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Mechanical Ventilation: Weaning Protocols

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Mechanical Ventilator Weaning Protocols Driven by Nonphysician Health-Care Professionals

Evidence-Based Clinical Practice Guidelines

Abstract

Health-care professionals (HCPs) can provide protocol-based care that has a measurable impact on critically ill patients beyond their liberation from mechanical ventilation (MV). Randomized controlled trials have demonstrated that protocols for liberating patients from MV driven by nonphysician HCPs can reduce the duration of MV. The structure and features of protocols should be adapted from published protocols to incorporate patient-specific needs, clinician preferences, and institutional resources. As a general approach, shortly after patients demonstrate that their condition has been stabilized on the ventilator, a spontaneous breathing trial (SBT) is safe to perform and is indicated. Ventilator management strategies for patients who fail a trial of spontaneous breathing include the following: (1) consideration of all remediable factors (such as electrolyte derangements, bronchospasm, malnutrition, patient positioning, and excess secretions) to enhance the prospects of successful liberation from MV; (2) use of a comfortable, safe, and well-monitored mode of MV (such as pressure support ventilation); and (3) repeating a trial of spontaneous breathing on the following day. For patients who pass the SBT, the decision to extubate must be guided by clinical judgment and objective data to minimize the risk of unnecessary reintubations and self-extubations. Protocols should not represent rigid rules but, rather, guides to patient care. Moreover, the protocols may evolve over time as clinical and institutional experience with them increases. Useful protocols aim to safely and efficiently liberate patients from MV, reducing unnecessary or harmful variations in approach.

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This research was supported by National Institutes of Health grant No. AG01023-01A1 (EWE) and a Beeson Scholarship from the American Federation for Aging Research (EWE).

Introduction

Many advances have been made regarding the optimal methods of weaning ventilatory support and liberating patients from the ventilator. These efforts are important because mechanical ventilation (MV) is associated with considerable morbidity, mortality, and costs.[1] [2] [3] However, the premature discontinuation of MV can contribute to the incidence of failed extubation, nosocomial pneumonia, or increased mortality.[4] [5] [6] Traditionally, physicians have approached the discontinuation of MV through a gradual reduction in ventilatory support, which is reflected in universally applied but varying forms of "weaning." However, this gradual approach may unnecessarily delay the extubation of patients who have recovered from respiratory failure. With better recognition of the complications of MV, and with increasing awareness of the resources consumed during the care of patients experiencing respiratory failure, a change in the culture of weaning is well-supported by the literature. Evidence supports the current concept of "liberation" from MV [7] [8] [9] (*ie*, that the timely recognition of recovery from respiratory failure is more important than the manipulation of MV in an attempt to facilitate weaning). Furthermore, utilizing the skills and expertise of nonphysician health-care professionals (HCPs) can improve patient outcomes.

The McMaster University Evidence-Based Practice Center has conducted a comprehensive review of the literature regarding weaning to address key questions posed by the Agency for Health Care Policy and Research (AHCPR).[1] To create this 380-page document, which reviewed approximately 1,000 articles from 1971 to 2000, the authors chose 154 articles for final review and evaluation. Among the many aspects of weaning reviewed by the McMaster-AHCPR investigators, the strongest conclusions were drawn in regard to the development and implementation of ventilator weaning protocols and the use of nonphysician HCPs (*eg*, respiratory-care practitioners [RCPs] and nurses) in the ICUs to enhance patients' liberation from MV.

Materials and Methods

We have described the methods of our reviews in the introduction to this supplement and in the article concerning alternative discontinuation assessment methods and weaning modes. Herein, we summarize these methods briefly, focusing on aspects specific to this topic.

Eligibility Criteria

We included all studies of adult patients who were receiving MV that compared weaning conducted according to an explicit protocol to the traditional, physician-directed approach. We included randomized trials, or controlled nonrandomized studies. We excluded studies that reported physiologic outcomes exclusively.

Search for Relevant Studies
To identify relevant studies, we searched MEDLINE, EMBASE, HEALTHStar, CINAHL, the Cochrane Controlled Trials Registry, and the Cochrane Data Base of Systematic Reviews from 1971 to September 1999, and we examined the reference lists of all included articles for other potentially relevant citations.

Data Abstraction and Assessment of Methodological Quality
Five respiratory therapists and five intensivists participated in data abstraction and in rating the methodological quality of all eligible randomized trials or nonrandomized controlled cohort studies that addressed treatment issues. One of the investigators rechecked the final data abstraction. The methodological features of randomized trials that we abstracted included the following: the method of randomization and whether randomization was concealed; the extent to which groups were similar with respect to important prognostic factors; whether investigators conducted an intention-to-treat analysis; whether patients, clinicians, and those assessing outcome were blind to allocation; the extent to which the groups received similar cointerventions; and reporting of the reasons for study withdrawal. For nonrandomized controlled clinical trials, we considered the extent to which groups were similar with respect to important prognostic factors, whether the investigators adjusted for differences in prognostic factors, and the extent to which the groups received similar cointerventions.

Statistical Analysis
We abstracted or, when necessary, calculated effect sizes in terms of relative risks (RRs) and associated 95% confidence intervals (CIs) for binary outcomes and mean differences and 95% CIs for continuous variables.

Results

We identified four randomized controlled trials (RCTs) that compared protocol-based weaning to conventional weaning (Table 1).[9] [10] [11] [12] One very small trial[10] (15 patients) compared computer-directed weaning to physician-directed weaning and found trends in favor of the computer-directed weaning in both nonextubation and reintubation rates (Table 2).

Table 1.. Characteristics of RCTs Comparing Weaning Protocols to Physician-Directed Weaning*

Study/yr	ICU Population	Method of Randomization	Concealment	Weaning Criteria Reported	Extubation Criteria Reported	Reintubation Criteria Reported
Strickland and Hasson[10] /1993	15 adults with acute respiratory failure MV in a multidisciplinary ICU	Randomization table	Sealed envelopes	Yes	No	No
Ely et al[9] /1996	300 adults MV in medical and coronary ICUs	Randomization table	Sealed opaque envelopes	Yes	No	No
Kollef et al[11] /1997	357 adults MV in 4 medical and surgical ICUs	Coin flip	Sealed opaque envelopes	Yes	Yes	No
Marelich et al[12] /2000	335 adults MV in a medical and trauma ICU	Randomization table	Sealed opaque envelopes	Yes	No	No

* MV = receiving mechanical ventilation.

Table 2.. Results of Individual RCTs Comparing Weaning Protocols to Physician-Directed Weaning*

Study/yr	Outcome	Results	Effect Magnitude	p Value
Strickland and Hasson[10] /1993†				
Continuous variables	Duration of weaning, h	Int 1: 18.70 ± 5.90 Int 2: 25.60 ± 5.60	- 6.90 (- 12.88–- 0.92)‡	0.02
Binary variables	Nonextubation	Int 1: 2/9 patients Int 2: 4/6 patients	0.39 (0.12–1.30)§	0.13

	Reintubation	Int 1: 0/7 patients Int 2: 2/2 patients	0.08 (0.00–1.15)[§]	0.06
	Combined end point	Int 1: 2/9 patients Int 2: 6/6 patients	0.27 (0.09–0.80)[§]	0.02
Ely et al[9] /1996[‖]				
Continuous variables	ICU LOS, d	Int 1: 8.00 ± 10.50 Int 2: 9.00 ± 8.25	- 1.00 (- 3.14–1.14)[‡]	0.36
	Hospital LOS, d	Int 1: 14.00 ± 12.75 Int 2: 15.50 ± 18.00	- 1.50 (- 5.03–2.03)[‡]	0.41
	Duration of MV, h	Int 1: 108.00 ± 126.00 Int 2: 144.00 ± 144.00	- 36.00 (- 66.64–-5.36)[‡]	0.02
	Duration of weaning, h	Int 1: 24.00 ± 36.00 Int 2: 72.00 ± 90.00	- 48.00 (- 63.55–-32.45)[‡]	< 0.01
Binary variables	MV for > 21 d	Int 1: 9/149 patients Int 2: 20/151 patients	0.43 (0.21–0.90)[§]	0.03
	Self-extubation	Int 1: 2/149 patients Int 2: 5/151 patients	0.46 (0.11–2.02)[§]	0.30
	Reintubation	Int 1: 5/149 patients Int 2: 12/151	0.45 (0.17–1.18)[§]	0.11

