

IMPROVING ADHERENCE TO A MECHANICAL VENTILATION WEANING PROTOCOL FOR CRITICALLY ILL ADULTS: OUTCOMES AFTER AN IMPLEMENTATION PROGRAM

Suzanne E. McLean, RN, MN, Louise A. Jensen, RN, PhD, Dallas G. Schroeder, RRT, BSc, Noel R. T. Gibney, MB, FRCPC, and Neil M. Skjodt, MD, MSc, FRCPC. From University of Alberta Hospital (SEM, DGS), University of Alberta (LAJ, NRTG, NMS), Edmonton, Alberta.

- **BACKGROUND** Despite multiple reminders, education sessions, and multidisciplinary team involvement, adherence to an evidence-based mechanical ventilation weaning protocol had been less than 1% in a general systems intensive care unit since implementation.
- **OBJECTIVE** To assess the effectiveness of using an implementation program, the Model for Accelerating Improvement, to improve adherence and clinical outcomes after restarting a mechanical ventilation weaning protocol in an adult general systems intensive care unit.
- **METHODS** A prospective comparative design, before and after implementation of the Model for Accelerating Improvement, was used with a consecutive sample of 129 patients and 112 multidisciplinary team members. Clinical outcomes were rate of unsuccessful extubations, rate of ventilator-associated pneumonia, and duration of mechanical ventilation; practice outcomes were staff's understanding of the mechanical ventilation weaning protocol, perceptions of the practice safety climate, and adherence to the weaning protocol.
- **RESULTS** After the intervention, the rate of unsuccessful extubations decreased, and staff's understanding of and adherence to the weaning protocol increased significantly. The rate of ventilator-associated pneumonia, duration of mechanical ventilation, and staff's perceptions of the practice safety climate did not change significantly.
- **CONCLUSION** Implementing the Model for Accelerating Improvement improved understanding of and adherence to protocol-directed weaning and reduced the rate of unsuccessful extubations. (*American Journal of Critical Care*. 2006;15:299-309)

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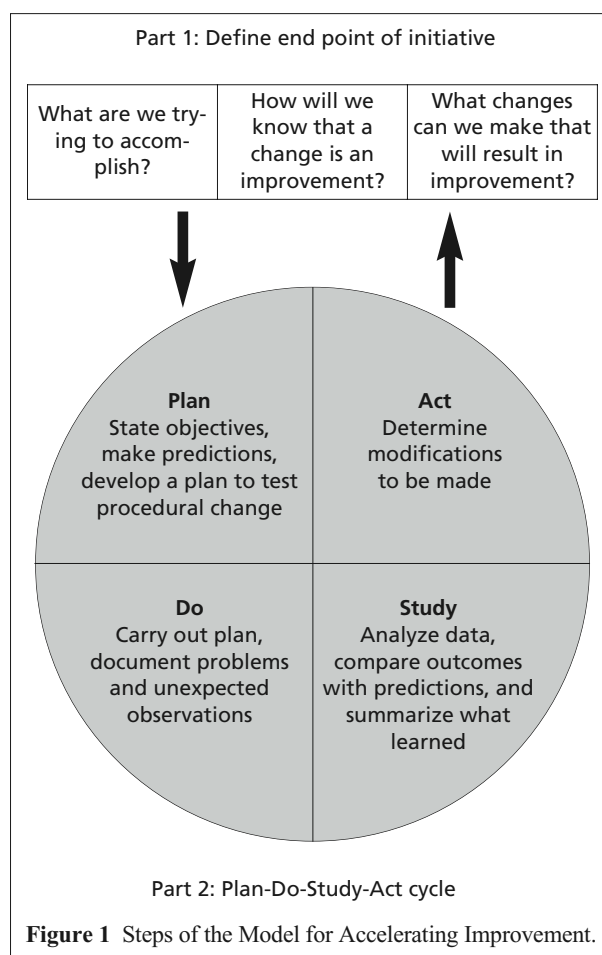
Mechanical ventilation is required in more than 90% of critically ill adults in intensive care units (ICUs).¹ Prolonged mechanical ventilation, defined as mechanical ventilation for more than 3 days, can increase healthcare costs as a result of longer stays in the ICU, costs associated with mechanical ventilation, and exposure of patients to unnecessary risks.² These risks include increased mortality, ventilator-associated pneumonia (VAP), airway trauma, increased need for sedation, and decreased satisfaction among staff, patients, and patients' families.²⁻⁵ On the other hand, premature dis-

continuation of mechanical ventilation can contribute to unsuccessful extubation, requiring reintubation.⁶ Rates of reintubation range from 4% to 33%.^{7,8} Reintubation potentially induces harm with associated airway trauma, gastric aspiration, acute lung injury, cardiovascular compromise, and hypoxia.⁹ Compared with the first intubation, with reintubation, the estimated risk for nosocomial pneumonia is 8 times higher and the increase for mortality increases 6- to 12-fold.¹⁰ Thus, discontinuation of mechanical ventilation must be balanced against the possibility of premature extubation and unnecessary prolonged ventilation.

