Subjective Perceptions and Physiological Variables During Weaning From Mechanical Ventilation

By Renee Twibell, RN, DNS, Debra Siela, RN, DNSc, CCRN, APRN, BC, CCNS, RRT, and Mahnaz Mahmoodi, RN, MS. From School of Nursing, Ball State University and Critical Care Division, Ball Memorial Hospital, Muncie, Ind.

• BACKGROUND *As costs related to mechanical ventilation increase, clear indicators of patients' readiness to be weaned are needed. Research has not yet yielded a consensus on physiological variables that are consistent correlates of weaning outcomes. Subjective perceptions rarely have been examined for their contribution to successful weaning.*

• OBJECTIVE *To explore the subjective perceptions of dyspnea, fatigue, and self-efficacy and selected physiological variables in patients being weaned from mechanical ventilation.*

• METHODS *Data were collected prospectively on 68 patients being weaned from mechanical ventilation. Subjective perceptions were measured by using 3 visual analog scales; physiological variables were measured by using the Burns Weaning Assessment Program and a patient profile. Weaning outcomes were recorded 24 hours after data collection.*

• RESULTS *Participants were primarily white women and required mechanical ventilation for a mean of less than 4 days. Participants reported mild dyspnea, moderate fatigue, and high weaning self-efficacy. High Pa_{O_2}, low Pa_{CO_2}, stable hemodynamic status, adequate cough and swallow reflexes, no metabolic changes, and no abdominal problems were associated with complete weaning (*P = .05). Subjective perceptions were associated with physiological variables but not with weaning outcomes.*

• CONCLUSIONS *Multidimensional assessment of both primary and secondary indicators of readiness to be weaned is necessary for timely, efficient weaning from mechanical ventilation. Primary assessments include physiological variables related to gas exchange, hemodynamic status, diaphragmatic expansion, and airway clearance. Secondary assessments include perceptions related to key physiological variables. Additional research is needed to determine the predictive value of physiological variables and perceptions of dyspnea, fatigue, and self-efficacy. (American Journal of Critical Care. 2003;12:101-112)*

As the population of the United States ages, the number of patients requiring mechanical ventilation is increasing.[1] Costs of hospitalization soar when mechanical ventilation is required,[2-6] and patients report that the experience of mechanical ventilation is uncomfortable and psychologically distressing.[7-11] Timely, effective weaning can limit the human and economic cost of mechanical ventilation.[1,12-15]

In 1993, weaning from mechanical ventilation was identified as a high priority for research in critical care settings.[16] Despite the many research studies on strategies for effective weaning, little consensus has evolved about key predictors of patients' readiness for weaning.[7,17-35] Weaning assessment tools include mea-

surement of potential physiological predictors,[36-38] but few physiological measures provide consistent and accurate estimates of weaning outcomes.[19-21] Patients' subjective perceptions may influence weaning outcomes[19,20,39-44] but are often omitted from assessment plans or receive minimal attention.[18,20,44,45] Accurate assessment of patients' readiness to be weaned is necessary to limit prolonged mechanical ventilation and prevent premature extubation.

Literature Review

Physiological measures that can influence complete weaning are gas exchange variables, including oxygenation,[21,22,24,30,46] $PaCO_2$,[21] and oxygen cost of breathing[47,48]; arterial pH[21,46]; pulmonary mechanics, including vital capacity,[24,28,46] rapid shallow breathing index,[27,35-39,49-57] negative inspiratory pressure,[17,21,23,24,26,28,29,55-57] minute ventilation,[23,24,28,29,46,50,54,55,57-62] mandatory minute volume,[29] respiratory rate,[25-27,48,50,54-56,59,60,62-66] tidal volume,[25,26,47,48,50,54,55,58-60,62,66,67] maximum inspiratory pressure,[50,54,60,62,64,65,68] and maximum voluntary ventilation[29]; somnolence[18]; hemodynamic variables, including mean arterial pressure,[21,46] systolic blood pressure,[66,69] cardiac output,[70] and ejection fraction[18,46]; patients' age[18,54]; and scores at admission on the Acute Physiology and Chronic Health Evaluation II[53,71] (Table 1). However, these variables are not consistent predictors of weaning in all populations of patients. Burns consolidated potential physiological predictors in the Burns Weaning Assessment Program (BWAP), which has been more sensitive than other measures for predicting patients' readiness to be weaned.[38]

■ Although shortening the duration of mechanical ventilation reduces hospitalization costs and complications, variables that are consistent correlates of successful weaning have not been identified. Although a wide variety of physiological parameters have been studied repeatedly, signs and symptoms such as dyspnea, fatigue, and the patient's confidence in weaning success (weaning self-efficacy) have received less attention, and their role in weaning is not clear.