		patients		
Kollef et al[11] /1997[¶]				
Continuous variables	Hospital LOS, d	Int 1: 12.70 ± 9.40	- 1.50 (- 3.70–0.70)[‡]	0.18
		Int 2: 14.20 ± 11.70		
	Duration of intubation, h	Int 1: 35.00 ± 74.25	- 9.00 (- 32.36–14.36)[‡]	0.45
		Int 2: 44.00 ± 141.00		
Binary variables	Hospital mortality	Int 1: 40/179 patients	0.95 (0.65–1.38)[§]	0.78
		Int 2: 42/178 patients		
	Reintubation	Int 1: 23/158 patients	1.18 (0.67–2.08)[§]	0.56
		Int 2: 18/147 patients		
	Requiring MV > 7 d	Int 1: 21/179 patients	0.68 (0.41–1.13)[§]	0.13
		Int 2: 31/178 patients		
	Combined end point	Int 1: 44/179 patients	0.89 (0.63–1.27)[§]	0.53
		Int 2: 49/178 patients		
Marelich et al[12] /2000[¶]				
Continuous variables	Duration of MV, h	Int 1: 68 (33–164)[#]	56[‡]	0.0001[**]
		Int 2: 124 (54–334)[#]		
Binary variables	Hospital mortality	Int 1: 17/166 patients	1.70 (0.81–3.54)[§]	0.16
		Int 2: 10/169 patients		

	Ventilator-associated pneumonia	Int 1: 11/166 patients Int 2: 20/169 patients	0.57 (0.29–1.14)§	0.11
	Combined end point	Int 1: 15/166 patients Int 2: 10/169 patients	1.50 (0.71–3.19)§	0.29

* Values given as mean ± SD, unless otherwise indicated. LOS = length of stay; Combined end point = nonextubation plus reintubation.

†Int 1 = intervention 1 (computer-directed weaning); Int 2 = intervention 2 (physician-directed weaning).

‡Values given as differences in means (95% CI).

§Values given as RR (95% CI).

‖ Int 1 = intervention 1 (daily screening plus SBT protocol); Int 2 = intervention 2 (physician-directed weaning).

¶ Int 1 = intervention 1 (protocol by nurse and respiratory therapist); Int 2 = intervention 2 (physician-directed weaning).

Values given as median (interquartile range).

** From survival analysis.

Three RCTs[9 11 12] compared weaning protocols that were largely implemented by RCPs and nurses to conventional physician-directed weaning. These trials were all methodologically strong (Table 1) and, for this field, very large (300 to 357 patients). All three studies enrolled virtually all patients who were receiving MV in the participating units during the study periods.

Ely and colleagues[9] reported a two-step protocol that was driven by nurses and RCPs incorporating daily screening followed by a spontaneous breathing trial (SBT). Although the 151 patients who were managed in the medical and coronary ICUs and were in the intervention group had a higher severity of illness than the 149 control patients, they were removed from the ventilator 1.5 days earlier, had 2 fewer days of weaning, had 50% fewer complications related to the ventilator, and had mean ICU costs of care that were lower by more than $5,000 lower per

patient.[9] These investigators studied patients whose median durations of MV were 4.5 and 6 days, respectively, in the protocol-directed and physician-directed groups. The RR of successful extubation in the protocol-directed group was 2.13 (95% CI, 1.55 to 2.92; $p < 0.001$), indicating that MV was successfully discontinued sooner in the protocol-directed group than in the control group. The largest separation between groups was at approximately 5 days, and differences disappeared by about 15 days. Patients in the physician-directed group spent a day longer in the ICUs and 1.5 days longer in the hospital. Neither of these differences reached statistical significance.

Kollef and colleagues[11] conducted their study in four ICUs using three different weaning protocols that had been developed and tested by the ICU staff prior to the start of the study. Despite the large sample size, the power of their study to detect differences in key end points was limited by the fact that most patients spent a relatively short period of time on the ventilator. In the protocol-directed and physician-directed groups, 25% of the patients were extubated by 15 and 21 h, respectively, 50% were extubated by 35 and 44 h, respectively, and 75% were extubated by 114 and 209 h, respectively. Only 12% and 17%, respectively, of the patients spent > 7 days on the ventilator. Survival and regression analyses suggested a difference that favored patients in the protocol group. Simple analyses also favored the protocol-directed group, but they failed to reach statistical significance (Table 2) .

In a more recent investigation that included 335 patients (approximately 50% surgical, and predominantly trauma), Marelich and colleagues[12] showed in an RCT that the use of a weaning protocol incorporating multiple daily SBT assessments shortened the median duration of MV from 124 to 68 h ($p = 0.001$). Investigators censored patients in the protocol group for whom attending physicians violated the protocol, potentially excluding from the analysis patients who were destined to wean more slowly from ventilation. This may overestimate the reported benefit of the weaning protocol with respect to the duration of ventilation; thus, these results are potentially misleading.

In addition to these RCTs, 11 non-RCTs have examined the impact of, largely, respiratory therapist-directed or nursing-directed weaning compared to physician-directed weaning on weaning outcomes in critically ill patients (Tables 3 4 4A).[13] [14] [15] [16] [17] [18] [19] [20] [21] These studies, conducted in a variety of populations, are generally much larger than the corresponding RCTs but are more prone to bias, given their observational design (Table 3) . The results of these nonrandomized studies are generally consistent with the results of the RCTs, demonstrating statistically significant reductions or trends toward reductions in the duration of MV and ICU length of stay. Protocol-based weaning was associated with other favorable process-of-care outcomes such as fewer arterial blood gas analyses. Mortality and reintubation rates did not appear to differ between the experimental and control groups. Complications of protocol-based weaning were not reported.

Table 3.. Characteristics of Clinical Non-RCTs Comparing Weaning Protocols to Physician-Directed Weaning*

Study/yr	ICU Population	Demonstrate Baseline Similarity	Cointervention Similarity	Weaning Criteria Reported	Extubation Criteria Reported	Reintubation Criteria Reported
Foster et al[13] /1984	Cardiac bypass surgery (n = 63)	Age	Not demonstrated	Yes	Yes	No
Tong[14] /1991	Postoperative (n = 54)	Age	Not demonstrated	No	No	No
Rotello et al[15] /1992	Multidisciplinary adult ICU (n = 63)	Proportion with pneumonia, COPD	Not demonstrated	Yes	No	No
Wood et al[16] /1995	Cardiac surgery (n = 284)	Age	Not demonstrated	Yes	Yes	No
Saura et al[17] /1996	Adult medical (n = 101)	Age, prestudy time on ventilation, COPD, APACHE II score	Not demonstrated	Yes	Yes	No
Djunaedi et al[18] /1997	Multidisciplinary adult ICU (n = 107)	Age, proportion postoperative, APACHE II score	Not demonstrated	Yes	Yes	No
Burns et al[19] /1998	Multidisciplinary adult (n = 409)	Proportion postoperative, with neuromuscular disease, time on ventilation	Not demonstrated	Yes	No	No
Horst et al[20] /1998	Postoperative adult ICU (n = 893)	APACHE II score	Not demonstrated	Yes	Yes	No
Kollef et al[21]	Surgical ICU (n = 347)	None reported	Not demonstrated	No	No	No

/1998						
Kollef et al[21] /1998	Mixed adult ICU (n = 88)	Age, MPM score	Not demonstrated	No	No	No
Kollef et al[21] /1998	Mixed adult ICU†	Age	Not demonstrated	No	No	No

* APACHE = acute physiology and chronic health evaluation; MPM = mortality prediction model.

†No. of patients not reported.

