently it was not. In fact, even in subjects who could not meet the increased energy requirements of weaning (those not able to wean within 24 hours of study),

higher anxiety was not necessarily associated with increased inspiratory effort. Therefore, in this sample of ventilator patients, anxiety intensity was not always associated with increased work of breathing.

Dyspnea and anxiety intensities and weaning method.

A final hypothesis proposed that lower work loads during PSV weaning would translate into increased comfort. Although comfort is often cited as a goal of mechanical ventilation, there is no clear definition of this concept. However, it is reasonable to assume that lower levels of dyspnea intensity, and anxiety intensity, could translate into increased comfort. Therefore, comfort in the current study was defined by the dyspnea and anxiety intensities. Even though the work levels were lower during PSV weaning, this work sparing effect did not translate into lower dyspnea or anxiety intensity scores. Therefore, the hypothesis was not supported. Neither weaning method was more "comfortable".

Weaning Completion

The outcome of the weaning trial was not controlled in this study. Subjects were followed for 24 hours following data collection, to see if the endotracheal tube was successfully removed. House staff and attending physicians made all extubation decisions. The reasons for postponing extubation and continuing ventilation included: hypoxemia, possibly due to increased lung water (2 subjects); poor respiratory muscle strength and lack of endurance (6 subjects); and increased $\dot{V}e$ requirement, possibly due to fever or anxiety (3 subjects). Therefore, ten subjects successfully completed weaning within 24 hours of data collection, whereas eleven subjects did not.

The hypothesized relationship that pre-weaning variables would be associated with ability to complete weaning was not supported. This finding

suggests that how patients feel prior to weaning should not be used to guide the weaning process. Of the weaning process variables, only dyspnea intensity was associated with ability to wean. Neither anxiety intensity nor inspiratory effort correlated with weaning outcome. The association between dyspnea intensity and weaning outcome was stronger during IMV weaning, as compared to PSV weaning. The ability to complete the IMV protocol was also associated with the outcome of weaning. The higher work loads throughout the IMV weaning trial may have contributed to these significant relationships. Since the work loads were higher during IMV, only subjects most capable of spontaneous breathing (those with lower dyspnea scores, despite high work loads) were able to complete the protocol. Hence, the IMV protocol may have been a more stringent test of the subjects' abilities, and therefore a better predictor of outcome.

The breathing pattern was also different between those who did and those who did not complete weaning within 24 hours of data collection. During PSV weaning, the Vt separated the patients who completed weaning from those who did not. This difference in Vt during PSV weaning suggests that volume was limited by the impedance characteristics of the group who did not wean. In contrast, it was the breathing frequency during IMV weaning that was different for those who could versus those who could not wean within 24 hours of data collection. These relationships between breathing patterns and weaning outcome support the work of Tobin and colleagues (1986), who found a rapid shallow breathing pattern in patients who failed to wean successfully. These easily assessed parameters may be useful indicators of when to abort a weaning trial.

It was hypothesized that the Pavg/Pmax ratio, which correlates with

ventilatory muscle fatigue (Roussos & Macklem, 1977), would also be associated with weaning outcome. Previous work by Kline and colleagues (1987) found that a Pavg/Pmax ratio of .4 separated successful and unsuccessful weaning outcomes. A ratio of ≤ .4 predicted a successful outcome, whereas a value of > .4 predicted failure. In the present study, the Pavg/Pmax ratio was not different between those who weaned within 24 hours and those who did not.

A possible explanation for the differences between the two studies is the sample composition. Kline et al. (1987) included only patients who met previously established criteria to predict weaning ability (such as the Pmax and breathing pattern). In the current study, patients did not necessarily meet the conventional criteria. In fact, several patients had Pmax values lower than the traditional criteria and a few had minute ventilations above the criterion (Sahn & Lakshminarayan, 1973). Even though subjects did not meet all of the conventional criteria, they were supposed to be capable of ten minutes of CPAP (although some subjects could not for the reasons stated on p. 97). By including patients with a broader range of capabilities, the author hoped that the protocols would provide a clearer picture of the interactions that affect the outcome of weaning.

There is another possible explanation for the differences between the present study and the work of Kline et al. (1987). Despite including patients who were not necessarily weanable, the Pavg/Pmax values in the current study were not within the fatigue range, except at the lowest IMV levels. Additionally, the subjects breathed for only ten minutes at each support level. Therefore the 45 minute time limit used to predict fatigue, and therefore weaning outcome, may not have been achieved. Therefore, the current study

was not an adequate test of the Pavg/Pmax ratio as a predictor of weaning outcome.

A final potential explanation for the lack of agreement between the findings of this study and those of Kline et al. (1987) is the differences in how the Pavg was calculated. Even though Kline and colleagues (1987) used the equation of motion, the flow, resistance and compliance were calculated differently.

Limitations

Several limitations of the study, not addressed above, need to be mentioned. Because the sample included patients with a broad range of weaning capabilities, there were missing data at many of the support levels. Statistical tests were adjusted accordingly. However, when interpreting the findings this fact must be considered.

The impact of routine nursing care that occurred during the weaning trial could not be controlled. Attempts were made to keep interactions at a minimum; however, the effects of these essential interactions cannot be evaluated. The variability of procedures and interactions that occurred during the rest period between protocols also could not be controlled. Attempts were made to ensure that subjects had adequate rest prior to the start of the second weaning trial. The two protocols were separated by at least one hour. The second protocol was not started until the subjects indicated they felt ready. Sometimes the rest period lasted as long as three hours. Participation in two weaning protocols in one day did not seem to adversely affect the patients. This clinical impression was validated by the correlation between dyspnea intensity measured at the end of the IMV protocol, compared to dyspnea intensity measured at the end of the PSV protocol. Anxiety intensities

measured at the same two time points were also highly correlated. Therefore, subjects were no more dyspneic or anxious at the end of one protocol compared to the other, no matter which protocol came first.

The effect of the physiological instrumentation on the subjective measurements could not be controlled. Subjects had been hospitalized in an intensive care unit for at least three days. The author hoped that they were somewhat desensitized to the technology, so that the research equipment would not impact significantly on the subjective indices.

The use of the PTI, defined by airway measurements, to estimate inspiratory effort is also a limitation. Ideally, the inspiratory effort would be measured directly with esophageal balloons. However, placement of balloons in these weaning patients was avoided so as to not interfere with the weaning process. Therefore, the values must be interpreted as estimates of the actual inspiratory effort.

Finally, the protocols, by design, were relatively short. Subjects breathed for approximately ten minutes at each support level, with each weaning trial lasting approximately two hours. How the results of the current study would compare to a longer protocol cannot be determined.

Clinical Implications

In contrast to most research comparing weaning methods, it was not the primary goal of this study to see if subjects weaned faster with one method compared to the other. The goal was to evaluate the process with both methods. By understanding the physiological and psychological interactions during weaning, it may be possible to better understand the etiologies that precipitate the need for prolonged ventilation. The ability to wean successfully and be extubated within 24 hours of data collection was not a controlled

outcome variable, but a means of defining a clinically useful end point.

Impact of Feelings

With both IMV and PSV, weaning was not affected by subjects' psychological distress nor anxiety. However, the researcher was continually at the bedside during the weaning process. The reality of critical care nursing is that the most stable patients, i.e. the weaning patients, are frequently assigned two patients to one nurse. Therefore, the nurse has less time to spend with the patient during weaning. In a situation that more closely approximated clinical reality, would these subjective feelings have more of an effect?

The work of Henneman (1989) found that the presence of the nurse, who used touch and verbal interaction during weaning, produced no change in physiological responses. However, duration of ventilation was not reported, and subjective feelings were not assessed. It would be interesting to evaluate the effect of the nurse's presence, during weaning, on the feelings of long-term ventilator patients.

If future research supports the findings that psychological distress and anxiety are not associated with the weaning process, it suggests that patient emotional state is not a major deterrent to weaning. It would be important to know if there are subgroups of patients whose feelings are significant to outcome. In this instance, staffing in busy intensive care units could be adjusted to accommodate the needs of these particular patients. Alternatively, a nurse could be assigned the task of managing the weaning trials of patients on a particular unit. This nurse could provide consistency and a systematic approach to the weaning process.

Impact of Work Load and Inspiratory Effort

Work load and inspiratory effort were estimated from the equation of motion. The purpose of using estimates of work was to avoid placing esophageal balloons in patients preparing for a weaning trial. Work load was found to be less on PSV than IMV. However, this work-sparing was not necessarily helpful for patients. Dyspnea and anxiety intensities were not different, despite the differences in work load. Ability to wean within 24 hours of data collection was also not different between the two methods.

The methodology problems previously described, and the complexity of calculation, suggest that estimating work and effort from the equation of motion needs further refining before it can be used clinically. Computer programs designed to complete the calculations would be essential. If the Pavg could be easily calculated, it would be useful for monitoring work load during weaning in order to define an optimal balance between work and rest.

From a clinical perspective, the information provided by bedside assessments (such as breathing pattern, resistance and compliance) may provide sufficient data to estimate the impedance to breathing, and therefore, the work load. If this is true, then complex calculations would not be necessary.

Approach to Weaning

Despite the lower work loads on PSV, it appears that there is little difference in comfort between the two methods. Therefore, it may be that the weaning method is less important than a systematic approach. What is meant by a systematic approach? With the two weaning methods used in this study, the approach would involve gradual withdrawal of support, while monitoring for indicators of poor outcome, such as breathing pattern changes, dyspnea

intensity, and facial signs of respiratory distress. Since work of breathing was higher on IMV, it would be important to ensure that patients were not continuously subjected to fatiguing work loads. Adding low levels of pressure support to overcome the resistance of the endotracheal tube may be helpful. However, caution must be used to not completely unload the muscles with PSV and then suddenly return the work load to the patient at the end of weaning. Muscle atrophy could occur and the sudden transition could be uncomfortable and frightening for patients. Again, monitoring the Pavg could prove useful in this situation by helping to determine the optimal work load for weaning.

During weaning with a systematic approach, clinical assessment of parameters that predict weaning outcome would be essential. Potential clinical assessment parameters could include breathing pattern changes, dyspnea intensity, and facial signs of respiratory distress. The findings of the current study are in agreement with previous work that suggests the importance of monitoring breathing pattern changes. An increased f during IMV weaning, and low tidal volumes during PSV weaning, may be useful.

The dyspnea intensity was also associated with weaning outcome, and could be used to assess progress during the weaning trial. However, the difficulty with marking the visual analogue scale when distressed, along with other methodology problems, may limit its utility. Further research, to develop instruments that validly measure the sensation of dyspnea during weaning, could provide useful assessment information during the weaning trial.