Results of studies have suggested the importance of subjective perceptions to patients' readiness to be weaned, including dyspnea,[9,10,39,43,72,73] anxiety,[7,44] fatigue,[9,10,41,42] anger,[42] hopelessness,[7] depression,[7,41,72] hope,[39] social support,[39] sense of mastery,[39] uncertainty,[40] stress,[40] and weaning self-efficacy[44] (Table 1). However, few investigators have identified subjective perceptions as correlates of weaning outcomes, and none have examined relationships between subjective perceptions and physiological variables in patients being weaned from mechanical ventilation.[21] We are especially interested in the subjective perceptions of dyspnea, fatigue, and weaning self-efficacy.

Perceptions of dyspnea during mechanical ventilation and weaning were examined in a few studies. In interviews with patients after extubation, Logan and Jenny[9] found that dyspnea was a primary subjective experience during weaning. In studies by Powers and Bennett[73] and Knebel,[72] patients had moderate[73] and high[72] levels of dyspnea during mechanical ventilation. Connelly et al[42] and Bouley et al[43] found low to moderate levels of dyspnea in patients receiving mechanical ventilation. No differences in dyspnea were noted between patients who were weaned completely from mechanical ventilation and those who were not.[42] Knebel et al[74] and Bouley et al[43] examined the occurrence of dyspnea during different methods of weaning and found no differences between the methods.

Perceptions of fatigue during mechanical ventilation and weaning were examined in 4 studies.[8-10,42] In an investigation by Logan and Jenny,[9] patients ($n = 20$) who were interviewed after extubation reported a lack of energy, extreme fatigue, and exhaustion during weaning that decreased breathing effectiveness and caused discomfort and frustration.

Weaning self-efficacy is defined as confidence in one's ability to breathe without ventilatory support.[7,9] However, research that measures perceptions of self-efficacy during weaning is scarce. Moody et al[39] found that sense of mastery related to weaning from mechanical ventilation was a significant predictor of complete weaning in a sample of long-term ventilator-dependent patients. Although sense of mastery was conceptualized as an indicator of self-efficacy, mastery was measured by using 6 Likert-scale items that focused on perception of personal control.

Purpose

The influence of subjective perceptions and physiological variables on weaning outcomes remains inconclusive. The role of subjective perceptions is particularly unclear. Therefore, the aim of this study was to explore perceptions of dyspnea, fatigue, weaning self-efficacy, and selected physiological parameters in a sample of intubated patients who were beginning an initial weaning process.

The study was conceptualized within the framework of the Weaning Continuum Model,[17] which has 3 stages of weaning. In the preweaning stage, patients' physiological conditions are unstable, and critical preadmission factors are unresolved. In the weaning process stage, multiple variables influence the course of

Table 1 Variables that may influence weaning outcomes in adults*

Physiological variables		Perceptual variables	
Pulmonary mechanics	Oxygenation[46]	Dyspnea[9,10,39,43,73]	Depression[7,41,72]
Vital capacity[46]	Oxygen cost of breathing[47,48]	Fatigue[9,10,42]	Social support[39]
Negative inspiratory pressure[55-57]	$Paco_2$[21]	Anxiety[7,44]	Sense of mastery[39]
Minute ventilation[46]	Arterial pH[46]	Anger[42]	Uncertainty[40]
Maximum inspiratory pressure[54,60,62,64,65,68]	Hemodynamic status[18,69]	Hopelessness[7]	Stress[40]
Respiratory rate[27,48,54,55,59,62-66]	Mean arterial pressure[46]	Hope[39]	Self-efficacy[44]
Tidal volume[48,54,55,58-60,62,66-67]	Ejection fraction[18]		
Rapid shallow breathing index[27,35,36,39,54,56,57,59,63,64,68]	Cardiac output[70]		
Age[18,54]	Systolic blood pressure[66,69]		
Somnolence[18]	Score on Acute Physiology and Chronic Health Evaluation II on admission[53,71]		

*From published research, 1992 to 2002.

weaning, and peaks and valleys in patients' progress are common. Indicators of readiness to be weaned include oxygenation, ventilatory drive, nutrition, and psychological outlook. Cardiopulmonary assessments during weaning include evaluation of dyspnea. In the weaning outcomes stage, weaning efforts may be complete or incomplete. In our study, we focused on patients who were moving through the weaning process stage to the weaning outcomes stage.

Methods

Design and Sample

The study was descriptive, correlational, and prospective. It was approved by the institutional review board of the participating institution. Data were collected in a 17-bed medical-surgical intensive care unit in a midwestern state. The convenience sample consisted of 68 adults who had been receiving mechanical ventilation for at least 24 hours. Additional inclusion criteria included state of alertness, ability to see and hear, ability to understand English, physical and mental ability to complete the research instruments, age 18 years or older, and a physician's expressed intent to wean the patient within the next 24 hours.