Table 4.. Results of Individual Clinical Non-RCTs Comparing Weaning Protocols to Physician-Directed Weaning*

Study/yr	Outcome	Results	Effect Magnitude	p Value
Foster et al[13] /1984†				
Continuous variables	Duration of MV, h	Int 1: 10.80 ± 4.50 Int 2: 18.20 ± 8.50	- 7.40 (- 10.65–- 4.15)‡	< 0.01
	Duration of intubation, h	Int 1: 9.80 ± 4.40 Int 2: 16.50 ± 8.00	- 6.70 (- 9.79–- 3.61)‡	< 0.01
	ABGs performed, No.	Int 1: 6.60 ± 2.00 Int 2: 11.40 ± 5.30	- 4.80 (- 6.68–- 2.92)‡	< 0.01
Binary variables	Nonextubation	Int 1: 22/36 patients Int 2: 26/27 patients	0.64 (0.49–0.83)§	< 0.01

Tong[14] /1991[‖]				
Continuous variables	ABGs performed, No.	Int 1: 3.40 ± 0.50 Int 2: 6.20 ± 1.90	- 2.80 (- 3.85–- 1.75)[‡]	< 0.01
Rotello et al[15] /1992[¶]				
Continuous variables	Duration of weaning, min	Int 1: 170.00 ± 93.00 Int 2: 307.00 ± 131.00	- 137.00 (- 199.00–- 75.00)[‡]	< 0.01
	ABGs performed, No.	Int 1: 1.06 ± 0.24 Int 2: 2.85 ± 0.69	- 1.79 (- 2.02–- 1.56)[‡]	< 0.01
Wood et al[16] /1995[#]				
Continuous variables	Duration of MV, h	Int 1: 19.78 ± 7.58 Int 2: 21.00 ± 9.60	- 1.22 (- 3.62–1.18)[‡]	0.32
	Duration of weaning, h	Int 1: 3.01 ± 2.93 Int 2: 3.30 ± 4.65	- 0.29 (- 1.42–0.84)[‡]	0.61
Binary variables	Reintubation	Int 1: 1/55 patients Int 2: 3/142 patients	1.10 (0.17–7.27)[§]	0.92
Saura et al[17] /1996[**]				
Continuous variables	ICU LOS, d	Int 1: 16.70 ± 16.50 Int 2: 20.30 ± 13.20	- 3.60 (- 9.43–2.23)[‡]	0.23
	Duration of MV, d	Int 1: 10.40 ± 11.60 Int 2: 14.40 ±	- 4.00 (- 8.28–0.28)[‡]	0.07

		10.30		
	Duration of weaning, d	Int 1: 3.50 ± 3.90 Int 2: 3.60 ± 2.20	- 0.10 (- 1.34–1.14)‡	0.87
Binary variables	ICU mortality	Int 1: 4/51 patients Int 2: 8/50 patients	0.52 (0.18–1.52)§	0.23
	Nonextubation	Int 1: 5/51 patients Int 2: 4/50 patients	1.20 (0.37–3.92)§	0.76
	Reintubation	Int 1: 9/51 patients Int 2: 7/50 patients	1.24 (0.52–2.98)§	0.63
	Tracheostomy	Int 1: 1/51 patients Int 2: 4/50 patients	0.33 (0.05–1.99)§	0.23
Djunaedi et al[18] /1997†				
Continuous variables	Duration of MV, d	Int 1: 3.89 ± 4.43 Int 2: 3.18 ± 3.98	0.71 (- 0.89–2.31)‡	0.39
Burns et al[19] /1998††				
Continuous variables	Hospital LOS, d	Int 1: 12.70 ± 15.14 Int 2: 14.80 ± 15.68	- 2.10 (- 6.73–2.53)‡	0.37
	Duration of MV, h	Int 1: 11.60 ± 12.47 Int 2: 12.90 ± 13.57	- 1.30 (- 5.23–2.63)‡	0.52

Horst et al[20] /1998[†]				
Continuous variables	Duration of MV, h	Int 1: 112.60 ± 164.00 Int 2: 170.60 ± 164.00	- 58.00 (- 79.77–- 36.23)[‡]	< 0.01
Binary variables	ICU mortality	Int 1: 63/515 patients Int 2: 55/378 patients	0.84 (0.60–1.17)[§]	0.31
	Reintubation	Int 1: 2/515 patients Int 2: 6/378 patients	0.28 (0.07–1.21)[§]	0.09

[*] Values given as mean ± SD, unless otherwise indicated. ABG = arterial blood gas analysis; IMV = intermittent mandatory ventilation. NE = no estimate of variance was available/calculable. See Table 2 for abbreviations not used in the text.

[†] Int 1 = intervention 1 (respiratory therapist-directed protocol); Int 2 = intervention 2 (physician-directed weaning).

[‡] Values given as differences in means (95% CI).

[§] Values given as RR (95% CI).

[‖] Int 1 = intervention 1 (computer-directed weaning); Int 2 = intervention 2 (physician-directed weaning).

[¶] Int 1 = intervention 1 (nurse-directed oxygen weaning); Int 2 = intervention 2 (physician-directed weaning).

[#] Int 1 = intervention 1 (respiratory therapy-directed IMV weaning protocol); Int 2 = intervention 2 (physician-directed weaning). [**] Int 1 = intervention 1 (protocol-directed weaning); Int 2 = intervention 2 (physician-directed weaning).

[††] Int 1 = intervention 1 (multidisciplinary protocol-directed weaning); Int 2 = intervention 2 (physician-directed weaning).

[‡‡] Int 1 = intervention 1 (nurse and respiratory therapist-directed weaning protocol); Int 2 = intervention 2 (physician-directed protocol).

Table 4A.. Continued

Study/yr	Outcome	Results	Effect Magnitude	p Value
Kollef et al[21] /1998†				
Continuous variables	ICU LOS, d	Int 1: 4.40 ± NE	- 1.67‡	
		Int 2: 6.07 ± NE		
	Duration of MV, h	Int 1: 121.90 ± NE	- 48.70‡	
		Int 2: 170.60 ± NE		
Kollef et al[21] /1998‡‡				
Continuous variables	Hospital LOS, d	Int 2: 11 ± NE	- 3.00‡	
	ICU LOS, d	Int 1: 4.00 ± NE	- 4.00‡	
		Int 2: 8.00 ± NE		
	Duration of MV, h	Int 1: 72.00 ± NE	- 72.00‡	
		Int 2: 144.00 ± NE		
Binary variables	Hospital mortality	Int 1: 14/53 patients	0.84 (0.44–1.60)§	0.59
		Int 2: 11/35 patients		
Kollef et al[21] /1998‡‡				
Continuous variables	Hospital LOS, d	Int 1: 15.60 ± NE	- 4.60‡	
		Int 2: 20.20 ± NE		
	ICU LOS, d	Int 1: 5.80 ± NE	- 2.30‡	
		Int 2: 8.10 ± NE		
	Duration of MV, h	Int 1: 21.60 ± NE	- 43.20‡	
		Int 2: 112.80 ± NE		

Discussion

To provide clinicians with the most useful information set for the design and implementation of weaning protocols, we have structured this section into seven key recommendations (Table 5). The results of the foregoing evidence-based review were incorporated into the first three recommendations. The last four recommendations were derived from emerging data about weaning from MV and extubation, the optimal delivery of sedation and analgesia in the ICU, and the need for an objective and graded plan of implementation.

Table 5.. Summary of Recommendations for MV Weaning Protocols*

Recommendation Description
1. Nonphysician HCPs should be included in the development and utilization of protocols related to weaning from MV;
2. ICU clinicians should utilize protocols for liberating patients from MV to safely reduce its duration;
3. Clinicians should conduct SBTs at least once daily to identify patients who are ready for liberation from the ventilator;
4. When patients fail an SBT, clinicians should attend to potentially remediable factors, choose a safe and comfortable mode of MV with the head elevated at 30° to 45°,[46] conduct SBTs at least once daily, and, in the face of repeated failures, consider performing a tracheotomy or long-term care facilities;
5. When patients pass an SBT, clinicians should seriously consider prompt extubation;
6. For the delivery of psychoactive medications, clinicians should consider protocols that include daily ventilatory cessation and targeted sedation goals to reduce the duration of MV and ICU stay; and
7. For the implementation of weaning protocols, consider the following strategies: development of goals using an evidence-based approach by a multidisciplinary team; and implementation using effective behavior-changing strategies such as interactive education, opinion leaders, reminders, audit, and feedback.

* PSV = pressure-support ventilation; SIMV = synchronized intermittent mandatory ventilation. See Table 2 for abbreviations not used in the text.

Respiratory Care Provided by Nonphysician HCPs
Considerable evidence exists that allied HCPs can implement respiratory-care protocols that enhance clinical outcomes for critically ill patients with respect to appropriate blood gas analysis or chest physiotherapy.[21] [22] [23] [24] [25] [26] Respiratory-care protocols (*i.e.*, therapist-driven or patient-driven protocols) have been investigated extensively during the past few years.[27] [28] [29] [30] [31] From these studies, we have learned that the use of protocols can improve clinical outcomes and enhance the appropriate allocation of respiratory-care services.