A final assessment parameter that was not investigated in the present study, but may be useful, is facial expression changes associated with increased work of breathing. If there are patterns in the progression of facial

expression as work load increases, it may be possible to estimate when the work load has surpassed the patient's capabilities.

Utilization of a systematic approach to the weaning process, that assesses parameters for terminating weaning, may be useful. By utilizing this systematic approach to assessment and intervention, it may be possible to prevent the labeling of patients as "failures". The effect of labeling patients as failures has not been studied, but could potentially have detrimental effects on future weaning trials, not only for the patients but for the ICU staff as well.

Research Implications

The current study investigated interactions between physiological and psychological variables that affect weaning. Despite resting on full ventilator support prior to the start of weaning, subjects reported pre-weaning dyspnea and anxiety intensities as well as subjective feelings of fatigue/inertia and tension/anxiety. The feelings reported prior to weaning, did not impact on dyspnea intensity, anxiety intensity, nor inspiratory effort measured during weaning. The pre-weaning variables failed to identify those able to wean and those who could not.

It would be interesting in future research to evaluate the effect of the nurse's presence, during weaning, on the feelings of long-term ventilator patients. The nurse at the bedside may attenuate the dyspnea and anxiety of weaning patients. Without a nurse present who is constantly monitoring the patient, pre-weaning variables (psychological distress, anxiety and dyspnea) may have more of an effect on the weaning process.

The instruments used to measure psychological distress and anxiety may not have adequately measured these variables, thereby contributing to the lack of correlation in the present study. The difficulties with finding valid

instruments that do not overtax the ventilator patient, especially during weaning, remain a major challenge of critical care nursing research.

During the weaning trials dyspnea intensity and anxiety intensity were always correlated. Dyspnea intensity also correlated with inspiratory effort, but only at high work loads. In contrast, anxiety intensity correlated with inspiratory effort during IMV weaning, but not during PSV weaning. Dyspnea intensity was the only weaning process variable related to successful weaning completion.

The visual analogue scales to measure dyspnea and anxiety intensities may not accurately represent these subjective measurements. As stated above, future research to develop instruments to adequately measure subjective feelings in the critical care population is essential.

The use of the equation of motion to estimate the inspiratory effort was complex and time consuming. Research to define clinically useful indicators of work load would be one alternative. For example: Is there a pattern of facial expression change as breathing work load approaches an intolerable level? Do bedside measures of impedance and breathing pattern provide sufficient information to guide the weaning process?

Alternatively, research to further refine use of the equation of motion to estimate inspiratory effort would be helpful. Questions related to the calculation of Pavg would investigate ways to obtain the passive measurements so that the entire tidal volume range was included. Does the necessary hyperventilation prior to weaning substantially alter the measurements of resistance and compliance, and therefore, the estimates of inspiratory effort? What effect does the shape of the inspiratory flow wave form have on the estimates of Pavg?

The method of weaning resulted in lower inspiratory effort during PSV weaning as compared to IMV weaning. However, the difference in effort did not translate into less dyspnea or anxiety. There were no differences in dyspnea or anxiety intensities between the two methods.

The differences between the PSV and IMV weaning methods may have been related to the research design. Future studies to compare the two methods may use low levels of pressure support in conjunction with the IMV protocol to overcome the resistance of the endotracheal tube, thereby making the two methods more comparable. The effect of a longer protocol on the relationships among the variables would be interesting. Despite attempts to make the two protocols comparable, the highest support levels were not. Future studies would use assist-control ventilation to ensure that 100% IMV actually removed the spontaneous work load from the patient. In addition, the volume-cycled breaths delivered during IMV should perhaps be reduced to 7 cc/kg. During PSV weaning, then, 100% support would be adjusted to a more clinically appropriate range, achieving tidal volumes of 450-500 cc. With the reduced tidal volumes, breathing frequencies would most likely be higher than those observed in this study.

In conclusion, considering the limitations of the study, the findings suggest that pre-weaning data do not accurately predict the responses to the weaning process, nor the weaning outcome. Dyspnea during weaning may relate more closely to anxiety than to inspiratory effort, except at high work loads. Even though inspiratory effort was less during PSV weaning, the subjects did not report less dyspnea and anxiety intensities. Therefore, the method of weaning may be less important than a systematic approach to withdrawing ventilator support.

REFERENCES

Acosta, F. (1988). Biofeedback and progressive relaxation in weaning the anxious patient from the ventilator: a brief report. Heart & Lung, 17, 299-301.

Acosta, F. (1987). Weaning the anxious ventilator patient using hypnotic relaxation: case reports. American Journal of Clinical Hypnosis, 29, 272-280.

Agusti, A., Rodriguez-Roisin, R., Roca, J., Aguilar, J., & Agusti-Vidal, A. (1986). Oxyhemoglobin affinity in patients with chronic obstructive pulmonary disease and acute respiratory failure: role of mechanical ventilation. Critical Care Medicine, 14, 610-613.

Aitken, R. C. (1969). Measurement of feelings using visual analogue scales. Proceedings of the Royal Society of Medicine, 62, 989-993.

Aldrich, T., Karpel, J., Uhrlass, R., Sparapani, M., Eramo, D., Ferranti, R. (1989). Weaning from mechanical ventilation: adjunctive use of inspiratory muscle resistive training. Critical Care Medicine, 17, 143-147.

American Thoracic Society. (1986). Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease and asthma. 239-243.

Ashutosh, K. (1983). Gradual versus abrupt weaning from respiratory support in acute respiratory failure and advanced chronic obstructive lung disease. Southern Medical Journal, 76, 1244-1248.

Bassili, H., & Deitel, M. (1981). Effect of nutritional support on weaning patients off mechanical ventilators. Journal of Parenteral and Enteral Nutrition, 5, 161-163.

Belitz, J. (1983, May/June). Minimizing the psychological complications of patients who require mechanical ventilation. Critical Care Nurse, 42-46.

Bellemare, F. & Grassino, A. (1982). Effect of pressure and timing of contraction on human diaphragm fatigue. Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology, 53, 1190-1195.

Belman, M. (1981). Respiratory failure treated by ventilatory muscle training. European Journal of Respiratory Disease, 62, 391-395.

Bone, R. (1981). Acute respiratory failure and chronic obstructive lung disease: recent advances. Medical Clinics of North America, 65, 563-578.

Brochard, L., Harf, A., Lorino, H., Lemaire, F. (1989). Inspiratory pressure support prevents diaphragmatic fatigue during weaning from mechanical ventilation. American Review of Respiratory Disease, 139, 513-521.

Brooks, C. (1983, November/December). The adult way to wean from mechanical ventilation. Critical Care Nurse, 64-65; 78.

Browne, D. (1984). Weaning patients from mechanical ventilation. Intensive Care Medicine, 10, 55-58.

Campion, E. W., Mulley, A. G., Goldstein, R. L., Barnett, G. O., & Thibault, G. E. (1981). Medical intensive care for the elderly. A study of current use, costs, and outcomes. Journal of the American Medical Association, 264, 2052-2056.

Cohen, C., Zagelbaum, G., Gross, D., Roussos, Ch., & Macklem, P. (1982). Clinical manifestations of inspiratory muscle fatigue. The American Journal of Medicine, 73, 308-316.

Cullen, D. J., Keen, R., Waternaux, C., Kunsman, J., Caldera, D., & Peterson, H. (1984). Results, charges, and benefits of intensive care for critically ill patients: Update 1983. Critical Care Medicine, 12, (2) 102-106.

Davis, H., II, Lefrak, S., Miller, D., & Malt, S. (1980). Prolonged mechanically-assisted ventilating. An analysis of outcome and charges. The Journal of the American Medical Association, 243, 43-45.

Douglass, P. S., Rosen, R. L., Butler, P. W., & Bone, R. C. (1987). DRG payment for long-term ventilator patients: implications and recommendations. Chest, 91, 413-417.

Dudley, D., Glaser, E., Jorgenson, B., & Logan, D. (1980). Psychosocial concomitants to rehabilitation in chronic obstructive pulmonary disease. Part I psychosocial and psychological considerations. Chest, 77, 413-420.

Fedullo, A. J. & Swinburne, A. J. (1983). Relationship of patient age to cost and survival in a medical ICU. Critical Care Medicine, 11, 155-159.

Fiastro, J.F., Habib, M., Quan, S. (1988). Pressure support compensation for inspiratory work due to endotracheal tubes and demand continuous positive airway pressure. Chest, 93, 499-505.

Fiastro, J.F., Habib, M., Shon, B., & Campbell, S. (1988). Comparison of standard weaning parameters and the mechanical work of breathing in mechanically ventilated patients. Chest, 94, 232-238.

Gift, A. G. (1989). Visual analogue scales: measurement of subjective phenomena. Nursing Research, 38, 286-288.

Gift, A. G., Plaut, S. M., & Jacox, A. (1986). Psychologic and physiologic factors related to dyspnea in subjects with chronic obstructive pulmonary disease. Heart & Lung, 15, 595-601.

Gilbert, R., Auchincloss, J., Peppi, D., & Ashutosh, K. (1974). The first few hours off a respirator. Chest, 65, 152-157.

Gillespie, D. J., Marsh, H. M., Divertie, M. B., & Meadows, J. A. (1986). Clinical outcome of respiratory failure in patients requiring prolonged (> 24 hours) mechanical ventilation. Chest, 90, 364-369.

Girard, K., & Raffin, T. (1985). The chronically critically ill: To save or let die? Respiratory Care, 30, 339-347.

Goldberg, A. I. (1988). Life-sustaining technology and the elderly: prolonged mechanical ventilation, factors influencing the treatment decision. Chest, 94, 1277-1282.

Grossbach-Landis, I. (1980). Successful weaning of ventilator-dependent patients. Topics in Clinical Nursing, 2 (3), 45-65.

Grossman, G. (1973). Factors influencing the response to withdrawal from mechanical ventilation: COPD. Postgraduate Medicine, 54, 165-168.

Harpin, R., Baker, J., Downer, J., Whitwell, J., & Gallacher, W. (1987). Correlation of the oxygen cost of breathing and length of weaning from mechanical ventilation. Critical Care Medicine, 15, 807-812.

Henneman, E. (1989). Effect of nursing contact on the stress response of patients being weaned from mechanical ventilation. Heart & Lung, 18, 483-489.

Herrera, M., Blasco, J., Venegas, J., Barba, R., Doblas, A., & Marquez, E. (1985). Mouth-occlusion pressure ($P_{0.1}$) in acute respiratory failure. Intensive Care Medicine, 11, 134-139.