■ During the weaning process, the patient's report of level of dyspnea, fatigue, and weaning confidence (weaning self-efficacy) were recorded along with data from the Burn's Weaning Assessment Program. Weaning outcome (weaned completely or incompletely) was documented 24 hours later.

Because multiple weaning trials may increase patients' anxiety and dyspnea, potential participants were excluded if they had experienced previous weaning attempts during the current hospitalization. Patients were also excluded if they were candidates for terminal weaning. Because no previous research had indicated differences in subjective perceptions between patients receiving short- and long-term mechanical ventilation, all patients who had received mechanical ventilation for at least 24 hours were potential participants in the study.

Instruments

Subjective Perceptions. Fatigue, dyspnea, and weaning self-efficacy were measured by using visual analog scales (VASs). The VAS instrument, consisting of a 100-mm vertical line, is a valid and reliable measure of subjective phenomena in a variety of populations[75-79] and in selected cohorts of patients treated with mechanical ventilation.[7,11,72,73] The VAS line used to measure fatigue was anchored at the top by the words "as tired as I can possibly be" and at the bottom by the words "not at all tired." The dyspnea VAS was anchored at the top by "shortness of breath as bad as can be" and at the bottom by "no shortness of breath." The weaning self-efficacy VAS was anchored at the top by "no confidence" and at the bottom by "completely confident." The 3 VAS tools were printed in large letters in black ink on bright gold paper, and each VAS was on a separate page.

Physiological Variables. Physiological data were collected by using the BWAP[38] and the Patient Information Form. Items on the BWAP included 12 general criteria and 14 respiratory criteria. Nine general criteria, including such variables as body strength, adequacy of nutrition, electrolyte levels (sodium, potassium, chloride, carbon dioxide content, magnesium, phosphorus, and calcium corrected for albumin level), hydration, and hemodynamic status, were assessed by means of a paper chart review. Three general variables on the

BWAP, level of anxiety, adequacy of sleep/rest, and pain control, were not physiological variables but were still evaluated in the study. Respiratory criteria, such as spontaneous respiratory rate, no abdominal problems including distention, thinness of secretions, cough and swallow reflexes, negative inspiratory pressure, spontaneous tidal volume, vital capacity, and arterial blood gases, were evaluated by using a paper chart review. Responses to all items on the BWAP were scored as yes, no, or not assessed.

The Patient Information Form was designed for recording demographic variables, such as medical diagnoses, smoking history, and duration of mechanical ventilation. The form was completed by using paper chart reviews.

Data Collection

The researchers and 2 critical care staff nurses collected data. First, patients were evaluated for the extent to which they met inclusion criteria. If a patient met all inclusion criteria, consent to participate was obtained from him or her. The 3 VAS tools were presented in a consistent order: the dyspnea VAS first, the weaning self-efficacy VAS second, and the fatigue VAS third. While the patient looked at each tool, the data collector read the words on each VAS and provided a pencil or pen for the patient to mark on the scale. Ninety percent of the participants were able to mark on the VAS. Seven pointed to the place on the VAS where they wanted their mark placed. Then the BWAP and Patient Information Form were completed by using the patients' records.

Each patient's weaning process during the next 24 hours was recorded in the patient's chart, including changes in ventilator settings, the patient's responses, and time of extubation or discontinuation of weaning. Patients were categorized as completely weaned if extubation and spontaneous breathing without distress occurred within 24 hours after the VAS tools were completed. Patients who were not extubated or who had distress after 24 hours were categorized as incompletely weaned. Distress was defined as increased work of breathing greater than baseline values, decreased pulse oximetry values, abnormal results on blood gas analyses, verbalizations of fatigue, and verbalizations of intolerable dyspnea or anxiety.

Data Analysis

Data were analyzed by using the SPSS Advanced Statistics for Windows statistical package, version 8.0 (SPSS Inc, Chicago, Ill). Descriptive analysis was used to determine mean sample characteristics. Participants listed more than 1 admitting diagnosis. Relationships among variables were examined by using χ^2 of association and Pearson product moment correlations. Differences between selected groups were analyzed by using *t* tests and analysis of variance. Logistic regression was used to examine predictive significance of study variables. The significance level was set at $P < .05$.

Results

Characteristics of the Sample

Three women who met the study criteria declined to participate because of fatigue. No participants dropped out of the study after data collection began.

The sample was predominately white women who were experiencing chronic obstructive pulmonary disease (COPD) or respiratory failure (Tables 2 and 3). No participants were admitted for myocardial infarction or cardiac surgery. All participants were weaned by using synchronized intermittent mandatory ventilation or pressure-support ventilation. Forty-five participants (66%) were treated with mechanical ventilation for 3 days or fewer.