Recommendation 1: *Based on evidence from randomized trials, we recommend that nonphysician HCPs be included in the development and utilization of respiratory-care protocols (not confined to liberation from MV).*

Weaning Protocols
The McMaster evidence-based AHCPR report on weaning[1] concluded that there is strong evidence that weaning protocols can, under some circumstances, decrease the length of time that a patient spends on the ventilator. These protocols may be organized and led by physician opinion leaders, then implemented on a daily basis by nonphysician HCPs. A major transition in thought regarding weaning began in 1994 and 1995, when it was demonstrated for the first time in RCTs,[8] [32] that one modality of weaning might be superior to another if it was executed in a specified fashion. However, these data did not establish that a weaning protocol was superior to the standard of care, which was the individual physician's best management.[33] Now, the results of three randomized trials,[9] [11] [12] including 992 patients, suggest that protocols can, at least under some circumstances, result in important decreases in the duration of MV. The implementation of nurse-driven or RCP-driven weaning protocols, regardless of the specific weaning mode employed, can significantly expedite safe liberation from MV.[1] [31]

That three RCTs using appreciably different protocols have all demonstrated statistically significant reductions in the time spent receiving MV (although the magnitude of the difference between groups varied substantially) suggests that it is the protocols (and the culture change that these protocols represent) that effect the benefit, rather than any specific modality of weaning. The current data do not support the use of any one protocol (although some guidelines are offered below), and the selection of an appropriate protocol is best left to multidisciplinary teams at individual institutions. Importantly, each institution must endorse the fiscal commitment and the staffing modifications that are necessary for developing and implementing a multidisciplinary weaning protocol team of dedicated HCPs.[34] While institutions should embrace collaborative weaning efforts[35] and should customize protocols to local practices, several important general concepts may ease the process of implementation and may enhance success, and these are reviewed in multiple sections below.

Recommendation 2: *Based on evidence from RCTs, we recommend that ICU clinicians utilize protocols for liberating patients from MV in order to safely reduce the duration of MV.*

SBTs
Given the low negative predictive value of most weaning parameters (*ie*, the available parameters

predict weaning failure poorly),[3 36 37] it appears most prudent to conduct daily assessments of the patient's ability to breathe spontaneously.[8 9 11 32] Clinicians should have a low threshold to perform such a trial. Yet, in a recent international utilization review[38] of the actual weaning practices of 412 medical and surgical ICUs in 1,638 patients receiving MV, only 20% of patients were weaned using some form of SBT, and in the United States, SBTs were incorporated into weaning in < 10% of all patients studied. Patients chosen for SBTs should be in hemodynamically stable condition, and their condition should be improving with regard to the underlying cause of respiratory failure. SBTs can be performed safely by nonphysician HCPs using a T-piece, continuous positive airway pressure without pressure support, or with pressure support up to 7 cm H_2O, and for durations of 30 min to 2 h.[6 8 9 11 32 34 39 40] The monitored assessment of spontaneous breathing should be conducted at least once daily (with the head of the bed elevated and after notifying the patient of the start of the SBT) and should be integrated with other major events in the patient's daily care, including the cessation or temporary reduction in delivery of sedation and analgesia medications.[41] There are emerging data about the utility of noninvasive positive-pressure ventilation to facilitate weaning and to avoid reintubation,[42 43 44 45] as well as ongoing multicenter trials that are studying protocols using this modality of respiratory support for weaning patients from MV.

Recommendation 3: *Based on evidence from randomized trials, we recommend at least once daily SBTs to identify patients who are ready for liberation from the ventilator.*

Recommendations for Patients Who Are "Not-Yet-Ready" for Liberation

When a patient does not demonstrate readiness for liberation from the mechanical ventilator, but is improving as indicated by lessening support requirements, the clinician is faced with a decision about how to wean MV support. In randomized trials, both Esteban et al[8] and Brochard et al[32] employed a screening process whereby patients were enrolled into the trials only if they failed to demonstrate readiness via an SBT. In these studies, either once-daily SBTs or pressure support ventilation were both superior to intermittent mandatory ventilation alone. Reported differences in the superiority of SBTs vs pressure support ventilation have been attributed to variations in the management protocols. The value of differing modes depends on thresholds for initiating, progressing through, and terminating weaning. Unfortunately, these thresholds involve more than objective data and appear to be related to physician judgment.[1] Therefore, based on evidence from these investigations, we can offer the following recommendations.

Recommendation 4: *When patients fail an SBT, we recommend the following assessments and interventions, based on varying levels of evidence:*

1. All remediable factors should be addressed to enhance the prospects of successful liberation from MV (e.g., electrolyte derangements, bronchospasm, malnutrition, patient positioning, or excess secretions).
2. The patient should be placed in an upright position[46] on a comfortable, safe, and well-monitored mode of MV (such as pressure support ventilation).
3. An SBT should be performed at least once daily. Few data support multiple manipulations of ventilator settings each day in an effort to wean or "train" the patient. For clinicians who prefer stepwise reductions in MV, both multiple daily SBTs and weaning pressure support ventilation appear to be superior to intermittent mandatory ventilation.[8 32]

4. In the face of repeated failures at daily SBTs, clinicians should consider longer-term options, including both tracheotomy and a long-term acute-care or stepdown ventilator facility.[47]

Extubation Decisions

The clinical trials[6 8 9 11 32] discussed above each outlined a rigid extubation protocol or, alternatively, an approach that incorporated the clinician's judgment and preferences for the timing of extubation. Despite the care and rigor with which a team of HCPs evaluates their patients' abilities to be liberated from MV, some patients will require reintubation,[5 48] which carries an estimated 8-fold higher odds ratio for nosocomial pneumonia[49] and a 6-fold to 12-fold increased mortality risk.[4 6 39 50] Reported reintubation rates range from 4 to 20% for different ICU populations[4 5 6 8 9 32 34 51] and may be as high as 33% in patients with mental status changes and neurologic impairment.[48] The optimal rate of reintubation is not known but likely rests between 5% and 15% in non-neurologically impaired patients.

One important cause of reintubation is self-extubation or accidental extubation of patients who are inadequately sedated and/or restrained. However, self-extubation also can occur in patients who are ready to be liberated from the ventilator. For instance, approximately 50% of patients who self-extubate do not require reintubation.[50 52 53 54 55] This fact should further motivate physicians to adopt proactive protocols directed toward earlier extubation. In fact, two investigations have shown an associated reduction in reintubation rates by incorporating a protocol driven by nonphysician HCPs.[9 56]

Recommendation 5: *Based on the sum of evidence from randomized trials and observational studies, we recommend that when patients have passed an SBT, clinicians seriously consider prompt extubation.*

Sedation and Analgesia

When other key features in the management of patients receiving MV, such as sedation and analgesia, are protocolized and managed by nonphysician HCPs, further reductions in the time spent receiving MV can be realized. Standardizing the delivery of sedatives and analgesics is the most recent development in the area of protocolization and weaning from MV. One RCT, using a nursing-implemented protocol to manage the delivery of sedation, showed a reduction in the duration of MV by 2 days ($p = 0.008$), decreased length of stay in the ICU by 2 days ($p < 0.0001$), and a lower tracheostomy rate among the treatment group (6% vs 13%; $p = 0.04$).[41] In another recently published RCT[57] among 128 patients receiving MV in an ICU, those in whom sedation was maintained at a lighter level (via daily interruption of their sedative infusion) spent 2 days less receiving MV ($p = 0.004$) and 3 days less in the ICU ($p = 0.02$) than did patients in whom infusions were not interrupted. In addition, the pharmacoeconomic impact of guidelines for analgesia, sedation, and neuromuscular blockade appear to be favorable and have received more attention in the medical literature recently.[58] In summary, these studies have demonstrated the important interactions between the delivery of psychoactive medications and the expeditious weaning from MV. However, considering the nearly universal use of these agents in patients receiving MV and the relative paucity of controlled investigations in this area,[59] further study is required before detailed and specific methods of protocolization can be recommended. For example, studies to date have monitored only the *arousal* component of consciousness and have

tracked relatively few adverse events, none of which included patients' distress during awakening, recollections of discomfort after their stay in the ICU, delirium, or persistent neuropsychological outcomes. Emerging work in the area of the *content* of consciousness (*eg*, delirium) is revealing important interactions between the development of delirium and outcomes including the duration of the hospital stay, as well as long-term neuropsychological outcomes.[60] [61] [62]

Recommendation 6: *Based on evidence from randomized trials for the delivery of psychoactive medications, we recommend the consideration of protocols that include daily cessation and targeted sedation goals to reduce the duration of MV and of the length of stay in the ICU.*