Hess, D. (1987). Perspectives on weaning from mechanical ventilation, with a note on extubation. Respiratory Care, 32, 167-171.

Hudelson, E. (1977). Mechanical ventilation from the patient's point of view. Respiratory Care, 22, 654-656.

Janson-Bjerklie, S., Carrieri, V., & Hudes, M. (1986). The sensations of pulmonary dyspnea. Nursing Research, 35, 154-159.

Joyce, C. R., Zutshi, D. W., Hrubes, V., & Mason, R. M. (1975). Comparison of fixed interval and visual analogue scales for rating chronic pain. European Journal of Clinical Pharmacology, 8, 415-420.

Kaempfer, S.H. (1982). Relaxation training reconsidered. Oncology Nursing Forum, 9 (2), 15-18.

Kemper, M., Weissman, C., Askanazi, J., Hyman, A., & Kinney, J. (1987). Metabolic and respiratory changes during weaning from mechanical ventilation. Chest, 92, 979-983.

Khan, F., Mukherji, R., Chitkara, R., Juliano, J., & Iorio, R. (1983). Positive airway pressure in patients receiving intermittent mandatory ventilation at zero rate. The role in weaning in chronic obstructive pulmonary disease. Chest, 84, 436-438.

Kline, J., Zimnicki, G., Antonenko, D., & Bander, J. (1987). The use of calculated relative inspiratory effort as a predictor of outcome in mechanical ventilation weaning trials. Respiratory Care, 32, 870-876.

Knaus, W. A., Draper, E. A., Wagner, D. P., Zimmerman, J. E., Birnbaum, M. L., Cullen, D. J., Kohles, M. K., Shin, B., & Snyder, J. (1982). Evaluating outcome from intensive care: a preliminary multi-hospital comparison. Critical Care Medicine, 10, 491-496.

Krieger, B., Ershowsky, P., Becker, D., Gazeroglu, H. (1989). Evaluation of conventional criteria for predicting successful weaning from mechanical ventilatory support in elderly patients. Critical Care Medicine, 17, 858-61.

Larca, L., & Greenbaum, D. (1982). Effectiveness of intensive nutritional regimes in patients who fail to wean from mechanical ventilation. Critical Care Medicine, 10, 297-300.

LaRiccia, P., Katz, R., Peters, J., Atkinson, W., & Weiss, T. (1985). Biofeedback and hypnosis in weaning from mechanical ventilators. Chest, 87, 267-269.

Lemaire, F., Teboul, J-L., Cinotti, L., Giotto, G., Abrouk, F., Steg, G., Macquin-Mavier, I., & Zapol, W. (1988). Acute left ventricular dysfunction during unsuccessful weaning from mechanical ventilation. Anesthesiology, 69, 171-179.

Lewis, W.D., Chwals, W., Benotti, P., Lakshman, K., O'Donnell, C., Blackburn, G., & Bistrian, B. (1988). Bedside assessment of the work of breathing. Critical Care Medicine, 16, 117-122.

Luce, J., Tyler, M., & Pierson, D. (1984). Intensive respiratory care. Philadelphia: W.B. Saunders.

Lush, M., Janson-Bjerklie, S., Carrieri, V., & Lovejoy, N. (1988). Dyspnea in the ventilator-assisted patient. Heart & Lung, 17, 528-535.

MacIntyre, N. (1986). Respiratory function during pressure support ventilation. Chest, 89, 677-683.

Marini, J.J. & Wheeler, A. (1989). Critical care medicine- the essentials, Baltimore: Williams & Wilkins.

Marini, J. J., Smith, T. C., & Lamb, V. (1988). External work output and force generation during synchronized intermittent mechanical ventilation: effect of machine assistance on breathing effort. American Review of Respiratory Disease, 138, 1169-1179.

Marini, J. J. (1988). Monitoring during mechanical ventilation. Clinics in Chest Medicine, 9, 73-100.

Marini, J. J., Smith, T. C., & Lamb, V. (1986). Estimation of inspiratory muscle strength in mechanically-ventilated patients: the measurement of maximal inspiratory pressure. Journal of Critical Care, 1, 32-38.

McSweeny, A., Grant, I., Heaton, R., Adams, K., & Timms, R. (1982). Life quality of patients with chronic obstructive pulmonary disease. Archives of Internal Medicine, 142, 473-478.

Menzies, R., Gibbons, W.J., Goldberg, P. (1989). Determinants of weaning and survival among patients with COPD who require mechanical ventilation for acute respiratory failure. Chest, 95, 398-405.

Montenegro, H. (1987). Positive pressure ventilation. In M. Nochomovitz & H. Montenegro (Eds.), Ventilatory support in respiratory failure (pp.1-26). Mount Kisco, NY: Futura Publishing.

Montgomery, A.B., Holle, R., Neagley, S., Pierson, D., & Schoene, R. (1987). Prediction of successful ventilator weaning using airway occlusion pressure and hypercapnic challenge. Chest, 91, 496-499.

Morganroth, M., Morganroth, J., Nett, L., & Petty, T. (1984). Criteria for weaning from prolonged mechanical ventilation. Archives of Internal Medicine, 144, 1012-1016.

Muir, J. F., & Levi-Valensi, P. (1987). When should patients with COPD be ventilated? European Journal of Respiratory Disease, 70, 135-139.

Murciano, D., Boczkowski, J., Lecocguic, Y., Milic-Emili, J., Pariente, R., & Aubier, M. (1988). Tracheal occlusion pressure: a simple index to monitor respiratory muscle fatigue during acute respiratory failure in patients with chronic obstructive pulmonary disease. Annals of Internal Medicine, 108, 800-805.

Myers, D. (1985). Weaning from mechanical ventilation. Indiana Medicine, 78, 1008-1011.

Nett, L., Morganroth, M., & Petty, T. (1984). Weaning from mechanical ventilation- a perspective and review of techniques. In R. Bone. (Ed). Critical Care- A Comprehensive Approach (pp. 171-188). Park Ridge, IL: American College of Chest Physicians.

Nett, L. (1982). Respiratory care techniques. In T. Petty. (Ed), Intensive and Rehabilitative Respiratory Care (3rd ed.) (pp. 151-185). Philadelphia: Lea & Febiger.

NIH workshop summary. Withholding and withdrawing mechanical ventilation. (1986). American Review of Respiratory Disease, 134, 1327-1330.

Pardee, N., Winterbauer, R., & Allen, J. (1984). Bedside evaluation of respiratory distress. Chest, 85, 203-206.

Parno, J., Teres, D., Lemeshow, S., & Brown, R. (1982). Hospital charges and long-term survival of ICU versus non-ICU patients. Critical Care Medicine, 10, 569-574.

Pearlman, R. A. (1987). Variability in physician estimates of survival for acute respiratory failure in chronic obstructive pulmonary disease. Chest, 91, 515-521.

Plutchik, R. (1970). Emotions, evolution, and adaptive processes. In M. Arnold (Ed.), Feelings and Emotions. The Loyola Symposium (pp. 3-24). New York: Academic Press.

Popovich, J., Jr. (1986). Mechanical ventilation: physiology, equipment design, and management. Postgraduate Medicine, 79, 217-227.

Pourriat, J., Lamberto, CH., Hoang, P., Fournier, J., & Vasseur, B. (1986). Diaphragmatic fatigue and breathing pattern during weaning from mechanical ventilation in COPD patients. Chest, 90, 703-707.

Prigatano, G., Wright, E., & Levin, D. (1984). Quality of life and its predictors in patients with mild hypoxemia and chronic obstructive pulmonary disease. Archives of Internal Medicine, 144, 1613-1619.

Quan, S., & Hasan, F. (1980). Difficulties in weaning from mechanical ventilation. Arizona Medicine, 37, 622-625.

Raffin, T. (1989). Intensive care unit survival of patients with systemic illness. American Review of Respiratory Disease, 140, S28-S35.

Revill, S. I., Robinson J. O., Rosen, M., & Hogg, M. I. (1976). Reliability of a linear analogue for evaluating pain. Anaesthesia, 31, 1191-1198.

Riggio, R., Singer, R., Hartman, K. & Sneider, R. (1982). Psychological issues in the care of critically-ill respirator patients: differential perceptions of patients, relatives, and staff. Psychological Reports, 51, 363-369.

Roussos, C., Macklem, P. (1977). Diaphragmatic fatigue in man. Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology, 43, 189-197.

Sahn, S. (1986, September). Weaning from mechanical ventilation. Paper presented at the meeting of the American College of Chest Physicians, San Francisco, CA.

Sahn, S. & Lakshminarayan, S. (1973). Bedside criteria for discontinuation of mechanical ventilation. Chest, 63, 1002-1005.

Sahn, S., Lakshminarayan, S., & Petty, T. (1976). Weaning from mechanical ventilation. Journal of the American Medical Association, 235, 2208-2212.

Sassoon, C., Te, T., Mahutte, C. K., & Light, R. (1987). Airway occlusion pressure: an important indicator for successful weaning in patients with chronic obstructive pulmonary disease. American Review of Respiratory Disease, 135, 107-113.

Schachter, E.N., Tucker, D., & Beck, G. (1981). Does intermittent mandatory ventilation accelerate weaning? Journal of the American Medical Association, 246, 1210-1214.

Schmidt, C. D., Elliott, C. G., Carmelli, D., Jensen, R., Cengiz, M., Schmidt, J., Tolman, D., & Clemmer, T. (1983). Prolonged mechanical ventilation for respiratory failure: a cost-benefit analysis. Critical Care Medicine, 11, 407-411.

Shacham, S. (1983). A shortened version of the profile of mood states. Journal of Personality Assessment, 47, 305-306.

Smith, T. & Marini, J. (1988). Impact of PEEP on lung mechanics and work of breathing in severe airflow obstruction. Journal of Applied Physiology, 65, 1488-1499.

Snider, G. (1989). Historical perspective on mechanical ventilation: from simple life support system to ethical dilemma. American Review of Respiratory Disease, 140, S2-S7.

Spielberger, C. (1972, Fall). Reviews, etc. Professional Psychology, 387-388.

Sporn, P., & Morganroth, M. (1988). Discontinuation of mechanical ventilation. Clinics in Chest Medicine, 9, 113-126.

Strieter, R., & Lynch J., III. (1988). Complications in the ventilated patient. Clinics in Chest Medicine, 9, 127-139.

Sutherland, H., Walker, P., & Till, J. (1988). The development of a method for determining oncology patients' emotional distress using linear analogue scales. Cancer Nursing, 11, 303-308.