The process of weaning critically ill adults from mechanical ventilation refers to the gradual discontinuation of mechanical ventilation.¹⁰ Although a variety of approaches are available to wean patients from mechanical ventilation, evidence from clinical trials suggests that protocol-directed weaning consistently reduces duration of mechanical ventilation,^{4,11,12} reduces ventilator-associated complications,⁶ and reduces the rate of reintubation.¹¹ A total of 4 randomized controlled trials^{4,11-13} and 14 nonrandomized trials¹⁴⁻²⁷ in which protocol-directed weaning was compared with standard weaning in critically ill adults have been reported. In all 4 randomized controlled trials,^{4,11-13} compared with weaning directed by a physician, protocol-directed weaning resulted in a reduction in duration of mechanical ventilation. In 2 randomized controlled trials,^{11,13} the rate of reintubation decreased when weaning was protocol directed, and in 1 trial,⁴ the rate of VAP decreased when weaning was protocol directed. In 7 nonrandomized trials,^{15,18,20-22,26,27} the duration of mechanical ventilation was significantly shorter for protocol-directed weaning than for physician-directed weaning. In 1 trial,¹⁸ compared with physician-directed weaning, protocol-directed weaning resulted in significant reductions in the rates of both reintubation and VAP.

Protocol-directed weaning is effective but may be perceived as reducing clinical judgment and individualized patient care.

Thus, protocol-directed weaning seems to be an effective strategy for managing mechanical ventilation, yet few reports about how to transfer this knowledge to practice have been published. Protocols potentially can create resentment and frustration among healthcare professionals because procedural care may be perceived as removing clinical judgment without considering all facets of the patients involved.^{10,28} However, an



improvement in staff's perceptions related to a proposed procedural protocol has been associated with decreases in the number of errors, lengths of stay, and employee attrition.²⁹ The Model for Accelerating Improvement,³⁰ initially developed as a framework for accelerating improvement in clinical outcomes, is a process that guides healthcare teams in making procedural changes (Figure 1).

The Model for Accelerating Improvement is a process that guides healthcare teams to make procedural changes to improve outcomes.

Purpose of the Study

The purpose of this study was to assess outcomes before and after implementing the Model for Accelerating Improvement³⁰ in restarting a mechanical ventilation weaning protocol in adult ICU patients at