■ Overall, patients reported mild dyspnea, moderate fatigue, and high weaning confidence. As found in previous studies, several physiological variables were associated with successful weaning (high PaO2, low PaCO2, stable hemodynamic status, adequate cough and swallow reflexes, no metabolic changes), whereas abdominal distention was associated with incomplete weaning. Although dyspnea, fatigue, and weaning self-efficacy were not directly associated with weaning outcomes in this study, their effect on physiological variables may influence weaning outcome indirectly.

According to the BWAP data, three fourths of the sample were adequately nourished, had stable hemodynamic and metabolic status, had adequate cough or swallow reflexes, had no abdominal problems, had normal respiratory values, and were receiving adequate pain control. Most of the patients had thin secretions, normal levels of electrolytes, improvements in their condition as indicated by chest radiographs, improved body strength, appropriate levels of anxiety, and adequate rest. Thirty-two participants (47%) had smoked tobacco within the preceding year. Fifty-four participants (79%) were weaned successfully within 24 hours after they completed the VAS instruments.

VAS scores were categorized as mild (0-39 mm), moderate (40-60 mm), and high (61-100 mm).[41,68] Over-

Table 2 Sex, ethnicity, and admitting diagnosis/purpose of admission of the sample

Characteristics	Total sample (n = 68)		Weaned completely (n = 54)		Weaned incompletely (n = 14)	
	No.	%	No.	%	No.	%
Sex						
Male	25	37	19	35	6	43
Female	43	63	35	65	8	57
Ethnicity						
White	66	97	52	96	14	100
African American	2	3	2	4	0	0
Admitting diagnosis/purpose of admission						
Chronic obstructive pulmonary disease	36	53	28	52	8	57
Respiratory failure	30	44	24	44	6	43
Pneumonia	9	13	5	9	4	29
Vascular surgery	9	13	9	17	0	0
Gastrointestinal surgery	13	19	10	19	3	21
Congestive heart failure	13	19	12	22	1	7

all, the participants reported mild dyspnea, moderate fatigue, and high weaning self-efficacy (Table 4).

Physiological Variables and Weaning Outcomes

The physiological variables significantly associated with complete weaning included $Paco_2$ 40 mm Hg or less, Pao_2 60 mm Hg or greater when the fraction of inspired oxygen was 0.40, stable hemodynamic status, no metabolic change such as fever, adequate cough/swallow reflexes, and no abdominal distention (Table 5). Physiological variables associated with complete weaning at $P = .07$ were eupneic spontaneous respiratory rates and normal arterial pH.

Physiological variables not significantly associated with weaning outcomes included the general assessment variables of nutritional status, electrolyte levels, body strength, hydration, hematocrit, bowel problems, and improvement in condition as indicated by chest radiographs. Also not significantly associated with weaning outcomes were the respiratory criteria of negative inspiratory pressure, spontaneous tidal volume, vital capacity, no neuromuscular disease or deformity, no adventitious breath sounds, thin secretions, and size of endotracheal tube. Data on positive expiratory pressure were not adequate for analysis. The 3 nonphysiological variables of pain, adequacy of sleep/rest, and level of anxiety were not significantly associated with weaning outcomes.

Data were missing for up to 8 participants (12%) on several physiological measures. However, results related to these variables most likely were not affected, because data were not missing in a systematic manner. The number of participants with missing data accounted for less than 20% of the total number of patients in the study. The only variables that may have been influenced by missing data were improvement in condition as indicated by chest radiographs and body strength, for which data were available for 48 and 53 participants, respectively.

Subjective Perceptions

We found no significant associations between weaning outcomes and the 3 subjective perceptions. Although patients who were not completely weaned reported more fatigue, more dyspnea, and less weaning self-efficacy than did the patients who were completely weaned, differences between the 2 groups were not significant.

An examination of relationships among the 3 VAS scores (Table 6) indicated that dyspnea was significantly

Table 3 Duration of mechanical ventilation and age of the sample

Characteristic	Total sample (N = 68)				Weaned completely (n = 54)				Weaned incompletely (n = 14)			
	Mean	SD	Range	Median	Mean	SD	Range	Median	Mean	SD	Range	Median
Days of mechanical ventilation	3.72	3.59	1-15	3.0	3.22	3.1	1-10	2.0	5.6	4.7	1-15	4.0
Age, years	66.64	13.88	19-93	66.0	67.8	14.4	19-93	70.0	62.1	10.8	40-77	59.0

Table 4 Subjective perceptions of the sample

Perception	Total sample (n = 68)		Weaned completely (n = 54)		Weaned incompletely (n = 14)	
	Mean	SD	Mean	SD	Mean	SD
Dyspnea	35.54	28.48	35.1	30.1	37.2	21.8
Weaning self-efficacy	72.46	29.60	73.7	28.6	67.6	34.0
Fatigue	44.74	33.05	42.7	31.9	52.6	37.3

associated with fatigue and weaning self-efficacy. The greater the degree of dyspnea was, the lower the perception of self-efficacy and the greater the perception of fatigue were. The relationship between fatigue and weaning self-efficacy was not significant.