Swartz, M., & Marino, P. (1985). Diaphragmatic strength during weaning from mechanical ventilation. Chest, 88, 736-739.

Tobin, M., Guenther, S., Perez, W., Lodato, R., Mador, M.J., Allen, S., Dantzker, D. (1987). Konno-Mead analysis of ribcage-abdominal motion during successful and unsuccessful trials of weaning from mechanical ventilation. American Review of Respiratory Disease, 135, 1320-1328.

Tobin, M., Perez, W., Guenther, S., Semmes, B., Mador, M.J., Allen, S., Lodato, R., & Dantzker, D. (1986). The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation. American Review of Respiratory Disease, 134, 1111-1118.

Truwit, J., Lamb, V., Knebel, A., & Marini, J. (1989). Pressure-time index and mechanical efficiency correlate with dyspnea during ventilatory stress. American Review of Respiratory Disease, 139, part 2, A97.

Tomlinson, J., Miller, K.S., Lorch, D., Smith, L., Reines, H. D., Sahn, S. (1989). A prospective comparison of IMV and T piece weaning from mechanical ventilation. Chest, 96, 348-352.

van den Berg, B., & Stam, H. (1988). Metabolic and respiratory effects of enteral nutrition in patients during mechanical ventilation. Intensive Care Medicine, 14, 206-211.

Weisman, I., Rinaldo, J., Rogers, R., & Sanders, M. (1983). State of the art: Intermittent mandatory ventilation. American Review of Respiratory Disease, 127, 641-647.

Whitelaw, W., Derenne, J., & Milic-Emili, J. (1975). Occlusion pressure as a measure of respiratory center output in conscious man. Respiration Physiology, 23, 181-199.

Witek, J. T., Schachter, E. N., Dean, N., & Beck, G. (1985). Mechanically assisted ventilation in a community hospital. Immediate outcome, hospital charges, and follow-up of patients. Archives of Internal Medicine, 145, 235-239.

Wright, P., Marini, J., Bernard, G. (1989). In vitro versus in vivo comparison of endotracheal tube airflow resistance. American Review of Respiratory Disease, 140, 10-16.

Zaren, B., & Hedstrand, U. (1987). Quality of life among long-term survivors of intensive care. Critical Care Medicine, 15, 743-747.

Zook, C., & Moore, F. (1980). High-cost users of medical care. The New England Journal of Medicine, 302, 996-1002.

Zwillich, C., Pierson, D., Creagh, E., Sutton, F., Schatz, E., & Petty, T. (1974). Complications of assisted ventilation. A prospective study of 354 consecutive episodes. The American Journal of Medicine, 57, 161-169.

Appendix A Methods of Weaning

Authors/ Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Statistics	Results/ Conclusions
Schachter, et al., 1981	To determine whether IMV reduces weaning time	Retrospective chart audit of all pts. receiving MV during the first 3 months of 1975 & 1976 at Yale/ Descriptive	65 of 77 pts treated with IMV in the first 3 months of 1976 matched to 65 patients treated with assisted or controlled vent. in 1975. Matching variables: age, race, sex, smoking history, pulm. disease, diagnosis, location of therapy. Duration of vent. not stated	Time on vent.	IMV vs. conventional ventilation: assist control	unpaired t test, Chi square, Wilcoxon signed rank test	Two groups not different on match characteristics. Pts. who received conventional MV were less sick than those who received IMV. For the matched groups, length of time on ventilator not different between IMV (145 hours) and conventional MV (142 hours) Length of hospitalization did not differ between IMV (36 days) and conventional (30 days) MV. Matched subjects were mostly surgery patients. In a subgroup of medical patients, length of ventilator time and hospitalization was longer with IMV

Appendix A Methods of Weaning

Author/ Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Statistics	Results/ Conclusions
Ashutosh, 1983	Does gradual weaning have an advantage over abrupt weaning?	not stated/ Descriptive	14 male veterans with ARF and COPD who had been ventilated for at least 30 days	Success or failure of weaning trial; Total time on vent.	Weaning method: -abrupt, 0 CPAP -gradual, IMV	Chi square	18 episodes of ARF evaluated in 14 pts.; 6 failed to wean (4 died on vent., 2 discharged on vent.) Gradual weaning (GW) attempted in 14 instances & was successful in 3; of the 11 failures, 5 eventually weaned with the abrupt method (AW); AW attempted in 13 instances & was successful in 9; of the 4 that failed 2 were eventually weaned with GW. Thus the 2 methods were signif. different ($p < .05$). Time on vent. shortest with AW (42 ± 12.5 days) and longest with those who required both methods to

Appendix A Methods of Weaning

Author/ Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Statistics	Results/ Conclusions
Ashutosh, 1983 (contd.)							achieve weaning (83± 47 days).
Tomlinson, et al., 1989	To determine if IMV and T piece weaning methods are equally efficacious if specific ventilatory and gas transfer criteria are met	200 consecutive pts. over 16 months/ Prospective, randomized	All adult pts. requiring MV at 3 hospitals in South Carolina who were ready for weaning based upon specific criteria: PaO2<.5, pH ≥ 7.3 & ≤ 7.5, PEEP < 5, f ≤ 36, Ve < 12 & two of the following: MVV > 2x Ve, Vt > 5 cc/Kg, FVC > 10ml/kg, NIF ≤ -20 cmH2O. 3 groups: a) ventilated < 72 hrs. before met criteria b) ≥ 72 hrs. before met criteria c) did not meet criteria after 7 days or failed 3 weaning attempts. 133 surgical/trauma, 67 medical.	Weaning time: time from having acceptable weaning parameters to completion of weaning. Total ventilation time: time from initiation of MV to completion of successful weaning	Weaning methods: For group A: 2 hour IMV or T piece protocol; group B: 7 hr IMV or T piece protocol; Group C: 3 day IMV or T piece protocol	ANOVA Kruskal-Wallis	165 of 200 maintained in study until weaning initiated. Of these 165, 155 weaned by protoco;19 required more than one attempt to wean by protocol. IMV or IMV or T piece weaning can be successful in short- term patients when simple bedside criteria are met. Time on vent. not different between groups.

Appendix A Methods of Weaning

Author/ Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Statistics	Results/ Conclusions
Khan, et al. 1983	To compare airway pressure of patients breathing on 0 IMV versus T piece	not stated/ Descriptive	9 pts. intubated for ARF. Causes of failure: 3 ARDS, 1 Asthma, 1 Obesity, 4 COPD. Time on vent. not stated, but 4 long-term	airway pressure	Weaning method: -IMV 0 -T piece (each pt. breathed with both systems)	paired t test	Peak expiratory airway pressures were signif. higher on IMV than T piece. End expiratory pressure was slightly higher during IMV compared to T piece in 7 of 9 pts.
Brochard, et al. 1989	1) To determine if PS prevents diaphragmatic fatigue during weaning by decreasing work load and VO2 of vent. muscles. 2) Search for optimal level of PS that maintains substantial diaphragmatic activity without inducing fatigue.	Convenience/ Descriptive	8 pts recovering from ARF who failed previous weaning attempts Time on vent. > 9 days. COPD 4 Pneumonia 3 Obesity 1	Inspiratory work of breathing, transdiaphragmatic pressure (Pdi), electrical activity of diaphragm (H/L ratio), Electrical activity of sternomastoid, VO2, ABG's, Optimal PS level- lowest level of PS where H/L ratio didn't decrease	Four successive levels of PS: 1) 0 cmH2O 2) 10 cmH2O 3) 15 cmH2O 4) 20 cmH2O	Descriptives, 2 way ANOVA, Linear Regression	During 0 cmH2O PS- H/L ratio decreased indicating the potential for fatigue; Vt decreased; f increased; VO2, PaCO2, HR, and B/P increased. At high PS levels Vt increased, f, PaCO2, work, B/P, HR, VO2, and AP decreased therefore preventing fatigue. Optimal PS varied from pt to pt. When work loads

Appendix A Methods of Weaning

Author/ Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Statistics	Results/ Conclusions
Brochard, et al. 1989 (contd.)							were > 8 -10 j/min pts. showed evidence of fatigue. Monitoring activity of sternomastoid allows clinical assessment for increased work load.

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Sahn & Lakshminarayan	1973	To establish simple, bed-side criteria to predict weaning	Convenience/ Quasi-experimental	100 alert ventilator patients; 60 men, mean age 52.4; 40 women, mean age 43.7 yrs; Diagnoses: 61 surgical, 15 COPD, 6 ARDS, 5 pneumonia, 2 pulm. edema, 8 drug OD, 2 CNS pathology	Ve< 10L/ min MVV 2x Ve NIF more negative than -30cm H_2O	T piece	Def: ABG's & clinical condition stable 2-8 hours/ Time on ventilator: range 12-144 hrs., mean 37 hrs.; Results: 76 met criteria & weaned (true positive); 17 failed criteria, required continued MV (true negative); 7 failed criteria yet weaned (false negative)

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Krieger, et al.	1989	To determine whether weaning criteria derived from younger individuals was predictive of weaning outcome in elderly pts.	All pts. ≥ 70 yrs at one institution who weaned from MV and did not require reinstitution of MV from Jan 1984 - June 1985/ Retrospective	All medical & non-open heart patients weaned under the direction of the pulmonary service. Excluded pts. who required elective reintubation or reintubation for upper airway edema or pts. who extubated themselves (because not adequate prediction)	f, Vt, Ve, NIF, ABG's on same day as weaning, P/F ratio	Decreasing IMV rate to 0. Spont. breathing trial ranged from 1 hour for pts. ventilated < 24-36 hrs. and up to 16 hrs. for pts. ventilated > 1 week	Def: Required reinstitution of MV within 48 hrs. of weaning due to resp. failure, tachypnea, agitation, arrhythmia, hemodynamic instability diaphoresis, &/or ABG deterioration. Time on Vent: Successful- 62 ± 98 hrs, Unsuccessful- 147 ± 144 hrs. Results 241 of 269 pts weaned. Demographics not different between the 2. Failure group ventilated longer. Mechanics and gas exchange not different, except for NIF and pH. However signif. differences were clinically very small. Standard criteria developed on younger populations do not predict weaning in older pts.