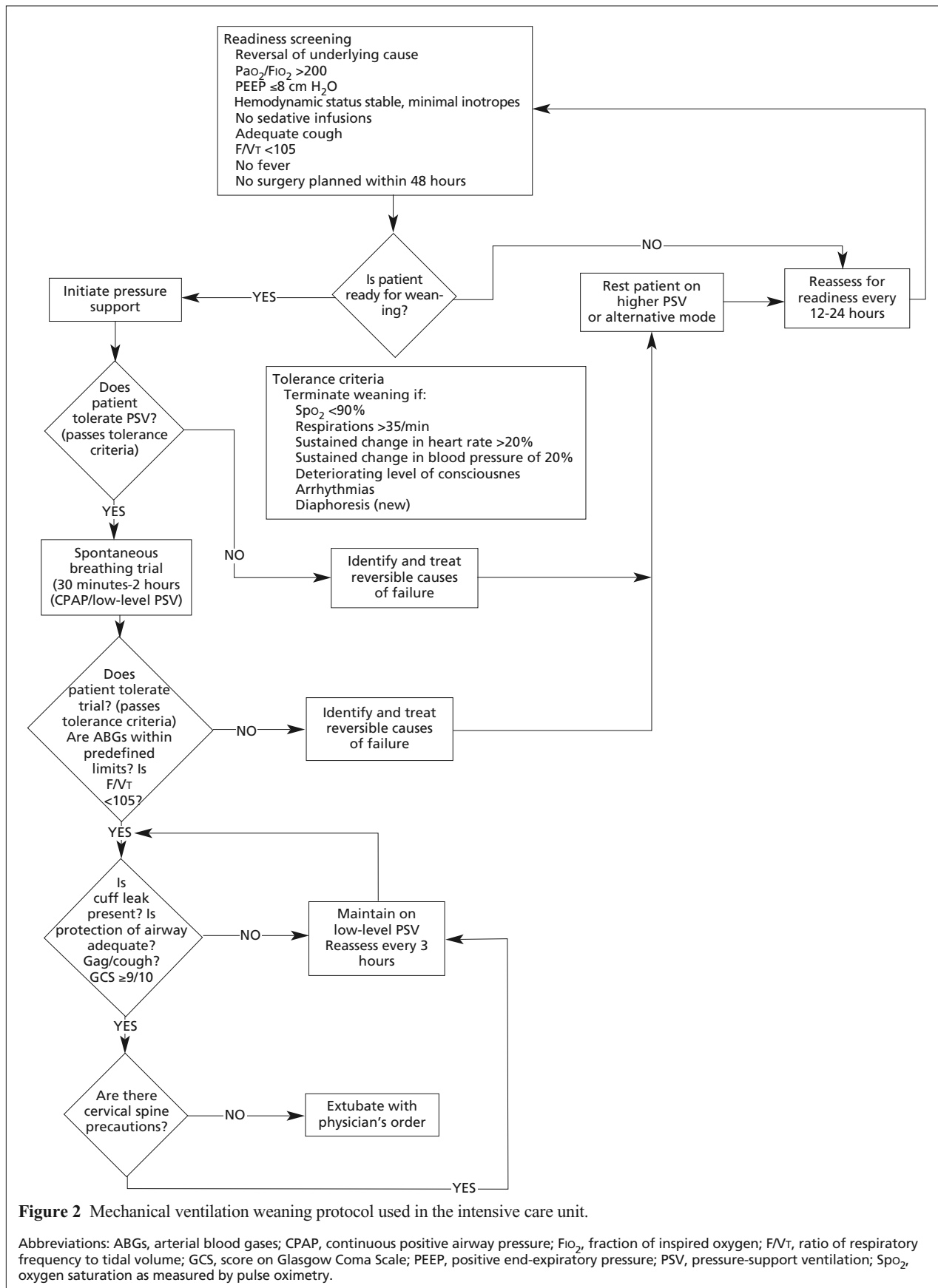


Figure 2 Mechanical ventilation weaning protocol used in the intensive care unit.

Abbreviations: ABGs, arterial blood gases; CPAP, continuous positive airway pressure; FiO_2 , fraction of inspired oxygen; F/V_T , ratio of respiratory frequency to tidal volume; GCS, score on Glasgow Coma Scale; PEEP, positive end-expiratory pressure; PSV, pressure-support ventilation; SpO_2 , oxygen saturation as measured by pulse oximetry.

University of Alberta Hospital, Edmonton, Alberta. Protocol-directed weaning (Figure 2) had been implemented in the ICU for more than a year, yet the estimated adherence to the evidence-based protocol was less than 1%. We hypothesized that engaging the multidisciplinary team in making a procedural change by using the Model for Accelerating Improvement³⁰ would improve adherence to the protocol and clinical outcomes. Specifically, we hypothesized that the following would occur:

- a decrease in the number of unsuccessful extubations,
- a decrease in the rate of VAP,
- a decrease in the duration of mechanical ventilation,
- an increase in the multidisciplinary staff's understanding of the mechanical ventilation weaning protocol,
- an improvement in the multidisciplinary staff's perceptions of the practice safety climate, and
- an increase in adherence to the weaning protocol.

Methods

Design

A prospective comparative design, before and after implementing the Model for Accelerating Improvement,³⁰ was used. Data from before the intervention were obtained with the first 103 critically ill adults enrolled in the study. For each patient, data were collected from the time the patient was intubated to 48 hours after extubation. Once data had been collected before the intervention, the 4 steps of the Model for Accelerating Improvement³¹ were conducted. The first step, or Plan, was to assess the multidisciplinary staff's perceptions of the mechanical ventilation weaning protocol and the practice safety climate through focus group sessions and survey completion. The second step, or Do, was to implement the change objective, which was to increase awareness of how the weaning protocol contributes to decreasing the number of unsuccessful extubations, VAP, and duration of mechanical ventilation. The third step, or Study, was analyzing and summarizing the results of the focus group sessions and the survey data and then making modifications needed to translate protocol-directed weaning into practice. The fourth step, or Act, included learning sessions with the multidisciplinary team. Once the 4 steps were completed, postintervention data with the next 100 critically ill adults were collected. Once data had been collected after the intervention, the multidisciplinary staff's perceptions of practice safety and understanding of the weaning protocol were reassessed.

Sample and Setting

A consecutive sample of 203 patients (103 before intervention, 100 after intervention) were enrolled during a 5-month period. This period was pragmatically determined. The organizational structure of the ICU is a closed 29-bed unit in a university teaching hospital. The ICU admits 90 to 100 patients a month, and 90% of these patients are intubated. The ICU has a heterogeneous population with admitting diagnoses of trauma, posttransplantation complications, sepsis, cancer, overdose, multisystem organ failure, shock, and respiratory failure.

Inclusion criteria for the study were 18 years of age or older, receiving mechanical ventilation via endotracheal intubation, and eligible to be on the ICU mechanical ventilation weaning protocol. Exclusion criteria were having been extubated within the preceding 48 hours, laryngeal disease or trauma, suspected or confirmed severe acute respiratory syndrome, receiving unconventional forms of mechanical ventilation (ie, home ventilation, high-frequency jet ventilation or oscillation), and adult respiratory distress syndrome if weaning from mechanical ventilation was not a goal (ie, the philosophy of care was to withdraw or withhold organ support).