Patients with adequate Pao_2 and those with improvement in their condition as indicated by chest radiographs reported lower levels of fatigue than did patients with inadequate Pao_2 and no radiographic evidence of improvement in their condition (Table 7). In addition, patients who were adequately rested reported less fatigue than did those with inadequate rest.

Patients with adequate Pao_2 reported significantly less dyspnea than did patients who had lower Pao_2 (Table 8). Differences in degree of dyspnea between patients with adequate and inadequate $Paco_2$ were not significant ($P = .06$).

Higher levels of weaning self-efficacy were significantly related to stable hemodynamic status ($\chi^2 = 54.5$, $df = 1$, $P = .04$) and no metabolic changes ($\chi^2 = 59.0$,

Table 5 Relationship of physiological variables to weaning outcomes (N = 68)*

Variable	Weaned completely (n = 54)		Weaned incompletely (n = 14)		Pearson $\chi^{2\dagger}$	*P*
	No.	%	No.	%		
$Paco_2 \leq 40$ mm Hg with minute ventilation <10 L/min						
Yes	40	85	5	38	11.47	.001
No	7	15	8	62		
$Pao_2 \geq 60$ mm Hg with fraction of inspired oxygen of 0.40						
Yes	46	98	10	77	7.18	.007
No	1	2	3	23		
Absence of abdominal distention						
Yes	44	86	8	62	4.16	.04
No	7	14	5	38		
Adequate cough/swallow reflexes						
Yes	50	98	11	85	4.18	.04
No	1	2	2	15		
Hemodynamic status						
Stable	50	98	12	86	3.79	.05
Unstable	1	2	2	14		
Free from metabolic change						
Yes	48	94	10	77	3.61	.05
No	3	6	3	23		
Eupneic spontaneous respiratory rate						
Yes	45	94	10	77	3.27	.07
No	3	6	3	23		
pH 7.30-7.45						
Yes	42	89	9	69	3.24	.07
No	5	11	4	31		

*Missing data <13% for some physiological variables.
†$df = 1$.

Table 6 Pearson *r* correlation coefficients among subjective perceptions (N = 68)*

Perception	Dyspnea	Fatigue	Self-efficacy
Dyspnea	—		
Fatigue	.50*	—	
Self-efficacy	-.40*	-.23†	—

*$P < .001$.
†$P = .06$.

df = 1, *P* = .02). Differences in degree of weaning self-efficacy between groups for BWAP variables were evaluated by using *t* tests (Table 9). Patients with appropriate levels of anxiety, no metabolic changes, adequate nutrition, normal electrolyte levels, eupneic respiratory rates, adequate pain control, and improvement in body strength reported significantly greater degrees of self-efficacy. However, results must be considered with caution, because the increased prevalence of type I error that occurs when multiple *t* tests are done.

Other Findings

Duration of Mechanical Ventilation. Patients who received short-term ventilation were more likely than those who received long-term ventilation to be completely weaned ($\chi^2 = 4.74$, df = 1, *P* = .03). The only physiological factor significantly associated with short-term ventilation was no abdominal problems, such as distention ($\chi^2 = 3.6$, *df* = 1, *P* = .04). Differences in subjective perceptions between patients who required mechanical ventilation for 3 days or fewer and patients who required mechanical ventilation for more than 3 days were not significant.

Smoking. Patients who had smoked tobacco within the preceding year were younger (*t* = -3.0, *P* = .004), had higher systolic blood pressure (*t* = 2.4, *P* = .02), higher diastolic blood pressure (*t* = 2.9, *P* = .006), and higher $Paco_2$ ($\chi^2 = 4.5$, df = 1, *P* = .004) than did those who did not smoke.

Respiratory Diagnoses. Patients with an admitting diagnosis of COPD had significantly lower levels of weaning self-efficacy than did patients without COPD (*t* = -2.0, *P* = .05). Differences in dyspnea or fatigue between those with and without COPD were not significant. Stable hemodynamic status was significantly associated with a diagnosis of COPD ($\chi^2 = 3.8$, *df* = 1, *P* = .05), as were inadequate sleep/rest ($\chi^2 = 4.4$, *df* = 1, *P* = .04) and inappropriate levels of anxiety ($\chi^2 = 7.3$, *df* = 1, *P* = .007). Associations between weaning outcomes and duration of mechanical ventilation and a diagnosis of COPD were not significant.