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Morganroth, et al.	1984	•To describe the weaning course of long-term vent. patients; •To determine utility of conventional criteria in assessing weaning ability; •To develop a scoring system, including number and severity of medical, psychological, & respiratory problems, which correlates with weaning	convenience/ retrospective chart review	11 instances of prolonged MV (30 days or >) in 10 patients; Age not given; Diverse diagnoses: 2 COPD, 1 TB, 1 Altered mental status 1 Burn, 1 Botulism, 5 Surgery	Conventional criteria: f, Vt, VC, Ve, VC/Vt; Ventilator Score (VS): FiO2, PEEP, Static compliance, Dynamic compliance, Triggered f; Adverse Factor Score (AFS): Vital signs, Medications, Nutrition, Emotional status, LOC, Mobility, Communication, Secretions, Arrhythmias	T piece	Def: 24 hours off ventilator without early signs of fatigue (change in HR or conventional criteria) Time on ventilator: range 30-100 days Results: 9 of 11 pts. weaned; Weaning time required 11-43 days; Pattern of weaning-when tolerated 7 hrs. spont. breathing, approx. half of weaning time had elapsed; Conventional criteria were not different between unsuccessful and progressive weaning; VS & AFS were calculated 179 times for 11 instances of long- term weaning; A combined VS & AFS < 55 predicted weaning success (false positive 14%) and > 55 predicted weaning failure (false negative 7%),

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Kemper, et al.,	1987	To examine whether changes in VO2 & VCO2 are different during successful & unsuccessful weaning trials	Randomly selected from the pool of patients deemed ready for a trial of weaning by the ICU medical staff/ Quasi-experiment	35 post-op pts. being weaned (not septic, fluid overloaded, or hemodynamic instability) Diagnoses: 26 abdominal procedures- 9 thoracotomies 1 BKA	VO2, Ve, PaCO2, VCO2	Weaning sequence: IMV 10-12 IMV 4-6 CPAP 3-4 cmH2O	Def: PaCO2 not increase > 55; PaO2 not decrease < 80; Time on Vent: at least 18 hrs Results: 18 of 35 successful; 14 men, 4 women; mean age 59±17 yrs.; 17 of 35 failed; 11 men, 6 women; mean age: 62±21 yrs; Both grps. increased VO2 & VCO2 during spont. breathing 6-10% (not signif. different); Both grps. decreased Ve (success grp. decreased 9 ± 8%; failure grp. decreased 15 ± 3%). The failure grp. had a signif. higher f. The higher f and the lower Ve in the failure grp resulted in acidosis and therefore weaning failure.
Lewis, et al.	1988	To describe results of measurements of VO2 made on pts. during weaning	not stated/ Quasi-experiment	30 pts. recovering from ARF who were candidates for weaning	"work of breathing" = VO2 spont. minus VO2 on vent. given as % VO2 Measurements: 1) baseline during MV; 2) continuously as spont.	MV either assist or IMV; Gradually decreasing IMV rate over 30-60 min. according to standard criteria	Def: 24 hrs off vent. Time on vent. not stated. Results: Successful: n=16; Preweaning mean VO2 127 ± 41 ml/min*m2; mean during weaning 137 ± 47; % Δ in VO2 between pre and during weaning < 15% in 14 of 16 pts. Unsuccessful: Returned to vent. within 24 hrs. of measurement; n=14; Preweaning mean VO2 142 ± 13 ml/min*m2; mean during

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Lewis, et al. (contd)					breathing increased with decreasing IMV rate		weaning 177 ± 39; % Δ in VO2 between pre and during weaning > 15% in all but one pt.
Harpin, et al.	1987	• To investigate the relationship between oxygen cost of breathing (OCB) and vent. dependence following acute illness • To see if OCB provides physiological insights into weaning.	not stated/ Quasi-experiment	20 patients: 12 men, 8 women. Age: 43-84 yrs. Diagnoses: 9 COPD, 3 cardiac arrest/ MI, 4 other pulm. problems, 3 neurological deficits, 1 abdominal surgery. All pts. failed conventional criteria: VC > 12cc/kg NIF > 20 cmH2O P[A-a] O2<350	OCB; OCB as a fraction of the oxygen cost of spont. breathing (OCB/VO2sv); OCB as a fraction of the ventilation requirement (OCB/Ve)	CPAP	Def: 24 hrs off vent. without fatigue, change in HR > 120, or change in B/P ≥ 15% Time on vent: Average 16.4 ± 7.2 days. Results: Average OCB 30 ± 6 ml/min. OCB and # of days to wean correlated r = .79. OCB/VO2sv and # of days to wean also correlated r = .84. An OCB/VO2sv of .1 separated long and short-term vent. pts., with a value of < .1 pts weaned in 3.3 ± .9 days; a value > .1 pts. took longer to wean 36.1 ± 16 days.

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Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Herrera, et al.	1985	To investigate the value of the mouth occlusion pressure (P0.1) as an indicator of weaning	not stated ? con-venience/ Descriptive	20 patients admitted to ICU for ARF; 6 females, 14 males; mean age: 62.2 yrs; Diagnoses: 11 COPD 9 non-COPD pneumonia ARDS trauma aspiration	P0.1 normal values 1-2cm H20	IMV & T piece	Def: Absence of mental changes & subjective fatigue; f< 30; no acidosis, asynchrony, tachycardia or hypoxemia (time frame not stated) Time on ventilator: not reported Results: All 20 patients had an elevated P0.1 during MV; COPD = 9.8 ± 1.9 cmH20, non-COPD = 12.6 ± 2.7 cmH2O; 4 tolerated T piece trial and weaned, 14 did not tolerate T piece and were eventually weaned with IMV, 2 died; A total of 52 measurements of P0.1 were made; A P0.1 of ≤ 4.2cm H2O predicted weaning success and a value > 4.2 predicted failure, 14 of 18 times success was predicted yet all 18 could have weaned (false negative 22%); 34 times a P0.1 of > 4.2 correctly predicted weaning failure (true negative100%)
Sassoon, et al.	1987	To determine if P0.1 is a useful predictor of successful weaning in COPD patients	convenience/ consecutive admissions	12 males with COPD; mean age 67 yrs.; judged ready for weaning by clinical stability (not defined) and by conven-tional criteria: NIF < -20 cm H20 & VC ≥ 10 ml/kg	P0.1	T piece	Def: 24 hrs off ventilator without: acidemia pH < 7.36, hypoxemia < 50, change in HR > 20, change in B/P > 15, anxiety, diaphoresis, or agitation. Time on ventilator: Prior to weaning not reported. Total time on vent. for successful group mean = 3.9 ± 1.1

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Sassoon, et al., (contd.)							days, for unsuccessful group (prior to death n=3) or eventual weaning (n=2) mean =16.4 ± 16.7 days. Results: 7 pts.weaned success fully, 5 failed weaning; P0.1 < 6 cmH2O predicted weaning success and > 6 predicted failure (100% accuracy); P0.1 remained stable throughout the weaning trial in all but one patient who increased; Patients who failed also had higher Vt/Ti and lower Ti/Ttot than those who weaned successfully.
Montgomery, et al.	1987	To determine if central vent. drive (measured by P0.1) during spontaneous breathing & during hyper-capnia predicts weaning success	not stated ? convenience/ Quasi-experiment	11 patients, 8 men & 3 women, recovering from ARF but who had marginal conventional weaning parameters (Ve, NIF & VC); mean age 54 Diagnoses: 2 ARDS, 3 Drug OD, 2 Flail chest, 1 Sepsis, 3 COPD; 2 patients with COPD & 1 with ARDS were studied twice.	P0.1 with & without hypercapnic challenge (increasing end tidal CO2 by 10 mmHg	T piece	Def : No hypercapnia during T piece trial and 24 hours of spontaneous breathing without respiratory deterioration. Time on ventilator: Prior to study: 1 -193 days, mean 58 days. Results: 14 trials, 7 successes & 7 failures. Both groups had increased P0.1, Success mean = 3.7 ± .7 cmH2O, Failure mean = 5.7 ± 1.4 cm H2O; P0.1 of two groups not significantly different; Successful grp augmented P0.1 in response to hypercapnia (increase 3.3 cmH2O), failure group did not (increase of only 9); The ratio hypercapnic P0.1/ baseline P0.1 separated successful and unsuccessful trials.

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Murciano, et al.	1988	•To assess resp. muscle fatigue in COPD pts. with ARF •To determine if P0.1 can be used to assess resp. muscle fatigue	not stated/ Quasi-experiment	16 intubated COPD pts. with ARF; 2 women, 14 men; mean age 65 ± 12 yrs.	Ve, Vt, f, P0.1, Diaphragm EMG, (espoh. electrode) ABG's, HR, Ti, Ttot, Measurements: 1) EMG recorded for 5 min. 2) ABG's 3) Breathing pattern recorded for 5 min. 5) Measurements repeated at 15 min.	15 min. T piece trials 24 hrs. after intubation & at 2 day intervals & prior to extubation	Breathing pattern the same for both grps on day 1: Vt & Ti/Ttot decreased (.35-.37), f increased, Ve constant, P0.1 increased, (7.1 ± 2.4), H/L ratio of EMG decreased (fatigue). Evolution of breathing pattern: 2 grps-successful weaning & required reintubation. Successful: n=11 ABG's increased Vt & Ti/Ttot increased, P0.1 decreased (4.7 ± 1.8), H/L no longer decreased. Reintubation: n=5 Pts. were more obstructed & hyperinflated; Vt stayed low & f stayed high, Ti/Ttot didn't change, P0.1 remained high and H/L still decreased; NIF was not different between grps.
Fiastro, et al.	1988	To compare standard weaning criteria to spontaneous mechanical work of breathing as indicators of successful weaning	Not stated convenience/ Quasi-experiment	17 stable medical/ surgical patients requiring MV due to pulmonary parenchymal disease; Age 51-78 yrs. mean 65 Diagnoses: Group 1- 7 COPD, 2 CHF, 2 Atlectasis	Conventional criteria: VC ≥ 10 ml/kg, NIF < 20 cmH2O, Ve ≤ 10 L/min, Vt ≥ 5 cc/kg Study Criteria: Mechanical work of spontaneous breathing; Work calculated from trans-pulm. P/V plots: work /breath x f = W/min;	T piece	Def: > 24 hours without ventilator support. Time on ventilator: Divided into 2 grps: #1) 11 patients on vent. 22-72 hrs., mean 45 hrs; #2) 6 patients on vent. > 24 hrs., range 4-26 days; One patient in grp. 2 died; Results: Conventional criteria did not distinguish successful and unsuccessful trials, 5 of 6 vent. dependent patients met conventional criteria; Inspiratory (Wi/L) and inspiratory work per minute (Wi/min)