Data Collection

Ethical approval was obtained from the health research ethics board. Subjects or guardians were given information about the purpose of the study, and informed consent was obtained. Staff participation in the focus groups, learning sessions, and surveys was voluntary. Patients, before and after the intervention, were enrolled in the study within 24 hours of admission to the ICU to ensure the inclusion criteria were met, and demographic and clinical variables were recorded. From the time of intubation until 48 hours after extubation, a researcher obtained information from each patient's chart and via discussions with the multidisciplinary team at the patient's bedside. Whether or not the patient met the inclusion and exclusion criteria was reassessed every 24 hours.

After the data had been collected before the intervention, ICU staff were provided the opportunity to voluntarily participate in a focus group session, to complete 2 surveys, and to participate in a learning session. Staff were provided an information sheet about the purpose of the study, told what was expected of them should they decide to participate, and assured that survey responses would remain anonymous.

The purpose of the focus group sessions was to gain an understanding of the staff's perceptions about the mechanical ventilation weaning protocol. Content analysis of the focus groups was used to make changes

to the protocol. A total of 112 staff members, including registered nurses, respiratory therapists, nursing attendants, physiotherapists, residents, and attending intensivists, attended the focus group sessions.

Participants' responses from the focus groups were broken down into 4 categories: awareness, strengths, limitations, and suggestions for improvements. The core labels for each category are given in Table 1. The first category was the staff's awareness of the mechanical ventilation weaning protocol; the majority indicated that they were not aware of the weaning protocol. The second category was strengths and limitations of the weaning protocol. The strengths were that the protocol provided direction, improved communication, and provided accessibility; the limitations were that protocols are rigid, outdated, and adhered to inconsistently. The final category was suggestions for improving the weaning protocol, which were used to make a number of changes, such as ensure the protocol is accessible with the patient's chart every day, post a sign at the respiratory station reminding the respiratory therapists to use the protocol, and have chest radiographs accessible early in the morning for patients who are ready for extubation.

Five weeks after the focus group sessions, staff were provided the opportunity to participate in a learning session. The learning sessions were attended by 101 health professionals, including registered nurses, respiratory therapists, nursing attendants, attending intensivists, residents, and clinical nurse educators. Learning sessions included the following: the definition of VAP, predictors of successful weaning from mechanical ventilation, the rationale for protocol-directed care, an interpretation of how to use the weaning protocol, and a summary of what we were trying to accomplish with the protocol. Additionally, the following instructions were given: the protocol starts with admission and is used continuously throughout the day; a physician's order is not required to initiate the protocol; the protocol is used for all patients except those receiving mechanical ventilation via tracheostomy; how to access the protocol, and if the protocol is not accessible, where a copy would be available; respiratory therapists in collaboration with registered nurses would initiate the protocol; low level of pressure support is a spontaneous breathing trial; document when the protocol is and is not initiated, and the reasons why; and the protocol is the standard of practice and expectation in the ICU.

Instruments/Measures

Unsuccessful extubation was defined as reintubation within 48 hours of tracheal decannulation as a

Table 1 Thematic categories and core labels

Category	Core labels
Awareness	Not aware of protocol Aware of protocol Aware of protocol, via study Aware of protocol, not seen in practice
Strengths	Provides direction Provides accessibility Improves communication Provides evidence-based practice Provides autonomy
Limitations	Rigidity Inconsistent adherence Becomes outdated Induces apathy
Suggestions for improvement	Protocol has to be simple, clear, and user friendly Make it accessible and visible to find in the unit Initiate protocol with admission Protocol must fit heterogeneous population Education on how to use the protocol Clarify that spontaneous breathing trial means low-level pressure support Ensure that protocol does not require a physician's order to initiate

result of one or more of the following: inability to protect the airway, need for bronchopulmonary toilet, inability to clear secretions, P_{aO_2} less than 70% on 50% oxygen or less than 55% on room air, P_{aCO_2} greater than 55 mm Hg, pH less than 7.25; carbon dioxide narcosis, cardiac arrest, and respiratory arrest.

VAP was defined as radiographic evidence of progressive or new pulmonary infiltrates, cavitation, or pulmonary effusion more than 48 hours after the onset of mechanical ventilation; isolation of one or more pathogens from cultures of endotracheal aspirates, bronchoscopy specimens, or lung biopsy specimens; and at least one of the following: fever (ie, body temperature $>38.5^{\circ}C$ via tympanic membrane), leukocytosis (white blood cell count $\geq 10 \times 10^9/L$), and sputum change (new onset of purulent sputum or change in character).^{4,32} For each patient, chest radiographs were obtained daily at the bedside, usually with the patient supine, and the radiographs were interpreted and reported by radiologists and subsequently reviewed by a researcher to determine whether the findings were normal or abnormal. Elevated white blood cell counts and sputum changes were recorded daily on the respiratory flow sheets. Patients who received mechanical ventilation for less than 48 hours (21 patients before the intervention and 29 after the intervention) did not meet the criteria for VAP, and their data were not reviewed.