Implementation of Protocols

Both the level of institutional commitment to improving clinical outcomes and the health-care team's leadership, persistence, and consistency in the implementation of protocols will determine the ultimate success of any management protocol. Protocolized care has been advocated in many facets of medicine, but relinquishing control of the patient's management often creates resentment and frustration on the part of physicians. Even when research clearly supports a change in approach, it is very difficult to get physicians to alter their practice and management styles.[63] Certain physicians may have a low "readiness to change," and these professionals may require either motivational interventions or consultation with respected opinion leaders.[64] [65] Negative reactions to protocols may be reasonable under some circumstances, since protocols have the potential to do harm. Important considerations that may facilitate behavioral changes include interactive education, timely and specific feedback, participation by physicians in the effort to change, administrative interventions, and even financial incentives and penalties.[63] Through a staged implementation process, using periodic reinforcement of all participants in ventilator management and the close monitoring of compliance with the protocol, large-scale implementation within major medical centers is possible.[34] Protocol implementation (and acceptance) is potentially less complicated in smaller, self-contained units with fewer staff and more direct communication channels. Tips for the implementation of weaning protocols and for avoiding barriers to success, which were derived from the study of > 15,000 patient-days of MV over nearly 2 years of implementation,[65] are presented in Table 6 . The effective implementation of protocols requires adequate staffing, and it has been shown that if staffing is reduced below certain thresholds, clinical outcomes may be jeopardized.[66] [67] Indeed, in the specific context of liberation from MV, reductions in nurse-to-patient ratios have been associated with a prolonged duration of MV.[68]

Table 6.. Tips for Implementation of Protocols to Maximize the Likelihood of Success in Achieving Both a Change of Behavior on the Part of HCPs and Long-term Protocol Implementation

■Identify the patient-care issue as a high-priority item (*e.g.*, timely extubation);
■Obtain baseline data at your institution (*e.g.*, lengths of stay and complication rates);
■Design the protocol using evidence-based methods complemented by a review of protocols in other programs and opinions of local experts;
■Acknowledge the need for a "change in culture" on the part of both physicians and nonphysician HCPs;
■Work hard to achieve the support of local experts, opinion leaders, and administrative officials;
■Establish a team including the hospital administration, physicians, RCPs, nurses/acute-care nurse practitioners, and potentially ethicists or other experts in end-of-life care;
■As a team, establish goals and set objective definitions of success and failure;
■Avoid changing personnel too often (*e.g.*, if possible, have staff dedicated to specific ICUs rather than rotating through all ICUs of a hospital)
■Structure a graded, staged implementation process that provides all of the following
Education
Timely feedback
Compliance monitoring
Tracking of appropriate outcomes (including cost) via daily data collection
Avoid complicated plans aimed at perfection; be pragmatic
Consider the implementation as a dynamic process; incorporate innovative changes over time; respond to feedback and new literature
■Avoid an overly rigid interpretation of the rules of the protocol that can delay attempts toward advancing "ready" patients through a protocol;
■Do not remove clinical judgment on the part of any team members; and
■Acknowledge the need for and plan to have periodic refresher implementation processes to avoid the otherwise inevitable regression to baseline

It is imperative that protocols not be used to replace clinical judgment, but rather to complement it. Protocols are meant to guide patient care and may serve as the general default management, unless they are based on patient response or if any of the HCPs (*i.e.*, physicians, nurses, or RCPs) can justify a departure from the protocol. Likewise, protocols should not be viewed as rigid rules, but rather as dynamic tools in evolution that can be improved on to address local problems and to accommodate new data. More studies regarding the impact of protocol-based weaning are needed to better delineate optimal approaches in specific patient populations (*e.g.*, neurosurgical,[69] [70] trauma,[12] [71] or COPD patients[42]), in specific organizational structures (*e.g.*, open vs closed units or teaching vs community hospitals[72]), and using computer-assisted decision making.[73] [74]

Recommendation 7: *We recommend the consideration of the following strategies for weaning protocols: development using an evidence-based approach by a multidisciplinary team; and implementation using effective behavior-changing strategies such as interactive education, opinion leaders, reminders, audit, and feedback.*

In summary, this evidence-based review suggests that protocols driven by nonphysician HCPs to manage the weaning and liberation of patients from MV can reduce the time that patients spend receiving MV. We have developed seven key recommendations to synthesize this information for those attempting to design a weaning protocol. We also have discussed key general issues to aid in protocol implementation. Acknowledging the important nuances in protocols that should be dictated by specific patient populations and institutional preferences, the following **two steps** in any successful weaning attempt derived from recent RCTs[9] [11] [12] [41] [57] bear repeating: **step A** should involve minimizing or temporarily discontinuing sedation and analgesia enough to observe patient **awakening**; and **step B** should involve an assessment of the patient's ability to spontaneously **breathe**.

The data included in this systematic review and a more comprehensive discussion of the original articles are included in an Evidence Report of the Agency for Healthcare Research and Quality.[75]

Footnotes

Abbreviations: AHCPR = Agency for Health Care Policy and Research; CI = confidence interval; HCP = health-care professional; MV = mechanical ventilation; RCP = respiratory-care practitioner; RCT = randomized controlled trial; RR = relative risk; SBT = spontaneous breathing trial

Brief Glossary of Terms related to mechanical ventilation:

Airway Pressure Release Ventilation (APRV) - A spontaneous mode of ventilation that employs a time cycled fluctuation in positive airway pressure. Continuous Positive Airway Pressure is periodically released to facilitate exhalation. The difference between CPAP and release pressure will be the net release pressure gradient. Tidal volumes will vary directly with lung compliance and inversely with changes in total resistance.

Assisted Ventilation - The continuous augmentation of the spontaneously triggered breathing effort with a mechanically generated breath. Can be volume, pressure or flow.

Assist Control Ventilation (AC) - A mode of ventilation in which both spontaneous and mechanically triggered breaths are supported by the ventilator. The mandatory breath rate is the minimum amount of breaths the machine will deliver in a minute. The patient can trigger additional machine breaths above the set rate. AC breaths can be pressure, volume or flow cycled.

Auto-PEEP - Positive End Expiratory Pressure (PEEP) that is not set by the clinician. This PEEP represents a dynamic hyperinflation of the lung. PEEP that is present but not reflected by the monitoring systems of the mechanical ventilator.

BiPAP - A registered acronym of Respironics. A form of noninvasive full-face or nasal mask ventilation that employs a flow augmented, pressure limited, flow/time/pressure cycled form of ventilation. A level of inspiratory pressure limited flow augmentation, (IPAP) is clinician pre-set above a clinician pre-set end expiratory pressure, (EPAP). Essentially this time/pressure/flow triggered; pressure limited; flow/time/pressure cycled method of noninvasive ventilation is PSV with PEEP. Bear in mind that the pressures are cumulative and the PSV level will be the difference between the IPAP and EPAP levels.

Continuous Mechanical Ventilation (CMV) - a mode a ventilation either assisted or controlled where all breaths are mechanical. Note: CMV is more classically used to designate Controlled Mechanical Ventilation, a mode in which the patient is unable to reach a "locked out" triggering threshold.

Continuous Positive Airway Pressure (CPAP) - a spontaneous mode of ventilation. The mechanical ventilator administers a continuous supra-atmospheric pressure to the airway. The patient breathes spontaneously above this pressure.

Control variables - the variable the ventilator manipulates to cause inspiration. Specifically; pressure, time, flow and volume. Pressure controllers maintain pressure despite downstream changes in impedance. Volume controllers monitor volume delivery.
Inverse Ratio Ventilation (IRV) - method of ventilation engaging a prolonged inspiratory time. This inspiratory time inverts the normal I:E creating a situation where the inspiratory time is 2-4 times longer than the expiratory time. This maneuver attempts to enhance oxygenation with an increased mean airway pressure, gas-liquid inter-phase and greater alveolar recruitment. This pattern of I:E can be utilized in both pressure and volume limited modes of assisted ventilation.
Mandatory Breath - a breath that is machine triggered and/or cycled. A non-spontaneous breath.
Mandatory Minute Ventilation - (MMV) A method of ventilation that allows the patient to breathe spontaneously with a clinician pre-set minute volume target. If the patient satisfies the preset minute volume threshold the machine remains dormant and continues monitoring exhaled volume. Should the patient fail to reach the targeted minute ventilation the machine delivers clinician prescribed breaths until the pre-set minute volume is satisfied.
Mean Airway Pressure (MAP) - The average airway pressure during one complete ventilatory cycle. MAP is directly related to PEEP and influenced by PAP, inspiratory time and inspiratory flow. NOTE: Frequently expiratory airways resistance is greater than inspiratory airways resistance. This will cause most machines to underestimate true MAP which will usually be greater in reality than the instrumentation will indicate.