Appendix B Criteria Studies to Predict Weaning

Authors	Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Fiastro, et al., (contd.)				Group 2- 3 ARDS, 3 COPD	work/min divided by Ve = W/L		progressively decreased during weaning; Values of Wi/L ≤ .14 kg-m and Wi/min ≤ 1.6 kg-m were both necessary in order to wean. A decrease in f also separated vent. dependent from successful weaning.
Kline, et al.	1987	To validate a simplified method to predict weaning	not stated ? con-venience/ Quasi-experiment	50 medical (n=20) & post-surgical (n=30) patients who satisfied conventional weaning criteria (Vt, Ve, f, NIF) and were clinically stable; No ages given; 11 had COPD	Relative inspiratory effort: ΔPt/NIF	T piece	Def: 24 hours spontaneous ventilation. Time on ventilator: range of means 1-70 days; Results: 27 with ΔPt /NIF <.40, (mean .32 ±.07), weaned (true positive); 21 with ΔPt/NIF>.40, mean (.53 ± .1), failed (true negative); 2 with ΔPt/NIF>.40, (values .42 &.43), weaned (false negative)
Menzies, et al.	1989	To determine factors associated with duration of intubation, weaning outcome and survival	Consecutive/ Quasi-Experiment	95 COPD pts.admitted over a 30 month period who required MV	Premorbid: activity level, lung function, lab data. Prior to weaning: NIF, f, Vt	T piece	Def: Survival for at least 72 hrs without MV; 50 males, 45 females; No relationship between cause of failure & outcome. 76% weaned successfully; 22% died while on MV; Additional 16% died within first month off vent.; 32% survival at 1 yr. For those with long-term survival, level of activity & life style scores decreased only slightly. Premorbid characteristics that separated success-

Appendix B Criteria Studies to Predict Weaning

Authors Date	Purpose	Sampling/ Design	Sample Type	Weaning Criteria	Weaning Method	Weaning Def./ Study Results
Menzies, 1989 et al. (contd.)						ful & unsuccessful trials: FEV1, level of activity, dyspnea & albumin. Weaning parameters associated with outcome: NIF, Vt, f measured during T piece. Duration of ventilation not predicted by any of variables. Duration of vent. not associated with outcome. Variable most highly correlated with outcome of weaning was premorbid activity (a good summary measure influenced by many clinical factors.

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Pardee, etal., 1984	To define the extent that clinical observations, that do not depend on special equipment, establish or exclude risk	not stated/ Descriptive	112 episodes of vent. support in 110 subjects Diagnoses: 4 medical cardiac disease; 19 lung disease; 14 multi. medical prob.; 52 thoracic surgery; 21 non-	VC, f, HR, Vt, Ve, Palpable scalene recruitment on inspiration, Abdominal muscle recruitment on expiration; Outcome of weaning trial: Favorable- successful weaning/	First trial of spont. breathing (weaning method not stated)	Chi Square $p<.05$	Time on vent. not reported, however vent. time not signif. related to weaning outcome. Unfavorable outcome more likely with: $f \geq 31$, $Ve < 30$ or > 210 ml/kg, $Vt/VC > .5$, $HR > 120$ or < 70, $VC < 17$ ml/kg, inability to perform VC maneuver, scalene and abdominal muscle recruitment. Clinical assessment of bedside measures (f, HR, scalene and abdominal muscle recruitment,

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Pardee, et al. 1984 (contd.)	of resp. failure as evaluated by responses during weaning		thoracic surgery	survived, Unfavorable- returned to vent. for > 24 hrs. or death or both			irregularity of breathing pattern with apneic pauses and inability to cooperate with VC testing) predict weaning outcome with 90% accuracy
Gilbert, et al., 1974	•To provide background information concerning changes in f, Vt, Ve, HR, PaO2, PaCO2, & subjective resp. distress during first trial off vent. •To see if changes in these parameters decrease the need for ABG's during first weaning trials	not stated/ Descriptive	14 pts. time on vent. (3-80 days); judged ready for weaning; 9 with trach, 3 with ET, 2 extubated immediately; 8 COPD, 1 asthma, 1 quadraplegic, 1 lung CA.	f, Vt (as measured with magnetic coils), Ve, HR, PaO2, PaCO2, Subjective distress (as indicated by pt. request to be returned to vent.)	First trial off vent. compared to baseline on vent. 30 min. prior to weaning	paired t test	4 pts. weaning trial terminated because of subjective distress; 2 pts. for deterioration of ABG's; Average length of trial: 3 hrs. Breathing pattern changes: Vt decreased 700 to 300, f increased 13 to 25, Changes were stable by 5 min. Ve not signif. different on and off vent. Changes in PaO2 & PaCO2 were unpredictable. HR increased average 9.5 at 15 min. of spont. breathing. COPD and non-COPD were not signif. different. Subjective distress did not provide clues about changes in ABG's

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Tobin, et al., 1986	To test the hypothesis that weaning failure results from inefficient gas exchange (rapid, shallow breathing)	selected not stated how/ Quasi-exp.	17 pts. judged ready for weaning based on clinical assessment & NIF. Diagnoses: 6 neurological (3 with and 3 without pulm. disease) 2 chest trauma 5 COPD 4 CHF	Breathing Pattern: Vt, f, Ve, Ti, Te, Ti/Ttot, Vt/Ti Success or failure of of weaning trial.	Spont. breathing trial (assume T piece)	Repeated measures one-way ANOVA; Paired t tests; Two-way ANOVA; Simple & multiple regression; Mann-Whitney U test.	Successful n = 10; average time on vent: 2.6 days; time of spont. breathing prior to extubation 57 ± 8 min.; no hypoxemia or acidosis; breathing pattern during first 15 min. of spont. breathing not different from MV; During the following hour of spont. breathing, Ve increased an average of .85 L/min. Failure n = 7; 6 developed acidosis and 1 hypoxemia; Average length of vent. support 42.4 days. Time of spont. breathing prior to reinstituting of MV 40 ± 11 min. During first 15 min off vent., Vt fell from 400 ± 61 ml to 194 ± 23 ml. and f increased from 21 ± 2 to 32 ± 2.3 breaths per min.; Ve increased by approximately 1.5 L/min and Vt/Ti increased by approx. 63 ml/sec. from beginning to end of trial. Comparison of success and failure groups: Vt was lower & f was higher in the failure group compared to success; A f > 25 and a Vt < 300 separated the 2 groups. Ti and Te were shorter, VC lower and NIF weaker in failure group.

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Cohen, et al., 1982	To describe EMG & physical exam techniques used to diagnose inspiratory muscle fatigue in pts. with respiratory failure & difficulty during discontinuing artificial ventilation	not stated/ Descriptive	12 pts. with hypercapnic respiratory failure; 5 females, 8 males; mean age 59.8 yrs; Diagnoses: 5 COPD, 2 ARDS, 1 Myopathy, 1 Pulm. edema, 1 Bronchiectasis, 1 Tracheal obstruction, 1 Unknown	Diaphragm & intercostal EMG; ABG's; f & depth; thoraco-abdominal motion (by inspection & palpation; NIF	Spontaneous breathing trial until clinical deterioration developed (f > 30, tachycardia, hypotension, change in LOC, acidosis, or undefined subjective stress) Trials not longer than 40 min.	Case reports	Two groups: Those with fatigue & those without Fatigue n = 7 Time on vent. 15.7 days; Sequence of failure: 1) increased f, 2) shift in EMG 20-60% drop in H/L, 3) development of paradox in 6 of 7 (1 had abd. binder & unable to assess) development of alternans in 4, 4) increased PaCO2 mean 11 ± 5.7 mmHg, 5) if progresses f & Ve decrease prior to arrest or death. No fatigue n = 5 mean time on vent. 14.8 days; no abnormal motion; 1 pt increased PaCO2
Swartz & Marino 1985	To assess whether weaning failure is related to diaphragmatic weakness	not stated/ Descriptive	7 pts who had failed weaning attempts (unable to sustain spont. ventilation at least 4 hrs.) mean age 68; 3 females, 4 males; ventilated: 4 days to 4 weeks; Diagnoses: 4 COPD, 2 ARDS 1 Aspira tion	Pdi, f, Vt, Pes, inspection & palpation of abdominal motion. Measures Taken: 1) within first 15 min. 2) every 15 min. x 1 hr. 3) every 30 min. during rest of weaning period	weaning trials method not stated	paired t test	Weaning failure defined: HR > 140, f > 40, PaCO2 >50 or increase >10, PaO2 <55. Length of weaning period: 12 to 245 min. Reason for failure of trials: 1 hypoxemia, 1 tachypnea, 5 hypercapnia, 2 both hypercapnia & hypoxemia. Vt, f & Ve did not change; Pdi & Pes increased (no fatigue); 3 had paradox, 7 had abd. exp. contraction.

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Pourriat, et al. 1986	To evaluate measures of resp. muscle function & breathing pattern to see if changes indicate medium term outcome of weaning	not stated/ Quasi-exp.	40 weaning trials on 15 COPD pts; age 55-70 yrs.; 11 men, 4 women; cause of failure all had bacterial infection; all had trach & had sustained Vt ≥ 5 ml/kg, f<30, PaO2 ≥ 50 during spont. breathing trial (2 hrs)	Ve, f, Vt, Pdi/Pdimax, P0.1, Ti, Te, Ttot, PaO2, PaCO2, pH	Weaning trial method not stated	t test	Failure grp n = 19; Duration of vent. 8.1 ± 3 days; Tolerated spont. breathing: mean 4.15 ± 2.41 hrs; 13 of 19 had Pdi/Pdimax > .4: mean .456 increased to .67 ± .11 prior to returning to vent.; Gastric pressure was negative, indicating abnormal diaphragm function (ie paradox) Ti/Ttot shorter than successful group .295 vs. .35. Successful Grp: n = 18; Duration of vent. 7.8 ± 3.2 days; still off vent at 12 hrs. (mean time off 25.8 hrs. no reason given for returning to vent.); 16 of 18 had Pdi/Pdimax < .4 mean =.33; no negative gastric pressure; Rest of breathing pattern and ABG's not different between grps.
Tobin, et al., 1987	To test the hypothesis that abnormal rib cage (RC) & abdomi-	selected not stated how/ Quasi-exp.	17 pts. judged ready for weaning based on clinical assessment & NIF.	RC & Ab Indices: Phase angle; Asynchrony index; Paradox; MCA/Vt;	Spont. breathing trial (assume T piece)	Repeated measures one-way ANOVA; Paired t tests; Two-way ANOVA; Simple	Success n = 10; average length of time on vent. 2.6 days; time of spont. breathing prior to extubation 57 ± 8 min.; no hypoxemia or acidosis; Breathing movements during MV compared to normals: greater contribution of RC to Vt & increased expiratory RC paradox. During weaning compared to