Duration of mechanical ventilation was measured in consecutive minutes, with intubation or the establishment of an airway by means of an endotracheal tube as the first minute of mechanical ventilation and extubation or the removal of the endotracheal tube as the last minute of mechanical ventilation.

Practice outcomes were the multidisciplinary staff's understanding of the mechanical ventilation weaning protocol, as assessed by the Protocol-Directed Weaning Survey; the multidisciplinary staff's perceptions of practice safety, as assessed by the Safety Climate Survey²⁹; and adherence, as assessed by the percentage of patients having the weaning protocol followed. The Protocol-Directed Weaning Survey, designed to test the staff's understanding of protocol-directed weaning, consisted of 3 questions with 5 possible answers for each question, for a total score of 15. The Safety Climate Survey²⁹ consists of 19 questions plus demographic information and uses a 6-point scale: not applicable, agree strongly, agree slightly, neutral, disagree slightly, and disagree strongly. Safety climate refers to a culture of safety that encourages data collection and reporting,³³ reducing blame, involving leaders,³⁴ or focusing on systems.³⁵ Theoretical components required in constructing a culture of safety are as follows: commitment to safety is articulated at all levels of an organization; necessary resources, incentives, and rewards are provided; the primary priority is safety, a situation that may mean production and efficiency become secondary priorities; communication at and between all levels is frequent and candid; unsafe acts are rare despite high levels of production; errors and problems are transparent when they occur; organizational learning is a shared value; and behavior at all levels focuses on problem solving to improve the system rather than on individual blame.³⁶ Adherence to the protocol was determined by the percentage of patients having the weaning protocol followed, and factors contributing to adherence and nonadherence to the protocol were tabulated. The reasons for nonadherence were recorded on the respiratory flow sheets, and when the reasons were not documented, adherence was recorded as no, with reason unknown.

Data Analysis

Descriptive statistics were computed for all data. In order to compare the clinical and practice outcomes before and after the intervention, independent 2-tailed *t* tests and χ^2 tests were conducted. Relationships among scores on the Acute Physiology and Chronic Health Evaluation (APACHE) II, age, sex, reason for intubation, score on the Riker Sedation Agitation Scale, head-of-bed elevation, placement of feeding tube, subglottic

secretion drainage, and clinical outcomes were examined by using a χ^2 test. Level of significance was $P \leq .05$.

Results

Characteristics of the Sample

A total of 392 patients were admitted to the ICU during the 5-month study period. During the period before the intervention, 228 patients were admitted; 134 of those patients were eligible for the study. Of the patients who were eligible, 71 were not enrolled for the following reasons: enrolled in another study, unable to obtain informed consent within 24 hours of admission, not assessed by the researcher before extubation, weaning from mechanical ventilation was not a goal (ie, the philosophy of care was to withdraw or withhold curative therapy), receiving mechanical ventilation via tracheostomy, transferred to another intensive care unit, patient/family withdrew consent, died 48 hours or more after extubation, left hospital against medical advice and unable to be contacted by telephone, and declined to participate.

During the period after intervention, 164 patients were admitted to the ICU; 101 patients were eligible for the study. Of the eligible patients, 35 were not enrolled for the following reasons: extubated before being assessed; laryngeal disease; weaning from mechanical ventilation was not a goal (ie, the philosophy of care was to withdraw or withhold curative therapy); extubated within 48 hours; receiving mechanical ventilation via tracheostomy; had adult respiratory distress syndrome; declined to participate; and asked for time to think about participation, were discharged from hospital, and then could not be contacted by telephone. Thus, the final sample consisted of 63 patients from before the intervention and 66 patients from after the intervention.

The characteristics of the total sample ($n=129$) are summarized in Table 2. Demographic characteristics, comorbid health problems, and admitting diagnosis did not differ significantly between the group from before the intervention and the group from after the intervention. The mean (SD) APACHE II score within 24 hours of ICU admission was 20.8 (7.0) before the intervention and 20.2 (7.6) after the intervention ($P=.64$). Patients were either intubated with an endotracheal tube, or subglottic secretions were drained by using an EVAC endotracheal tube (Mallinckrodt Inc, St. Louis, Mo).