Gender-Related Differences. The women in the study were significantly more likely than the men to have inadequate sleep/rest ($\chi^2 = 5.6$, *df* = 1, *P* = .02). The men were significantly more likely than the women to require mechanical ventilation because of respiratory failure ($\chi^2 = 8.7$, *df* = 1, *P* = .003). No other study variables were associated with sex-related differences.

Prediction of Weaning Outcomes

We used further statistical analysis to examine the predictive value of study variables for weaning outcomes. Results of logistic regression computations were not conclusive, partly because of the relatively small number of patients who were not completely weaned. For further analysis, groups of equal sizes were artificially created. Eight patients were identified who were not completely weaned and for whom no data were missing. Eight patients who were completely weaned were randomly selected as a comparative group. The general BWAP variable abdominal disten-

Table 7 Comparison of fatigue perceptions in the presence or absence of physiological variables (N = 68)*

Variable	Fatigue					
	No.	Mean	SD	*t*	*df*	*P*
Adequate sleep/rest						
Yes	43	41.3	33.4	-2.1	58	.04
No	17	60.9	32.1			
Pao_2 ≥60 mm Hg with fraction of inspired oxygen of 0.40						
Yes	57	41.2	33.0	-2.1	59	.04
No	4	76.3	23.2			
Improvement as indicated by chest radiographs						
Yes	40	41.6	31.4	-2.0	46	.05
No	8	65.8	31.9			

*Missing data from <11% to <30% for some physiological variables.

Table 8 Comparison of dyspnea perceptions in the presence or absence of physiological variables (N = 68)*

Variable	Dyspnea					
	No.	Mean	SD	*t*	*df*	*P*
Pao_2 ≥60 mm Hg with fraction of inspired oxygen of 0.40						
Yes	57	32.0	26.6	-2.1	59	.04
No	4	60.5	19.6			
$Paco_2$ ≤ 40 mm Hg with minute ventilation <10 L/min						
Yes	45	30.0	26.7	-1.9	58	.06
No	15	45.3	26.2			

*Missing data <12% for some physiological variables.

tion and the respiratory BWAP variable $PaCO_2$ 40 mm Hg or less were included in the logistic regression analysis because they had the strongest associations with weaning outcomes. All 3 subjective perception variables were retained. Results indicated that $PaCO_2$ was a significant predictor of complete weaning ($P = .05$). The subjective perceptions did not explain additional significant variance in weaning outcomes when general and respiratory assessments were controlled for.

Discussion

Physiological Variables

Physiological variables that reflected gas exchange, airway clearance, diaphragmatic expansion, and hemodynamic balance were clearly associated with complete weaning. $PaCO_2$ 40 mm Hg or less was the respiratory variable that most strongly correlated with successful weaning outcomes. No abdominal distention was the general variable that most strongly correlated with successful weaning outcomes. Our findings that gas exchange is associated with complete weaning are consistent with those of previous research.[21,22,25,26,35,52,53] Goodnough Hanneman et al[21] concurred with the implications of our study that $PaCO_2$ was a crucial correlate of weaning outcomes. Goodnough Hanneman et al[21] furthermore suggested that previous research[24] did not include true negatives related to the prediction of incomplete weaning on the basis of poor arterial oxy-

Table 9 Comparison of weaning self-efficacy perceptions in the presence or absence of physiological variables (N = 68)*

Variable	Weaning self-efficacy					
	N	Mean	SD	*t*	*df*	*P*
Appropriate anxiety						
Yes	49	76.6	27.7	3.1	58	.003
No	11	48.0	27.6			
Free from metabolic change						
Yes	59	74.4	28.7	2.6	63	.01
No	6	42.5	28.0			
Adequate nutrition						
Yes	51	77.2	27.0	2.6	63	.01
No	14	55.2	32.5			
Normal electrolyte levels						
Yes	48	76.9	28.6	2.36	64	.02
No	18	58.1	29.2			
Eupneic spontaneous respiratory rate						
Yes	56	75.4	28.4	2.2	60	.03
No	6	48.0	32.1			
Pain controlled						
Yes	57	73.0	28.4	2.2	61	.03
No	6	45.7	34.6			
Improvement in body strength						
Yes	28	77.5	28.1	2.1	51	.04
No	25	60.7	30.4			

*Missing data <3% to <22% for some physiological variables.

genation and that therefore oxygenation alone is not sensitive enough for predicting weaning outcomes in all populations. Our study included a patient who met the oxygenation criteria and yet was incompletely weaned. Therefore, as best practice guidelines are developed for assessment of readiness to be weaned, both PaO_2 and $PaCO_2$ must be considered.

$PaCO_2$ was not used as a variable related to weaning in recent studies, perhaps because of the invasive procedure required to obtain samples for arterial blood gas analysis and the time required to obtain results. Instead, measures of pulmonary mechanics were studied. However, in our study, none of the pulmonary mechanics variables were as strongly associated with weaning outcomes as was $PaCO_2$. Our study, however, did not include pulmonary mechanics variables not on the BWAP, such as rapid shallow breathing index, maximum inspiratory pressure, and minute ventilation.