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Tobin, et al., 1987 (contd.)	nal (Ab) movement is common in early stages of weaning & its presence doesn't inevitably imply an unsuccessful outcome		Diagnoses: 6 neurological (3 with and 3 without pulm. disease) 2 chest trauma 5 COPD 4 CHF	RC/Vt		regression; Unpaired t test	normals: all indices of paradox & asynchrony increased. Following extubation: paradox and asynchrony decreased. Expiratory paradox > inspiratory throughout study. Failure n = 7; 6 developed acidosis and 1 hypoxemia; Average length of vent. support 42.4 days. Time of spont. breathing prior to reinstitution of MV 40 ± 11 min. Breathing movements during MV compared to normals: Same trends but > abd. paradox. During weaning compared to successful: Greater asynchrony, paradox, and variation in compartmental contribution to Vt. However asynchrony and paradox overlapped between 2 grps. MCA/Vt of 1.18 separated failure and success grps. All failures had value > 1.18 and 80% of successes had value < 1.18.
Lemaire, et al. 1988	To examine cardiopulmonary performance during MV and spont.	convenience/ Descriptive	15 pts. with severe COPD & pre-existing heart disease who satisfied conventional criteria yet could not be	mean Pes, CI, B/P, HR, wedge pressure,	MV vs. spont. vent. (through Seimens servo	multiple paired t tests with Bonferroni correction	9 of 15 eventually weaned approx. 1 week after study; 5 died in hospital due to Lt. heart failure, pneumonia & infection; 1 discharged on vent., died 5 mon.later. Duration of vent: mean 3.9

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Lemaire, et al. 1988 (contd.)	vent. in pts. who could not be weaned from vent.		weaned as evidenced by inability to tolerate SV > 30 min. on at least 2 trials. Causes of ARF: 11 acute pulm. inflamation, 3 abd. surgery, 1 illeus	blood volumes by isotope studies, catecholamine levels	900c vent. circuit); Lasix; nutritional support		weeks. All pts. increased wedge during spont. vent., usually accompanied by wheezing; always had dyspnea, tachypnea, and CO2 retention (increased 42-58 mmHg); mean Pes CI, & HR increased but ejection fraction didn't change; O2 sat decreased 97 to 84%; Plasma epinephrine & norepinephrine levels increased; 8 pts. restudied after treatment with Lasix & weaning: weight decreased 5 kg; blood volume also decreased; wedge did not increase as seen before
Agusti, et al. 1986	•To analyze oxyhemoglobin affinity in pts. recovering from ARF •To compare standard & in vivo P50 data to determine influence of MV on position of oxyhemoglobin	consecutive pts./ Quasi-exp.	20 pts. COPD & ARF 10 on MV 10 conservative treatment Duration of vent. not stated	oxyhemoglobin affinity; PaCO2; pH; 2,3 DPG; Measures taken 24 & 48 hrs. after admission, & during weaning in vent. pts. or on discharge in non-vent. pts.	Treatments for ARF: MV vs. conservative (O2 & inhaled steroids, broncho-dialators) Both grps received antibiotics, aminophylline & steroids	Wilcoxon test for paired data within group; Mann-Whitney for differences between groups	Both grps not different on age, sex, PaO2; & had standard P50 left shifted throughout study; Ventilated: n =10; had lower pH and higher PaCO2 initially; At 24 hrs: pH, PaO2 & 2,3 DPG higher and PaCO2 lower than non-vent. At 48 hrs: only PaCO2 lower than non-vent. grp.; In vivo P50 left shifted throughout study. Non-Vent. Grp: n =10; At 24 hrs: in-vivo P50 higher than vent. grp was close to normal standard P50; At 48 hrs: had left

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Agusti, et al., 1986 (contd.)	dissociation curve						shift close to vent. grp value; Grp diff. disappeared when both breathed spont.
Bassili & Deitel, 1981	To compare effects of protein-free, energy-deficient IV diet with adequate nutritional support on outcome of MV	Retro-spective review/ Descrip-tive	47 pts. ventilated for 3 or more days; excluded cardiac arrest & pts. with brain stem injury; 31 males, 16 females; 14 medical, 33 surgical	Weaning ability; albumin	Nutritional support: 1) protein-free isotonic IV (400 Kcal) n = 33, 2) enteral or TPN (2000-3000 Kcal) n = 14	Chi Square	Standard IV diet: n=33 Duration of MV mean 9.2 days; mean age 61.5; 30 of 33 had albumin < 30; 18 of 33 weaned; rest died of multiple organ failure. Nutritional supp. grp: Duration of MV: mean 9.3 days; mean age 72.7 yrs; all 14 had albumin < 30; 13 of 14 weaned.
Larca & Greenbaum 1982	To de-termine useful-ness of intensive nutritional therapy in pts who fail to wean	Retro-spective/ Descrip-tive	14 pts. excluding terminal illnesses & mentally impaired Diagnoses: 10 COPD, 2 CHF, 1 Restrictive, 1 Dermatomyositis	Albumin, Transferrin, Total lymphocytes, Values recorded on transfer out of ICU for nutr. support & again with hospital outcome	Aggressive nutritional support: 4 TPN 10 Enteral	Stat. tests not men-tioned, yet signif. reported	Nutritional intake not different between successful & unsuccess-ful outcomes. Successful: n=8 mean age 66.8 yrs. Albumin increased .71 g/dl after nutr. support back to baseline values; Transferrin increased from 125 ± 13 mg/dl to 152 ± 64 mg/dl; mean time on vent. 18.5 days. Failure: n=6 mean age 73.3 yrs. 5 of 6 died; Albumin continued to fall

Appendix C Weaning Failure

Authors Date	Purpose	Sampling/ Design	Sample Type	Dependent Variables	Independent Variables	Stats	Weaning Def./ Study Results
Larca & Greenbaum 1982 (contd.)							despite nutritional support: 3.4 g/dl to 2.7 g/dl; Transferrin decreased from 104 ± 27 mg/dl to 94 ± 28 mg/dl; mean time on vent: 28.8 days. Total lymphocytes didn't change in either group.
van den Berg & Stam, 1988	•To study effect of nutrition on VO2 & VCO2 in pts on long-term MV •To study effect of nutritional support on VO2 & ABG's during weaning	con-venience/ Quasi-exp.	9 pts. 6 males, 3 females; Diagnoses: 4 Gullian-Barre; 3 polyneuropathy; 1 tetanus; 1 COPD. All vent. dependent & stable; 4 of 9 had weaning trials, but don't state which patients they were. Duration of vent. not stated	Ve, f, VO2, VCO2, ABG's	Enteral feeding: at moderate intake (1.5 x resting energy expenditure) & high intake (2 x resting energy expenditure); Weaning trials: 2 modified T piece, 2 CPAP for 30 min. to 1 hr. during post-absorptive state compared to trials during feeding	Trends means SD	Moderate intake: increased VCO2 18 ml/min/m2; High intake increased VCO2 38 ml/min/m2; With moderate intake Ve increased to compensate therefore PaCO2 did not change; High Calorie intake Ve increased approx. 500 ml/min. Pts unable to sustain the added work and PaCO2 increased approx. 10 mmHg; Length of spont. breathing trial 30 min to 1 hr. in both experimental conditions

Appendix D Treatment of Weaning Failure

Authors Date	Purpose	Sampling	Sample Type	Dependent Variables	Treatment Description	Results/ Conclusions
Belman 1981	To describe rationale for isocapnic hyperpnea & feasibility of its implementation	Case studies/ Descriptive	2 pts. with hypercapnic resp. failure #1 60 year old male; #2 61 year old male; both with COPD	Ve recorded at end of each min. of training; End tidal CO2 recorded continuously; Outcome of weaning	Vent. muscle training with isocapnic hyperpnea; Started while pts. still on vent. & continued postextubation; #1 Started after 5 days of vent.; had three days of train- before extubated. #2 Started after 3 days on vent.; had 6 days of training before extubated. Pts instructed to breathe as deeply & quickly as possible for 15 min. if possible. FiCO2 titrated to maintain end tidal value. Pts completed 3-6 runs per day, were rested on assist control vent. at 10-12 breaths per min. between training sessions	Both trained without complication; Training associated with weaning success. Wide scatter of training Ve but overall trend- gradual improvement of Ve could sustain. Long-term effects post extubation: decreased dyspnea & ability to complete self care activities

Appendix D Treatment of Weaning Failure

Authors Date	Purpose	Sampling	Sample Type	Dependent Variables	Treatment Description	Results/ Conclusions
Aldrich et al. 1989	To use inspiratory resistive training to improve respiratory muscle endurance in pts. considered unweanable	Convenience	27 pts who failed repeated weaning attempts & who had stable chronic, respiratory failure. Excluded active infections, unstable CV, renal, or endocrine or malnourished. Diagnoses: 7 Neuromuscluar 20 COPD	NIF, VC, T-piece tolerance	Inspiratory muscle resistive (R) training used with or without IMV. 2-14 sessions/ week. Increased amount of R depending on patient tolerance. If no improvement in 2 weeks, training terminated. Increased FiO2 given during training	Mean duration of vent: 12.8 weeks. 12 weaned successfully (4 neuromuscular) after 21 sessions in 21 days; 1 died; 5 weaned to nocturnal vent. (3 neuromusc.) after 18 sessions in 52 days; 10 unweanable after 21 sessions in 30 days (6 of 10 did show improvement of PFT) MIP & VC improved in all pts, but most dramatically in successful grp. Complication: bradycardia and syncopy in one pt.
LaRiccia, et al., 1985	To describe a case where biofeedback & hypnosis improved breathing pattern & facilitated	Case study/ Descriptive	30 year old female with multiple sclerosis who had failed IMV weaning Duration of vent.	Ve, Vt, f, VC, NIF, movements of chest & abdomen; weaning outcome	Biofeedback of movements of chest wall on oscilloscope via magnetometers; Hypnosis via eye fixation with suggestion to visualize breathing normally as had 5 yrs. before; Verbal praise given for increased chest	Paradoxic motion reversed; Weaning successful after 8 sessions; Pre Post Ve 6.5 5.7 f 26 20 Vt 249 286 VC 420 600 NIF -28 -20 Anxiety not mea-