Clinical Outcomes

The rate of unsuccessful extubations was 12.7% ($n=8$) before intervention and 3.0% ($n=2$) after intervention ($P=.05$). VAP developed in 22 patients before the intervention and in 13 patients after the intervention ($P=.14$, Table 3). The Centers for Disease Control

Table 2 Characteristics of the sample*

Variable	Total (N = 129)		Before intervention (n = 63)		After intervention (n = 66)		P
	No.	%	No.	%	No.	%	
Sex							.46
Female	46	35.7	20	31.7	26	39.4	
Male	83	64.3	43	68.3	40	60.6	
Age, years							.66
18-30	14	10.9	8	12.7	6	9.1	
31-40	13	10.1	8	12.7	5	7.6	
41-50	22	17.1	8	12.7	14	21.2	
51-60	23	17.8	12	19.0	11	16.7	
61-70	23	17.8	13	20.6	10	15.2	
71-80	25	19.4	10	15.9	15	22.7	
81-90	9	7.0	4	6.3	5	7.6	
Smoker							.29
Yes	16	12.4	10	15.9	6	9.1	
No	19	14.7	11	17.5	8	12.1	
Unknown	94	72.9	42	66.7	52	78.8	
Priority comorbid health problem							.99
Neurological disease/trauma	8	6.2	4	6.3	4	6.1	
Cardiovascular disease	24	18.6	14	22.2	10	15.2	
Respiratory disease	16	12.4	8	12.7	8	12.1	
Gastrointestinal disease	10	7.8	5	7.9	5	7.6	
Renal disease	3	2.3	1	1.6	2	3.0	
Endocrine disease	22	17.1	10	15.9	12	18.2	
Mental illness	21	16.3	10	15.9	11	16.7	
Cancer	4	3.1	1	1.6	3	4.5	
Infectious disease	8	6.2	3	4.8	5	7.6	
Musculoskeletal disease	5	3.9	3	4.8	2	3.0	
Unknown	8	6.2	4	6.3	4	6.1	
Admitting diagnosis							.36
Congestive heart failure	1	0.8	1	1.6	0	0	
Chronic obstructive pulmonary disease	11	8.5	5	7.9	6	9.1	
Asthma exacerbation	2	1.6	1	1.6	1	1.5	
Pneumonia	5	3.9	3	4.8	2	3.0	
Renal failure	4	3.1	1	1.6	3	4.5	
Liver disease	2	1.6	2	3.2	0	0	
Gastrointestinal disease	13	10.1	4	6.3	9	13.6	
Cancer	4	3.1	1	1.6	3	4.5	
Overdose	7	5.4	3	4.8	4	6.1	
Neurological disease/trauma	21	16.3	11	17.5	10	15.2	
Transplant	6	4.7	3	4.8	3	4.5	
Sepsis	9	7.0	8	12.7	1	1.5	
Other	44	34.1	20	31.7	24	36.4	
Score on Acute Physiology and Chronic Health Evaluation II, mean (SD)				20.8 (7.0)		20.2 (7.6)	.64

*Because of rounding, percentages do not all total 100.

and Prevention recommends 2 formulas for computing the rate of VAP.³⁷ In the first formula, the number of patients with VAP is divided by the number of days of mechanical ventilation and then that number is multiplied by 1000 to obtain the rate as incidence per 1000 ventilator days. In the second formula, the number of patients with VAP is divided by the number of patients at risk (ie, all patients who received >48 hours of

mechanical ventilation) to obtain the rate as a percentage of patients. Table 4 gives the rate as the incidence per 1000 ventilator days and as a percentage of patients. The incidence of VAP per 1000 ventilator days was 107.8 before the intervention and 78.3 after the intervention. The rate as a percentage of patients was 52.4% before the intervention and 35.1% after the intervention. The rate of VAP may be overestimated because of the

Table 3 Clinical outcomes*

Outcome	Total (N = 129)		Before intervention (n = 63)		After intervention (n = 66)		P
	No.	%	No.	%	No.	%	
Extubation							.05
Successful	119	92.2	55	87.3	64	97.0	
Unsuccessful	10	7.8	8	12.7	2	3.0	
Ventilator-associated pneumonia							.14
Yes	35	27.1	22	34.9	13	19.7	
No	44	34.1	20	31.7	24	36.4	
Ventilation <48 hours	50	38.8	21	33.3	29	43.9	
Duration of mechanical ventilation, mean (SD), hours			86.0 (68.0)		70.8 (67.5)		.20

*Because of rounding, percentages do not all total 100.

inclusion of pulmonary effusions alone and/or infection with *Candida albicans* alone. When these were excluded, the rate of VAP was 42.9% (18/42) before the intervention and 21.6% (8/37) after the intervention.

After implementation of the improvement program, the rate of failed extubations decreased from 12.7% to 3.0%, but the duration of mechanical ventilation did not change.

A total of 11 of the 129 patients (7 before the intervention and 4 after the intervention) were intubated with an EVAC tube, which incorporates a separate lumen ending in the subglottic area for drainage of secretions. Before the intervention, 3 patients with an EVAC tube received mechanical ventilation for less than 48 hours; thus they did not meet the criteria for VAP, and their data were not reviewed. A total of 8 patients with an EVAC tube (4 before intervention, 4 after intervention) received mechanical ventilation for more than 48 hours; 5 (62.5%) of these 8 patients (4 before intervention, 1 after intervention) acquired VAP.