The finding that abdominal distention was associated with incomplete weaning and with longer time on mechanical ventilation is consistent with the results of previous research. In earlier studies, body positioning in intubated patients with abdominal distention influenced respiratory rate,[80] tidal volume,[80, 81] fatigue,[82] and carbon dioxide retention.[82] Our data suggest that patients may benefit from optimal positioning during the weaning process. Burns et al[80] recommended elevation of the patient's head to 45° as an optimal position for diaphragmatic expansion in patients receiving mechanical ventilation. Curley[83] reviewed 9 studies and recommended prone positioning with abdominal protrusion to improve gas exchange and pulmonary mechanics in patients with acute respiratory failure.

Our finding that adequate cough/swallow reflexes clearly correlate with complete weaning is logical; however, the relationship between airway maintenance and weaning outcomes has not been fully explicated in research or reported in other studies. Neuromuscular disorders, although not a correlate of weaning outcomes in this study, may influence the strength of cough reflexes, and cough reflexes did correlate significantly with weaning outcomes.

The finding of an association between arterial pH and weaning outcomes at $P = .07$ was consistent with previous research by Goodnough Hanneman.[46] Almost 50% of the patients with abnormal pH in our study were incompletely weaned. Conversely, 90% of patients who had a normal pH were completely weaned. Further research is needed to fully explicate the role of pH in weaning, because pH can be influenced by respiratory, renal, and circulatory function.

Although a stable hemodynamic status has been associated with weaning outcomes in cardiac patients,[18,21,22,27,37,46,70] our finding of a similar association is novel in a sample of noncardiac patients. However, specific indicators of stable hemodynamic status differed from previous studies. Per the BWAP, we considered pulse rate and cardiac output in determining hemodynamic status. In other studies, hemodynamic status was defined as a specific pulmonary artery systolic pressure[22] or as hypotension or hypertension that required pharmacological intervention.[46] The data from all these studies suggest that clinicians can closely consider multiple indicators of hemodynamic function when estimating a patient's readiness to be weaned.

Our finding of an association between eupneic respiratory rate and weaning outcomes at $P = .07$ is consistent with the results of previous studies.[18,21,25-27,37,46,48,54,55,60,64,66,68] The value of respiratory rate as an indicator of readiness to be weaned may be enhanced when it is considered along with measures of tidal volume and work of breathing, as in the rapid shallow breathing index.[28,37,48,54,55,59,60,62-66,68]

The relationships between minute ventilation, maximum voluntary ventilation, vital capacity, tidal volume, negative inspiratory pressure, and weaning outcomes are not clear. Although our findings concur with those of others[21,24,52,53] that certain variables in pulmonary mechanics are not strong predictors of weaning outcomes, some investigators[23,25,26,28,29,55-57] contend conversely that certain mechanical variables are valuable indicators of weaning success. The subjects in these comparative studies were cardiac surgery patients,[27,46] postoperative patients,[24,29] or neurological patients,[55] or the samples had fewer than 20 patients.[26,28] Our sample was predominately medical patients less than 70 years old. Further research is warranted to clarify the role of pulmonary mechanics as correlates of weaning outcomes in patients with and without pulmonary disease.

Our finding that nutrition was not a significant correlate of weaning outcomes was in contrast to previous findings in samples of long-term ventilator-dependent patients.[27,32,33,52] In a finding consistent with ours, in a study by Gluck,[35] albumin levels were not a predictor of weaning outcomes in a small sample of patients treated with long-term mechanical ventilation. The significance of albumin levels for weaning outcomes may depend on the population of patients and the duration of ventilator support.

Subjective Perceptions

In contrast to previous researchers,[73] we found that subjective perceptions were associated with physiological variables, which in turn were related to weaning outcomes. Subjective perceptions were not directly

associated with weaning outcomes. Interrelationships among perceptions, physiological variables, and weaning outcomes may be complex and nonlinear. Our data suggest that little significant variance in weaning outcomes is likely to be explained by a single subjective variable. Patients will benefit most from a multifactorial preweaning assessment that includes both subjective and objective assessments.

Fatigue and Dyspnea. Fatigue and dyspnea were associated with respiratory assessment variables but not with general assessment variables. Dyspnea was pivotally related both to gas exchange values and to fatigue and weaning self-efficacy. Our results extend previous findings of a relationship between dyspnea and lack of vigor[42] and suggest that dyspnea warrants further study as a direct or indirect indicator of readiness to be weaned.