Appendix D Treatment of Weaning Failure

Authors Date	Purpose	Sampling	Sample Type	Dependent Variables	Treatment Description	Results/ Conclusions
LaRiccia, et al., 1985 (contd.)	weaning.		not stated		movement; Sessions lasted 50-90 min.	sured, but stated was decreased.
Acosta 1987	To report 2 cases of weaning difficult pts with hypnosis induced relaxation	Case studies/ Descriptive	2 pts. #1- 60 yr old female with ALS who could not tolerate spont. vent. > 2.5 hrs. due to "fear of suffocation" #2 -70 yr old male with COPD and alcoholism could not tolerate > 2 hrs of spont. vent. due to "air hunger"	Anxiety on 3 point scale measured before and after sessions; Oximetry measured continuously	Hypnotically induced relaxation by eye fixation during T piece trials; Sessions lasted approx. 20 min.	#1 Treatment started after T piece trials for 23 days were unsuccessful. After 8 days of hypnosis, required vent. only at night. #2 Failed 1 weaning attempt after 10 days of MV, reintubated, attempted to wean again 2 days later but trials were unsuccessful; After 6 days of unsuccessful trials, treatment with hypnosis began; Weaned after 3 days of treatment. Discharged after 9. Subjective anxiety decreased

Appendix D Treatment of Weaning Failure

Authors Date	Purpose	Sampling	Sample Type	Dependent Variables	Treatment Description	Results/ Conclusions
Acosta 1988	To report how bio-feedback & pro-gressive relaxa-tion were combined to aid a pt with COPD and appre-hension during weaning trials	Case study/ Descrip-tive	58 yr old male with COPD & pneumonia who could tolerate only 4 hrs of spont. vent. despite adequate weaning parame-ters due to "fear of suffocation"	HR, RR measured before & after each session; SaO2 before, during & after sessions	Biofeedback of oximetry readings; Progressive relax-ation (tighten & relax muscles) in dark room, sitting in comfort-able chair; Sessions lasted 30 min.; Required 12 sessions.	T piece trials started after 46 days on vent. Time off vent. gradually in-creased from half hour to 13 hrs. Eventually weaned HR & RR de-creased, & SaO2 increased after sessions. SaO2 decreased or stayed the same during sessions. (Increased energy expended?)

APPENDIX E
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO
Consent to be a research subject

Purpose and Background:

Dr. Susan Janson-Bjerklie and Ann Knebel, RN, MSN, from the Department of Physiological Nursing, are conducting a study to learn if there is a relationship between feelings and breathing ability following gradual withdrawal of breathing machine support, using two different methods. Because I am judged by my doctors to be ready to begin breathing without the help of the breathing machine, I am asked to participate in this study

Procedures

If I agree to be in this study, the following will happen:

I will fill out a brief questionnaire that asks about how I am feeling.The amount of support the breathing machine gives me will be gradually decreased using two different methods. One of the methods is the standard usually used, the other is newer and therefore has not been tested as extensively. My breathing will be closely monitored on a recorder placed at my bedside.

Periodically, during the time I am breathing with less help from the machine, I will be asked whether or not I am short of breath or anxious and if so how much.

Eventually, I will breathe for a short period without the help of the machine. I will then rest for two hours. If at any time I feel uncomfortable and unable to continue breathing with less support from the machine, the level of support will be increased until I am comfortable again. After the two hours of rest, the level of support will be gradually decreased a second time until I breathe on my

own again briefly.

Participation in the study will take a total of three hours for the first procedure, including setting up of equipment and baseline measurements on full ventilator support. After the two hours of rest, the second procedure will take 2-3 hours.

All procedures will take place in my bed in the intensive care unit at the Medical Center at the University of California, San Francisco.

Risks/Discomforts

If I do not tolerate the decreased support from the breathing machine, I may become short of breath or the percent of oxygen in my blood may fall. There is also a slight chance that my heart will skip beats or may beat too fast. Any changes will be monitored closely and will be remedied by increasing the support from the breathing machine.

Confidentiality: Participation in research will be handled as confidentially as possible within the law. All my research records will be coded with a number and kept in a locked cabinet, only the study investigator will have access to my records.

Treatment and Compensation for Injury

If I am injured as a result of being in this study, treatment will be available. The costs of such treatment may be covered by the University of California depending on a number of factors. The University does not normally provide any other form of compensation for injury. For further information about this, I may call the office of the Committee on Human Research at (415) 476-1814.

Benefits

If I require continued ventilator support following the research study, the results of the study may help the doctor to understand the reasons why I am having trouble breathing without the machine. If I do not require further breathing assistance, the information gained from the study may help in the treatment of other patients with conditions like mine.

Alternatives

If I choose not to participate, my care will not be affected and the standard method of withdrawing breathing machine support will be used.

Costs

I will not be charged for any of the study procedures or measurements. All costs will be paid by the investigator.

Reimbursement

I will not be reimbursed for participating in this study.

Questions

This study has been explained to me by Ann Knebel, RN, MSN and my questions were answered. If I have any other questions about the study, I may call Dr. Janson-Bjerklie at (415) 476-5282 or Ann at (415) 566-5546.

Consent

I have been given copies of this consent form and the Experimental Subject's Bill of Rights to keep. Participation in research is voluntary. I have the right to decline to participate or to withdraw at any point in this study without jeopardy to my medical care. If I wish to participate, I should sign below.

Date	Subject's signature
6/27/89	Person obtaining consent

APPENDIX F

Dyspnea Intensity Visual Analogue Scale

HOW SHORT OF BREATH ARE YOU RIGHT NOW?

None **Extremely Severe**

APPENDIX G
Short Profile of Mood States

Below is a list of words that describe feelings people have. Please read each one carefully. Then choose one answer from the four options which best describes

How do you feel today.

NOT AT ALL..... 0
A LITTLE..... 1
MODERATELY..... 2
QUITE A BIT..... 3
EXTREMELY.....4

TENSE	LIVELY	ACTIVE	ENERGETIC
ANGRY	CONFUSED	ON EDGE	HOPELESS
WORN OUT	PEEVED	GROUCHY	UNEASY
UNHAPPY	SAD	BLUE	RESTLESS
RESENTFUL	BITTER	WEARY	WORTHLESS
NERVOUS	EXHAUSTED	BEWILDERED	FORGETFUL
MISERABLE	ANXIOUS	FURIOUS	VIGOROUS
CHEERFUL	HELPLESS	FULL OF PEP	

UNCERTAIN ABOUT THINGS
BUSHED

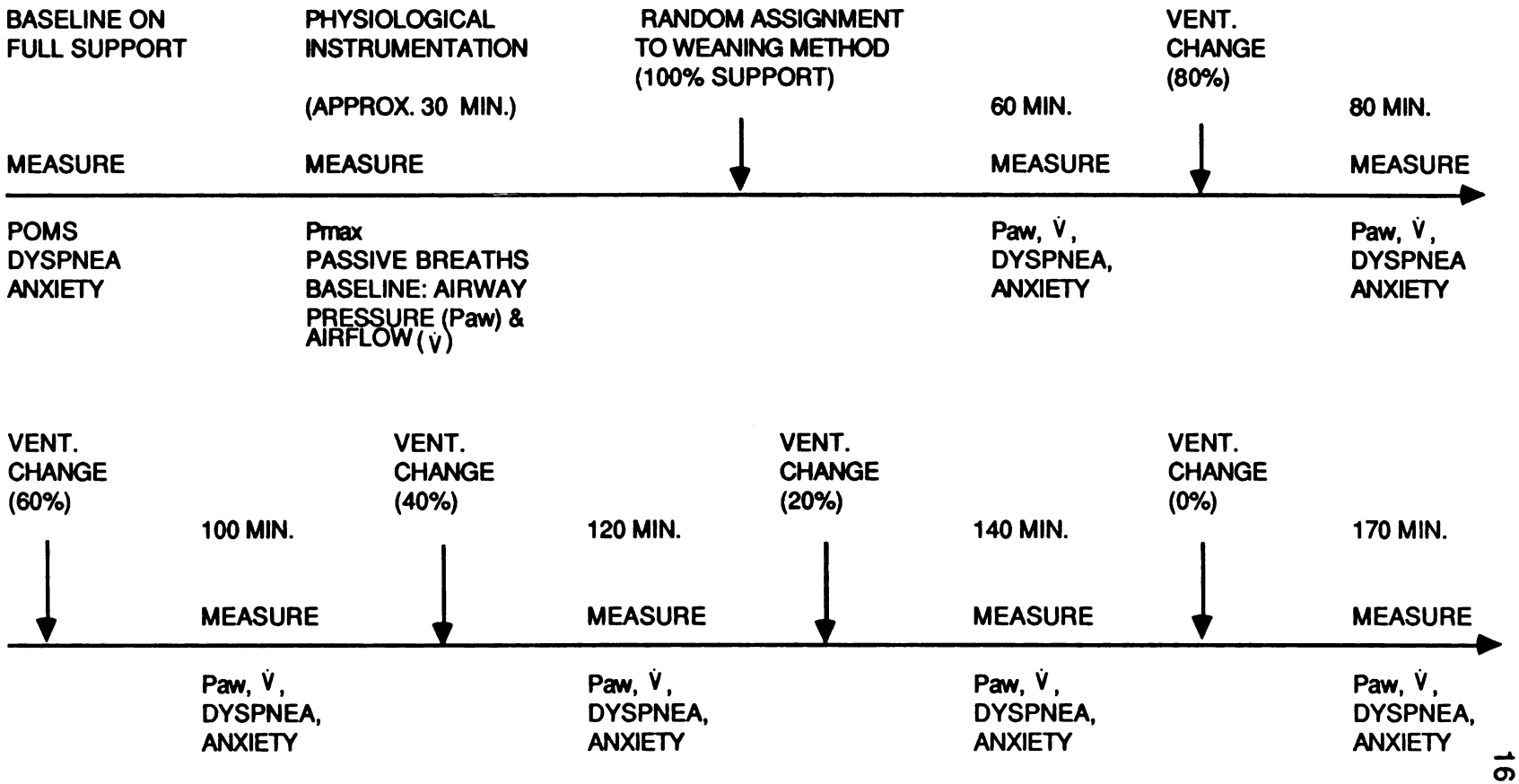
APPENDIX H

Anxiety Visual Analogue Scale

HOW DO YOU FEEL RIGHT NOW?

Not at all anxious **Extremely anxious**

APPENDIX I
DATA COLLECTION SEQUENCE



REST THEN REPEAT FOR SECOND METHOD

APPENDIX J Demographic Data

ID _____ Age _____

Sex _____ Cultural Background_____

Diagnosis

_____

Reasons for ventilation

_____

Prior ventilator experience Yes No number of times _____

Size of ET tube _____ Date of intubation _____

Lab	Values	Date
Hgb	_____	_____
Hct	_____	_____

Sedative/ Narcotics given in 12 hours preceeding data collection

Medication	Dose	Last time given
_____	_____	_____
_____	_____	_____
_____	_____	_____

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