Peak Airway Pressure - (PAP/PIP) The maximum airway pressure recorded during an inspiratory cycle. This maximum or extreme pressure is usually actualized at the end of inspiration. This pressure reflects the collective result of machine and patient variables and is dynamic in character.

Phase Variables - the aspects of the mechanically ventilated breath, (pressure, volume, flow and time) that affect the four phases of the mechanical breath. 1) the change from inspiration to exhalation, 2) inspiration, 3) the change from inspiration to exhalation and 4) exhalation.

Cycle variable - the variable that causes the change of phase from inspiration to exhalation. This variable can have a flow, time, pressure or volume threshold.

Trigger variable - the threshold of flow, time, pressure or volume that initiates mechanical inspiration. The trigger can be patient initiated or machine actuated.

Limit variable - the flow, pressure, time or pressure variable that frames the mechanical breath. The limit is a threshold that cannot be breached by the patient and remains constant.

Baseline variable - the mechanical parameter controlled during exhalation. (ZEEP and PEEP)

The PaO2/FiO2 index (P/F ratio) - quantifies the ratio of arterial oxygen tension to available oxygen concentration. It is a very useful formula in evaluating the degree of intrapulmonary shunt and subsequent compromise of cardiopulmonary function. The PaO2/FiO2 index is also a valuable indicie of diffusion capability and a primary tool in assessing the degree of injury to the lung. Low diffusion states will have a low ratio of arterial oxygen in relation to a given FiO2. The PaO2/FiO2 index acts to identify the severity of lung injury, If the PaO2/FiO2 index is < 300 strongly suspect Acute Lung Injury. (ALI) If the PaO2/FiO2 index is < 200 strongly suspect Acute Respiratory Distress Syndrome. (ARDS)

Plateau Pressure - (PPLAT) PPLAT is the pressure measured at the end of inspiration during an inflation hold. This inflation hold allows inspired gas to equilibrate in regions of the lung with incongruous time constants. PPLAT is the pressure required to counterbalance end inspiratory forces and is related to the static end inspiratory elastic recoil pressure of the total respiratory system. Airway pressure measured during an end inspiratory occlusion replicates the elastic threshold stress to the pulmonary system sans the inevitable resistive forces present during active inspiration. PPLAT faithfully approximates alveolar pressure and as such is a very useful clinical assessment tool.
Plateau pressure is needed to calculate total lung compliance as the relationship between PPLAT and delivered volume.
This lung and chest wall compliance is derived in the following manner. Cl = Vt / (PPLAT– PEEPtot)
The difference between Peak Airway Pressure and PPLAT is a function of resistive forces in the patient ventilator system. Raw is calculated by looking at the pressure gradient between the peak

airway pressure and the plateau divided by the flow.
Raw = PAP – PPLAT / Flow (L/sec.)

Positive End Expiratory Pressure - (PEEP) the application and maintenance of supra-atmospheric or positive airway pressure through the expiratory phase of a mechanical breath. The application of PEEP will increase both peak and mean airway pressures as well as the FRC. PEEP is primarily utilized to increase the
PaO2, maintain alveolar integrity and facilitate patient triggering.

Pressure Controlled Ventilation - (PCV) A method of ventilation that is time cycled, pressure limited, pressure controlled and patient, (AC-PCV), or machine, (TC-PCV), triggered. Volume to the lung will be variable and related to pulmonary compliance, time constant, inspiratory time, pressure gradient and flow rate. PCV can be employed in the CMV, AC or SIMV modes.

Pressure Support Ventilation - (PSV) A method of augmented spontaneous ventilation that is flow, pressure or time cycled pressure limited and patient triggered. A form of spontaneous ventilation where flow is delivered to the airway up to a clinician pre-set pressure limit and continued until the machine senses either a drop in inspiratory flow beyond a preset threshold, excessive inspiratory pressure or prolonged inspiratory time. In PSV the patient determines the inspiratory rate, time, volume and flow. PSV can be employed as a mode of mechanical ventilation or in the SIMV mode.

Rapid Shallow Breathing Index (RSBI) - predictor of a patient's potential for success in the weaning process. The clinician evaluates the patient's breathing pattern by analyzing the relationship linking breathing frequency and average Vt. The RSBI is an accurate forecaster of the patient's ability to perform endurance related work and assume the work of breathing when extubated.
The RSBI is calculated as the spontaneous frequency divided by the average spontaneous tidal volume in Liters. The patient is evaluated wile breathing spontaneously without inspiratory adjuncts such as PSV. An index of < 100 is a predictor of weaning success. An index of > 100 suggests probable weaning failure.

Spontaneous Breath - a patient triggered and cycled breath.

Synchronized Intermittent Mechanical Ventilation - (SIMV) A mode of mechanical ventilation that delivers mandatory machine breathes as well as spontaneous breaths. The mechanical breaths are delivered in synchrony with the patient's spontaneous breathing pattern. The mechanical breath can be time or patient triggered,

time or volume cycled and volume or pressure limited. The spontaneous breaths may have some level of PS.

Volume Assured Pressure Support - (VAPS) a form of pressure support ventilation that is flow-cycled, volume targeted. Inspiratory flow is augmented in the event the patient triggered breath fails to reach a clinician pre-set tidal volume. This form of ventilation delivers a pressure supported breath when patient demand is high and a constant-flow volume targeted breath is cases off low patient demand.

Volume Control - a method of mechanical ventilation in which volume is the control variable.

References

1. Cook, DJ, Meade, MO, Guyatt, GH, et al (2000) *Weaning from mechanical ventilationa; the McMaster Evidence Based Medicine Practice Center.* Agency for Healthcare Research and Quality Washington, DC.

2. Ely, EW, Baker, AM, Evans, GW, et al (2000) The cost of respiratory care in mechanically ventilated patients with chronic obstructive pulmonary disease. *Crit Care Med* **28**,408-413[CrossRef][ISI][Medline]

3. Ely, EW, Baker, AM, Evans, GW, et al (1999) The prognostic significance of passing a daily screen of weaning parameters. *Intensive Care Med* **25**,581-587[CrossRef][ISI][Medline]

4. Epstein, SK, Ciubotaru, RL, Wong, JB (1997) Effect of failed extubation on the outcome of mechanical ventilation. *Chest* **112**,186-192[Abstract/Free Full Text]

5. Epstein, SK, Ciubotaru, RL (1998) Independent effects of etiology of failure and time to reintubation on outcome for patients failing extubation. *Am J Respir Crit Care Med* **158**,489-493[Abstract/Free Full Text]

6. Esteban, A, Alia, I, Gordo, F, et al (1997) Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. *Am J Respir Crit Care Med* **156**,459-465[Abstract/Free Full Text]

7. Hall, JB, Wood, LD (1987) Liberation of the patient from mechanical ventilation. *JAMA* **257**,1621-1628[Abstract]

8. Esteban, A, Frutos, F, Tobin, MJ, et al (1995) A comparison of four methods of weaning patients from mechanical ventilation. *N Engl J Med* **332**,345-350[Abstract/Free Full Text]

9. Ely, EW, Baker, AM, Dunagan, DP, et al (1996) Effect on the duration of mechanical ventilation of identifying patients capable of breathing spontaneously. *N Engl J Med* **335**,1864-1869[Abstract/Free Full Text]

10. Strickland, JH, Jr, Hasson, JH (1993) A computer-controlled ventilator weaning system: a clinical trial. *Chest* **103**,1220-1226[Abstract/Free Full Text]

11. Kollef, MH, Shapiro, SD, Silver, P, et al (1997) A randomized, controlled trial of protocol-directed versus physician-directed weaning from mechanical ventilation. *Crit Care Med* **25**,567-574[CrossRef][ISI][Medline]

12. Marelich, GP, Murin, S, Battistella, F, et al (2000) Protocol weaning of mechanical ventilation in medical and surgical patients by respiratory care practitioners and nurses: effect on weaning time and incidence of ventilator-associated pneumonia. *Chest* **118**,459-467[Abstract/Free Full Text]

13. Foster, GH, Conway, WA, Pamulkov, N, et al (1984) Early extubation after coronary artery bypass: brief report. *Crit Care Med* **12**,994-996[ISI][Medline]

14. Tong, DA (1991) Weaning patients from mechanical ventilation: a knowledge-based system approach. *Comput Methods Programs Biomed* **35**,267-278[CrossRef][ISI][Medline]