Our patients reported quantitatively that they experienced mild degrees of dyspnea and moderate degrees of fatigue during weaning. The degree of dyspnea and fatigue reported by this sample of patients, who received mechanical ventilation for a short time, was similar to the intensity of symptoms reported by patients treated long-term with mechanical ventilation[41,42] and was consistent with qualitative reports that dyspnea and fatigue are pervasive and bothersome sensations during weaning.[7,9,10] In contrast, the patients in our study reported less dyspnea than did patients in 2 other studies.[72,73] Interventions to increase patients' comfort are warranted and may include positioning, rest and sleep management, visual imagery, reassurance, administration of sedatives, optimal air movement in the room, and energy conservation measures.

Self-efficacy. Although weaning self-efficacy did not directly influence outcomes, an attitude of self-efficacy may correlate with other factors in the weaning experience and therefore be critical to weaning success, as suggested by others.[38,39,44] For example, weaning self-efficacy was significantly associated with metabolic status and hemodynamic stability, which in turn were significantly associated with weaning outcomes.

Increased weaning self-efficacy was strongly associated with perceptions of reduced anxiety. The experience of anxiety during mechanical ventilation is well known.[38,42,84] Interventions to reduce anxiety may include coaching, reassurance, presence with the patient, comfort measures, administering anxiolytics, providing information, and optimizing visitation by patients' family members.[9,10,38,84]

Limitations

Our results were limited by the sample size, specifically by the number who were incompletely weaned. The results of logistic regression must be considered with caution, because of the small sample size. One patient in particular seemed to make an important contribution to the outcome of this analysis, a situation that suggests that the findings may not be replicable. An additional condition that affected the inconclusive results of the logistic regression was the quasi-complete separation of values on predictor variables. In the data set, the significant predictors of complete weaning were distinctly different from the predictors of incomplete weaning. Logistic regression is more powerful when an approximately even split of values exists between participants who were completely weaned and those who were incompletely weaned.[85]

In order to successfully use logistic regression as a statistic with the BWAP variables, a sample size of 100 is needed to allow detection of odds ratios between 1.65 and 2.72, depending on the split of values on predictor variables and the standard error of measurement.[86]

Nominal level of measurement of variables on the BWAP may have limited the findings. Interval-scale measurement may be more powerful than yes and no responses. For example, the recording of exact numbers for variables such as vital capacity, spontaneous tidal volume, hematocrit, negative inspiratory pressure, $PaCO_2$, and pH would allow for more rigorous statistical tests and may increase the likelihood that statistical significance could be found. Furthermore, the BWAP did not include all potential variables that might influence weaning outcomes.

Ordering of the VAS instruments may have influenced the findings. Fatigue scores may have been accentuated because the fatigue VAS was consistently presented last in the sequence.

An additional limitation may have been the assessment of weaning self-efficacy during an initial weaning attempt. When patients responded to the self-efficacy VAS, they at times were hesitant and looked puzzled. Conversely, patients readily marked the VAS tools for dyspnea and fatigue. Perhaps patients who are beginning an initial weaning attempt do not have a clear perception of what the experience might be like and find it difficult to report confidence about weaning. Logan and Jenny[9] identified one dimension of mechanical ventilation as "sense making," in which participants who tried to "make sense" of mechanical ventilation reported feelings of disorientation and difficulty anticipating the future. Further qualitative work on weaning self-efficacy is needed.

Conclusion

Our results indicate that $PaCO_2$ and PaO_2 are particularly strong correlates of weaning outcomes. Sub-

■ Although these results are limited by the small sample size, they may assist in the development of a clinical profile for weaning readiness that includes both physiological and subjective parameters.

jective perceptions, although not directly correlated with weaning outcomes, are associated with physiological variables that in turn influence outcomes. The findings are important in developing a clinical profile for weaning readiness that may include a set of primary assessments and a set of secondary assessments. Our data support hemodynamic status, cough/swallowing reflexes, abdominal distention, metabolic status, and $Paco_2$ and Pao_2 as primary assessment variables. Secondary assessment variables include dyspnea, fatigue, and weaning self-efficacy, which may influence the primary variables. In addition, our findings indicate the need for development and testing of interventions to modify perceptions of fatigue and dyspnea.

Continued research on indicators for readiness to be weaned is critical to limit patients' length of stay in acute care settings and increase patients' comfort. Best practice in weaning from mechanical ventilation also requires the following future studies:

• prospective studies with larger sample sizes to predict weaning outcomes;

• comparison of predictors in homogenous populations, such as patients receiving short-term and long-term mechanical ventilation;

• qualitative investigation of weaning self-efficacy to define dimensions of the concept and refine measurement;

• examination of interrelationships among specific diagnoses, sex, and outcomes;

• development and testing of critical pathways for the weaning of specific subgroups of patients; and

• examination of differences across weaning modes.

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Commentary by Mary Jo Grap (see shaded boxes).

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