The types of pathogens isolated from aspirates or bronchoscopy specimens were yeast, *Candida albicans*, *Pseudomonas*, *Enterococcus*, *Staphylococcus aureus*, *Haemophilus influenzae*, *Klebsiella*, *Streptococcus agalactiae* group B, *Streptococcus pyogenes*, and *Serratia marcescens*. Yeast was isolated most of the time and was found daily in 28.6% to 50% of samples before the intervention and in 20% to 60% of samples after the intervention. The next most commonly isolated pathogen was *Candida albicans*, found daily in 4.2% to 20% of samples before the intervention and in

10% to 44.4% of samples after the intervention. The least commonly isolated pathogens were *Klebsiella* (3 samples before intervention, 1 sample after intervention), *Pseudomonas* (2 samples before intervention), and *Serratia* (1 sample before intervention, 1 sample after intervention).

Duration of mechanical ventilation ranged from 3.6 to 247.6 hours (mean 86.0, SD 68.0 hours) before the intervention and from 9.6 to 398.9 hours (mean 70.8, SD 67.5 hours) after the intervention ($P = .20$; Table 3).

Factors associated with unsuccessful extubations, VAP, and duration of mechanical ventilation were examined for the total cohort. A relationship was detected between rate of VAP and reason for intubation ($P = .02$). Other relationships were detected between duration of mechanical ventilation and APACHE II score ($P = .04$) and reason for intubation ($P = .01$). When duration of mechanical ventilation was measured as either less than or greater than 72 hours, no significant relationship with rate of unsuccessful extubations was detected. A relationship was detected between rate of VAP and duration of mechanical ventilation. The mean (SD) duration of mechanical ventilation was 144.6 (71.7) hours for the 35 patients who acquired VAP and 86.8 (49.9) hours for the 44 patients who did not acquire VAP ($P < .001$).

Practice Outcomes

Staff members who participated in the focus groups and completed the surveys were multidisciplinary staff, mostly registered nurses (67.9% before intervention, 86.7% after intervention) and respiratory therapists (16.1% before intervention, 6.7% after intervention) who had from less than 1 year to more than 20 years of experience in their current position, critical care, and/or the institution. Most were perma-

Table 4 Rate of ventilator-associated pneumonia (VAP)

Formula	Before intervention	After intervention
(No. of patients with VAP on ventilator/No. of days of mechanical ventilation) x 1000	(22/204) x 1000	(13/166) x 1000
= rate as incidence per 1000 ventilator days	= 107.8	= 78.3
No. of patients with VAP/No. of patients at risk	22/42	13/37
= rate as a percentage of patients	= 52.4%	= 35.1%

ment full-time employees (66.1% before intervention, 60.0% after intervention). Only 17 of the staff completed the Safety Climate Survey²⁹ both before and after the intervention.

Staff groups both before (n=112) and after (n=31) the intervention could list 5 risks of prolonged mechanical ventilation. The mean (SD) numbers were 4.6 (0.74) before the intervention and 4.6 (0.80) after the intervention ($P=.97$; Table 5). Identification of 5 risks of reintubation improved after the learning sessions; the mean (SD) numbers were 4.1 (1.18) before the intervention and 4.5 (0.77) after the intervention ($P=.03$). Identification of the 5 criteria of readiness to wean also improved; the mean (SD) numbers were 1.2 (0.89) before the intervention and 3.78 (1.62) after the intervention ($P<.001$). Overall, responses improved after the learning sessions; mean (SD) scores were 9.8 (2.12) before the intervention and 12.8 (2.17) after the intervention ($P<.001$).

Perceptions of the safety climate did not change significantly from before to after the intervention. Most staff perceived the ICU as a culture where it is easy to learn from mistakes, thought that suggestions about safety would be acted on, knew the proper channels to which to direct questions about the safety of patients, were satisfied with the availability of clinical leadership, thought that personnel in the ICU take responsibility for patients' safety, and thought that safety is constantly reinforced as a priority.

Adherence to the protocol improved after the implementation program (1.6% before intervention, 21.2% after intervention, $P<.001$). No cases of unsuccessful extubation occurred with continual adherence to the protocol. The reasons for protocol abatement were as follows: intraoperative myocardial infarction, planned surgery, decreased level of consciousness, use of a sedative agent, use of a paralytic agent, decreased tidal volume, increased respiratory rate, increased work of breathing, desaturation, apnea, biting on the endotracheal tube causing compression and inability to receive mechanical ventilation, and self-extubation.