15. Rotello, LC, Warren, J, Jastremski, MS, et al (1992) A nurse-directed protocol using pulse oximetry to wean mechanically ventilated patients from toxic oxygen concentrations. *Chest* **102**,1833-1835[Abstract/Free Full Text]

16. Wood, G, MacLeod, B, Moffatt, S (1995) Weaning from mechanical ventilation: physician-directed vs a respiratory-therapist-directed protocol. *Respir Care* **40**,219-224[Medline]

17. Saura, P, Blanch, L, Mestre, J, et al (1996) Clinical consequences of the implementation of a weaning protocol. *Intensive Care Med* **22**,1052-1056[ISI][Medline]

18. Djunaedi, H, Cardinal, P, Greffe-Laliberte, G, et al (1997) Does a ventilatory management protocol improve the care of ventilated patients? *Respir Care* **42**,604-610

19. Burns, SM, Marshall, M, Burns, JE, et al (1998) Design, testing, and results of an outcomes-managed approach to patients requiring prolonged mechanical ventilation. *Am J Crit Care* **7**,45-57

20. Horst, HM, Mouro, D, Hall-Jenssens, RA, et al (1998) Decrease in ventilation time with a standardized weaning process. *Arch Surg* **133**,483-488[Abstract/Free Full Text]

21. Kollef, MH, Horst, HM, Prang, L, et al (1998) Reducing the duration of mechanical ventilation: three examples of change in the intensive care unit. *New Horiz* **6**,52-60[ISI][Medline]

22. Brock, WA, Nolan, K, Nolan, T (1998) Pragmatic science: accelerating the improvement of critical care. *New Horiz* **6**,61-68[ISI][Medline]

23. Clemmer, TP, Spuhler, VJ (1998) Developing and gaining acceptance for patient care protocols. *New Horiz* **6**,12-19[ISI][Medline]

24. Alexander, E, Weingarten, S, Mohsenifar, Z (1996) Clinical strategies to reduce utilization of chest physiotherapy without compromising patient care. *Chest* **110**,430-432[Abstract/Free Full Text]

25. Browning, JA, Kaiser, DL, Durbin, CG (1989) The effect of guidelines on the appropriate use of ABG analysis in the intensive care unit. *Respir Care* **34**,269-276

26. Hart, SK, Dubbs, W, Gil, A, et al (1989) The effects of therapist evaluation of orders and interaction with physicians on the appropriateness of respiratory care. *Respir Care* **34**,185-190[Medline]

27. Kollef, MH, Shapiro, SD, Clinkscale, DCL, et al (2000) The effect of respiratory therapist-initiated treatment protocols on patient outcomes and resource utilization. *Chest* **117**,467-475[Abstract/Free Full Text]

28. Komara, J, Stoller, JK (1995) The impact of a postoperative oxygen therapy protocol on use of pulse oximetry and oxygen therapy. *Respir Care* **40**,1125-1129[Medline]

29. Stoller, JK, Mascha, EJ, Kester, L, et al (1998) Randomized controlled trial of physician-directed versus respiratory therapy consult service-directed respiratory care to adult non-ICU inpatients. *Am J Respir Crit Care Med* **158**,1068-1075[Abstract/Free Full Text]

30. Stoller, JK, Skibinski, CI, Giles, DK, et al (1996) Physician-ordered use of a respiratory therapy consult service: results of a prospective observational study. *Chest* **110**,422-429[Abstract/Free Full Text]

31. Stoller, JK (1998) The rationale for respiratory care protocols: an update. *Respir Care* **43**,719-723

32. Brochard, L, Rauss, A, Benito, S, et al (1994) Comparison of three methods of gradual withdrawal from ventilatory support during weaning from mechanical ventilation. *Am J Respir Crit Care Med* **150**,896-903[Abstract]

33. Stoller, JK (1994) Why therapist-driven protocols? *Respir Care* **39**,706-708

34. Ely, EW, Bennett, PA, Bowton, DL, et al (1999) Large scale implementation of a respiratory therapist-driven protocol for ventilator weaning. *Am J Respir Crit Care Med* **159**,439-446[Abstract/Free Full Text]

35. Henneman, E, Dracup, K, Ganz, T, et al (2001) Effect of a collaborative weaning plan on patient outcome in the critical care setting. *Crit Care Med* **29**,297-303[CrossRef][ISI][Medline]

36. Chatila, W, Jacob, B, Guaglionone, D, et al (1996) The unassisted respiratory rate-tidal volume ratio accurately predicts weaning outcome. *Am J Med* **101**,61-67[CrossRef][ISI][Medline]

37. Krieger, BP, Ershowsky, P, Becker, DA, et al (1989) Evaluation of conventional criteria for predicting successful weaning from mechanical ventilatory support in elderly patients. *Crit Care Med* **17**,858-861[ISI][Medline]

38. Esteban, A, Anzueto, A, Alia, I, et al (2000) How is mechanical ventilation employed in the intensive care unit. *Am J Respir Crit Care Med* **161**,1450-1458[Abstract/Free Full Text]

39. Esteban, A, Alia, I, Tobin, M, et al (1999) Effect of spontaneous breathing trial duration on outcome of attempts to discontinue mechanical ventilation. *Am J Respir Crit Care Med* **159**,512-518[Abstract/Free Full Text]

40. Azevedo, JR, Teixeira, CM, Pessoa, KC, et al (2000) Weaning from mechanical ventilation: comparison of two methods [abstract]. *Crit Care Med* **28(suppl)**,A104[CrossRef]

41. Brook, AD, Ahrens, TS, Schaiff, R, et al (1999) Effect of a nursing implemented sedation protocol on the duration of mechanical ventilation. *Crit Care Med* **27**,2609-2615[CrossRef][ISI][Medline]

42. Nava, S, Ambrosino, N, Clini, E, et al (1998) Noninvasive mechanical ventilation in the weaning of patients with respiratory failure due to chronic obstructive pulmonary disease: a randomized controlled trial. *Ann Intern Med* **128**,721-728[Abstract/Free Full Text]

43. Girault, C, Daudenthun, I, Chevron, V, et al (1999) Noninvasive ventilation as a systematic extubation and weaning technique in acute-on-chronic respiratory failure. *Am J Respir Crit Care Med* **160**,86-92[Abstract/Free Full Text]

44. . American Thoracic Society. (2001) International consensus conferences in intensive care medicine: noninvasive positive pressure ventilation in acute respiratory failure. *Am J Respir Crit Care Med* **163**,283-291[Free Full Text]

45. Mehta, S, Hill, NS (2001) Noninvasive ventilation: state of the art. *Am J Respir Crit Care Med* **163**,540-577[Free Full Text]

46. Drakulovic, MB, Torres, A, Bauer, TT, et al (1999) Supine body position as a risk factor for nosocominal pneumonia in mechanically ventilated patients: a randomised trial. *Lancet* **354**,1851-1858[CrossRef][ISI][Medline]

47. Scheinhorn, DJ, Chao, DC, Stearn-Hassenpflug, M, et al (2001) Outcomes in post-ICU mechanical ventilation: a therapist-implemented weaning protocol. *Chest* **119**,236-242[Abstract/Free Full Text]

48. Vallverdu, I, Calaf, N, Subirana, M, et al (1999) Clinical characteristics, respiratory functional parameters, and outcome of a two-hour T-piece trial of patients weaning from mechanical ventilation. *Am J Respir Crit Care Med* **158**,1855-1862[Abstract/Free Full Text]

49. Torres, A, Gatell, JM, Aznar, E (1995) Re-intubation increases the risk of nosocomial pneumonia in patients needing mechanical ventilation. *Am J Respir Crit Care Med* **152**,137-141[Abstract]

50. Chevron, V, Menard, J, Richard, J, et al (1998) Unplanned extubation: risk factors of development and predictive criteria for reintubation. *Crit Care Med* **26**,1049-1053[CrossRef][ISI][Medline]

51. Burrowes, P, Wallace, C, Davies, JM, et al (1992) Pulmonary edema as a radiologic manifestation of venous air embolism secondary to dental implant surgery. *Chest* **101**,561-562[Abstract/Free Full Text]

52. Listello, D, Sessler, C (1994) Unplanned extubation: clinical predictors for reintubation. *Chest* **105**,1496-1503[Abstract/Free Full Text]

53. Tindol, GA, Jr, DiBenedetto, RJ, Kosciuk, L (1994) Unplanned extubations. *Chest* **105**,1804-1807[Abstract/Free Full Text]

54. Boulain, T (1998) Unplanned extubations in the adult intensive care unit: a prospective multicenter study; the Association des Reanimateurs du Center-Ouest. *Am J Respir Crit Care Med* **157**,1131-1137[Abstract/Free Full Text]

55. Betbese, AJ, Perez, M, Rialp, G, et al (1998) A prospective study of unplanned endotracheal extubation in intensive care unit patients. *Crit Care Med* **26**,1180-1186[CrossRef][ISI][Medline]

56. Wood, KE, Flaten, AL, Reedy, JS, et al (1999) Use of a daily wean screen and weaning protocol for mechanically ventilated patients in a multidisciplinary tertiary critical care unit [abstract]. *Crit Care Med* **27**,A94

57. Kress, JP, Pohlman, AS, O'Connor, MF, et al (2000) Daily interruption of sedative infusions in critically ill patients undergoing mechanical ventilation. *N Engl J Med* **342**,1471-1477[Abstract/Free Full Text]

58. Mascia, MF, Koch, M, Medicis, JJ (2000) Pharmacoeconomic impact of rational use guidelines on the provision of analgesia, sedation, and neuromuscular blockade in critical care. *Crit Care Med* **28**,2300-2306[CrossRef][ISI][Medline]

59. Ostermann, ME, Keenan, SP, Seiferling, RA, et al (2000) Sedation in the intensive care unit. *JAMA* **283**,1451-1459[Abstract/Free Full Text]

60. Ely, EW, Margolin, R, Francis, J, et al (2001) Evaluation of delirium in critically ill patients: validation of the confusion assessment method for the intensive care unit (CAM-ICU). *Crit Care Med* **29**,1370-1379[CrossRef][ISI][Medline]

61. Ely EW, Inouye SK, Bernard GR, et al. Delirium in mechanically ventilated patients: validity and reliability of the confusion assessment method for the intensive care unit (CAM-ICU). JAMA 2001 (in press)

62. Ely, EW, Siegel, MD, Inouye, S (2001) Delirium in the intensive care unit: an under-recognized syndrome of organ dysfunction *Semin Respir Crit Care Med* **22**,115-126

63. Greco, PJ, Eisenberg, JM (1993) Changing physicians' practices. *N Engl J Med* **329**,1271-1273[Free Full Text]

64. Main, DS, Cohen, SJ, DiClemente, CC (1995) Measuring physician readiness to change cancer screening: preliminary results. *Am J Prev Med* **11**,54-58[ISI][Medline]

65. Ely, EW (2000) The utility of weaning protocols to expedite liberation from mechanical ventilation. *Respir Care Clin N Am* **6**,303-319[CrossRef][Medline]

66. Fridkin, SK, Pear, SM, Williamson, TH, et al (1996) The role of understaffing in central venous catheter-associated bloodstream infections. *Infect Control Hosp Epidemiol* **17**,150-158[ISI][Medline]

67. Archibald, LK, Manning, ML, Bell, LM, et al (1997) Patient density, nurse-to-patient ratio and nosocomial infection risk in a pediatric cardiac intensive care unit. *Pediatr Infect Dis* **16**,1045-1048

68. Thorens, JB, Kaelin, RM, Jolliet, P, et al (1995) Influence of the quality of nursing on the duration of weaning from mechanical ventilation in patients with chronic obstructive pulmonary disease. *Crit Care Med* **23**,1807-1815[CrossRef][ISI][Medline]

69. Namen, AM, Ely, EW, Tatter, S, et al (2001) Predictors of successful extubation in neurosurgical patients. *Am J Respir Crit Care Med* **163**,658-664[Abstract/Free Full Text]

70. Coplin, WM, Pierson, DJ, Cooley, KD, et al (2000) Implications of extubation delay in brain-injured patients meeting standard weaning criteria. *Am J Respir Crit Care Med* **161**,1530-1536[Abstract/Free Full Text]

71. Collin, GR, Atkinson, N, Furrow, K, et al (2000) Decreasing the duration of mechanical ventilation through the use of a ventilation management protocol. *Crit Care Med* **27**,A110[CrossRef]

72. Carson, SS, Stocking, C, Podsadecki, T, et al (1996) Effects of organizational change in the medical intensive care unit of a teaching hospital: a comparison of "open" and "closed" formats. *JAMA* **276**,322-328[Abstract]

73. Dojat, M, Harf, A, Touchard, D, et al (2000) Clinical evaluation of a computer-controlled pressure support mode. *Am J Respir Crit Care Med* **161**,1161-1166[Abstract/Free Full Text]

74. Morris, AH (2000) Developing and implementing computerized protocols for standardization of clinical decisions. *Ann Intern Med* **132**,373-384[Abstract/Free Full Text]

75. Criteria for weaning from mechanical ventilation. Evidence Report/Technology Assessment No. 23 from the Agency for Healthcare Research and Quality: AHRQ Publication No. 01-E010

Mechanical Ventilation Weaning Examination

Select the ***best*** answer to each of the following items. Mark your responses on the Answer form.

1. Ventilator management strategies for patients who fail a trial of spontaneous breathing include the following _____.

a. consideration of all remediable factors (such as electrolyte derangements, bronchospasm, malnutrition, patient positioning, and excess secretions) to enhance the prospects of successful liberation from MV
b. use of a comfortable, safe, and well-monitored mode of MV (such as pressure support ventilation);
c. repeating a trial of spontaneous breathing on the following day
d. All of the above

2. Protocols should not represent rigid rules but, rather, guides to patient care. Moreover, the protocols may evolve over time as clinical and institutional experience with them increases.

a. True
b. False

3. The premature discontinuation of MV can contribute to _____.

a. the incidence of failed extubation
b. nosocomial pneumonia
c. increased mortality
d. All of the above

4. In studies reviewed in this course, the results of nonrandomized studies are generally consistent with the results of the RCTs, demonstrating statistically significant reductions or trends toward reductions in the duration of MV and ICU length of stay.

a. True
b. False

5. According to the recommendations in this course, nonphysician HCPs should be included in the development and utilization of protocols related to weaning from MV.

a. True
b. False

6. According to the recommendations in this course, clinicians should conduct SBTs at least once daily to identify patients who are ready for liberation from the ventilator.

a. True
b. False

7. Evidence supports the current concept of "liberation" from MV (*ie*, that the timely recognition of recovery from respiratory failure is more important than the manipulation of MV in an attempt to facilitate weaning).

a. True
b. False

8. According to the recommendations in this course, when patients pass an SBT, clinicians should seriously consider prompt extubation.

a. True
b. False

9. According to the recommendations in this course, when patients fail an SBT, clinicians should attend to potentially remediable factors, choose a safe and comfortable mode of MV with the head elevated at 30° to 45°, conduct SBTs at least once daily, and, in the face of repeated failures, consider performing a tracheotomy or long-term care facilities.

a. True
b. False

10. According to the recommendations in this course, for the delivery of psychoactive medications, clinicians should consider protocols that include daily ventilatory cessation and targeted sedation goals to reduce the duration of MV and ICU stay.

a. True
b. False

11. According to the recommendations in this course, for the implementation of weaning protocols, consider the following strategies: development of goals using an evidence-based approach by a multidisciplinary team; and implementation using effective behavior-changing strategies such as interactive education, opinion leaders, reminders, audit, and feedback.

a. True
b. False

12. SBTs can be performed safely by nonphysician HCPs using _____.

a. a T-piece
b. continuous positive airway pressure without pressure support,
c. with pressure support up to 7 cm H_2O, and for durations of 30 min to 2 h
d. All of the above

13. One important cause of reintubation is self-extubation or accidental extubation of patients who are inadequately sedated and/or restrained. However, self-extubation also can occur in patients who are ready to be liberated from the ventilator.

a. True
b. False

14. When other key features in the management of patients receiving MV, such as sedation and analgesia, are protocolized and managed by nonphysician HCPs, further reductions in the time spent receiving MV can be realized. Standardizing the delivery of sedatives and analgesics is the most recent development in the area of protocolization and weaning from MV.

a. True
b. False

15. Certain physicians may have a low "readiness to change," and these professionals may require either motivational interventions or consultation with respected opinion leaders.64 65 Negative reactions to protocols may be reasonable under some circumstances, since protocols have the potential to do harm. Important considerations that may facilitate behavioral changes include _____.

a. interactive education
b. participation by physicians in the effort to change
c. financial incentives and penalties
d. All of the above

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