Discussion

During the 5-month study period, the rate of unsuccessful extubations was 12.7% before the intervention and 3.0% after the intervention. In previously published reports,^{11,12,15,16,18,24,26,27} rates of reintubation were from 0.5% to 17% when protocol-directed weaning was compared with physician-directed weaning. In our study, the rate of unsuccessful extubations with protocol-directed weaning was less than that reported in other studies,^{11,12,15,19,32,37} and the rate of reintubation for critically ill adults whose weaning was protocol directed was lower than that in other studies.^{11-13,15,16,18,22,24,26,27} Compared with the first intubation, with reintubation, the estimated risk for nosocomial pneumonia is 8 times higher and the increase for mortality increases 6- to 12-fold.¹⁰ In addition, reintubation potentially induces harm due to associated airway trauma, gastric aspiration, acute lung injury, cardiovascular compromise, and hypoxic episodes.⁹

The rate of VAP in our study was 52.4% before the intervention and 35.1% after the intervention. Reported rates of VAP range from 1% to 20% when protocol-directed weaning is compared with physician-directed weaning.^{4,18,23} Thus, unlike other studies in which protocol-directed weaning was compared with physician-directed weaning, this study indicated a higher rate of VAP with a trend toward a decreased rate after the implementation program. This increased rate of VAP may, in part, be explained by the difference in definitions of VAP.

Reported duration of mechanical ventilation in other studies^{4,11-24,26,27} when protocol-directed weaning was compared with physician-directed weaning was from 9.8 to 170.6 hours and from 2.9 days to 14.5 (SD 11.1) days. Thus, the observed reduction in duration of mechanical ventilation (mean 86.0 hours, SD 68.0 before intervention; mean 70.8 hours, SD 67.5 after intervention) was similar to that reported by others.^{4,11-15,18-24,26,27} This clinical outcome may potentially reduce health-care costs because of shorter stays in the ICU and reduced risks associated with mechanical ventilation.

Table 5 Results of protocol-directed weaning survey

Survey question	No. of staff members	Score		P
		Mean	SD	
List 5 risks of prolonged mechanical ventilation				.97
Before intervention	112	4.6	0.74	
After intervention	31	4.6	0.80	
List 5 risks of reintubation				.03
Before intervention	112	4.1	1.18	
After intervention	31	4.5	0.77	
List 5 criteria of readiness to wean that assist clinicians in determining whether a patient is ready to be weaned off mechanical ventilation				<.001
Before intervention	112	1.2	0.89	
After intervention	31	3.7	1.62	
Total score				<.001
Before intervention	112	9.8	2.12	
After intervention	31	12.8	2.17	

Understanding of protocol-directed weaning increased significantly after the intervention. Most staff perceived a positive safety climate both before and after the intervention. Adherence to the weaning protocol also increased when implemented with the Model for Accelerating Improvement.³⁰ Adherence was 1.6% before the intervention and 21.2% after the intervention. Reported rates of protocol adherence range from 10% to 100% when protocol-directed weaning is compared with physician-directed weaning.^{15,19,24} Randolph et al³⁸ evaluated computerized protocol-directed weaning from mechanical ventilation and reported an adherence rate of 66%. On the basis of these results, the Model for Accelerating Improvement³⁰ was recommended as a model for activating change.³⁹

Using an improvement process improved the staff's understanding of and adherence to the weaning protocol.

The main limitation of our study is the limited sample size and length of follow-up. Perhaps more than 5 months should have been allocated to detect changes in the clinical and practice outcomes. Clinician bias may be a problem because the clinicians were not blinded to the design of the study. Another limitation is the definition of study outcomes. With VAP, interpretation of chest radiographs by radiologists, gathering of sputum samples, and practices followed when treatment with antibiotics was initiated all were inconsistent. Fur-

thermore, in critically ill adults, fever may also be due to blood transfusions, dehydration, extrapulmonary infection, or drug reaction; leukocytosis may be a natural inflammatory reaction mediated by a surgical procedure or an extrapulmonary infection. Additionally, when interpreting the rate of VAP, the probability of aspiration with intubation or community-acquired pneumonia was not considered. Finally, adherence to the ICU's mechanical ventilation weaning protocol was not known unless documented by the staff.

Conclusion

This ICU implemented an evidence-based mechanical ventilation weaning protocol, yet the extent of staff members' understanding of and adherence to this protocol was unknown. Data from before the intervention confirmed that adherence to the protocol was 1.6%. The Model for Accelerating Improvement,³⁰ a process used to guide healthcare teams in making procedural changes, was used to transfer a mechanical ventilation weaning protocol to the practice setting. The prediction that engaging the multidisciplinary team in a process of making a procedural change would improve translation to practice was confirmed. This process reduced the rate of unsuccessful extubations; improved the staff's understanding of the mechanical ventilation weaning protocol; increased adherence; and started a trend in reducing the rate of VAP, reducing the duration of mechanical ventilation, and constructing a culture of safety. Protocol-directed weaning is an effective strategy in the management of mechanical ventilation with critically ill adults when implemented with the Model for Accelerating Improvement.³⁰

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