Using a Collaborative Weaning Plan to Decrease Duration of Mechanical Ventilation and Length of Stay in the Intensive Care Unit for Patients Receiving Long-Term Ventilation

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***• Background** Patients requiring mechanical ventilation for prolonged periods typically are sicker and have more comorbid illnesses than do patients who can be weaned more rapidly. As a result, the weaning process is often complex, requiring shared decision making by a skilled, multidisciplinary team. Unfortunately, many of the structures used in critical care units to plan and evaluate care do not lend themselves to collaborative management of patients.*

***• Objective** To evaluate the effect of a collaborative weaning plan on outcomes, including duration of mechanical ventilation, for patients treated with mechanical ventilation for 7 days or more.*

***• Methods** A collaborative weaning plan (weaning board and flow sheet) was introduced into the medical intensive care unit at the University of California Los Angeles, Medical Center. A historical design was used to compare outcomes before and after the plan was used. The primary outcome variable was duration of mechanical ventilation. Other outcomes studied included length of stay in the unit, cost, prevalence of complications (ie, reventilation, readmission to the intensive care unit), and mortality rate.*

***• Results** The collaborative weaning plan decreased duration of ventilation by 4.9 days (P = .02) and decreased median length of stay in the unit by 4.5 days (P = .004). The median cost per stay in the unit decreased from $50 462 to $37 330 (P = .004). The prevalence of complications did not differ significantly between groups.*

***• Conclusions** Collaborative structures (eg, weaning boards, flow sheets) are useful in decreasing duration of mechanical ventilation for patients receiving long-term ventilation. (American Journal of Critical Care. 2002;11:132-140)*

Weaning patients off long-term mechanical ventilation can be challenging, particularly in an intensive care unit (ICU). Patients requiring mechanical ventilation for prolonged periods are generally sicker and have more comorbid illnesses than do patients who can be weaned more rapidly.[1-3] The transition to unsupported breathing is often complex, requiring skilled assessment and planning by a multidisciplinary team. Therefore, the use of a collaborative approach, in which decision making is shared among team members, seems a logical management strategy.

Unfortunately, the systems used in most ICUs to communicate a patient's progress and plan of care are not conducive to collaborative care planning. For example, practitioners from the various disciplines

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involved in a patient's care typically document their assessment and plan in separate areas of the medical record. This arrangement is clearly problematic for a patient who requires the ongoing assessment and management of a multidisciplinary team. Another problem is that the ICU flow sheet offers only a snapshot (12-24 hours) of the patient's condition. This method of documentation may be appropriate for short-term management of patients, but it is inadequate when long-term assessment and planning are needed. Last, but perhaps most important, our current system of documentation systematically excludes patients and patients' families from involvement in the plan of care. A patient's medical record is, in most cases, made inaccessible to the patient and his or her family, and they must have special "permission" to review it.

New structures that support communication are needed to promote collaborative decision making. Two such structures, a weaning board and a flow sheet, were used in this study to facilitate communication and promote collaborative care planning among the patient, the patient's family, and the healthcare team.

Attempts to improve the process of weaning off mechanical ventilation have included a number of creative approaches: ventilator management teams,[4] computerized weaning programs,[5-7] and weaning protocols.[8-12] These innovations have been successful in improving outcomes, primarily for patients who require short-term mechanical ventilation (eg, after cardiac surgery). Other researchers[2,13] have reported remarkable achievements with patients receiving long-term ventilation in non-ICU settings both within acute care hospitals and in rehabilitation facilities. Despite the success of these approaches, the management of ICU patients who require prolonged mechanical ventilation and weaning has not been well addressed.

The purpose of this study was to evaluate the effectiveness of a weaning board and a flow sheet in improving outcomes for patients receiving long-term ventilation in the ICU. We defined long-term as 7 days or more. We hypothesized that our interventions would improve important outcomes for patients, particularly the duration of mechanical ventilation.

Materials and Methods

A quasi-experimental design was used to compare patients' outcomes 1 year before (July 1995-June 1996) and 1 year after (July 1996-June 1997) the implementation of a new structure to support a collaborative approach to weaning. The appropriate institutional review board granted approval for the study. Because the nature of the intervention involved an organizational change, the committee for the protection of human subjects granted an exemption from informed consent. Therefore, healthcare providers, patients, and patients' families were unaware of the specific outcome variables being assessed. The study took place in the medical ICU of the University of California Los Angeles, Medical Center.

All patients admitted to the medical ICU who received mechanical ventilation either via a tracheostomy or an endotracheal tube for 7 days or more were included in the study. Patients admitted to the medical ICU from another ICU within the hospital were included in the study so long as they met all other inclusion criteria and did not meet any criteria for exclusion. Patients were excluded if weaning off mechanical ventilation was not a goal (eg, patient with neuromuscular disease requiring partial or continuous ventilatory support), or if they were transferred to another facility before being successfully weaned off the ventilator. A power analysis done by using an α of .05, a moderate effect size, and a β of .80 indicated that a sample size of 140 patients (70 per group) would be required to detect a significant difference between groups.

The intervention, implemented in July 1996, was termed "the collaborative weaning plan" and consisted of the following:

1. The multidisciplinary team developed the plan of care related to weaning during morning rounds. The team consisted of the nurses, physicians, respiratory therapists, and other support staff (eg, pharmacist, dietician) as appropriate. This first step was not unique to the interventional period and, in fact, represented "care as usual." It is included here only to present a comprehensive picture of the process.

2. The plan of care for weaning the patient was then documented on a weaning board (Figure 1). The weaning board was a large (76 cm [30 in] wide by 51 cm [20 in] high), white dry-erase board that hung on the wall at the patient's bedside. The board was used to communicate to the healthcare team, the patient, and the patient's family important data related to assessing the patient's readiness to be weaned (eg, blood gas results and other laboratory values) and the plan for weaning for the day. The weaning plan also included specific parameters for when the weaning trial should be stopped (eg, respiratory rates, tidal volumes).

3. Data on the weaning process and the patient's responses to each weaning trial were recorded on the weaning flow sheet (Figure 2). The weaning flow sheet was a large (61 cm [24 in] wide by 46 cm [18 in] high) sheet of paper that hung next to the weaning board. Items on the flow sheet included (1) the method of weaning used (eg, T-piece, pressure sup-

Assessment	Plan
ABGs: (Date: _____ Time: _____) pH: _____ PaO_2: _____ $PaCO_2$:_____ O_2 Sat: _____ HCO_3 _____ Base ex: _____ $ETCO_2$ Grad: _____ **Labs**: (Date: _____) K:_____ Phos.:_____ Mg: _____ Hg: _____ Pre-alb _____ (Date: _____)	Date: _____ Stop Weaning Trial for the Following: RR>_____ TV<_____ O_2 Sat < _____ $ETCO_2$ > _____

Figure 1 The weaning board. A white, dry-erase board 61 cm (24 in) wide by 46 cm (18 in) high that is hung by the patient's bedside. Relevant laboratory data and the weaning plan for the day are written on the board.

Patient Name ____

	Date		Date		Date		Date		Date		Date		Date		Date		
Trial START time																	Trial START time
Trial STOP time																	Trial STOP time
TOTAL trial duration																	TOTAL trial duration
REASON Trial Stopped	Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		Tachypnea Tachycardia Low T.V. Agitation Short of breath Planned stop Other:		REASON Trial Stopped
Type wean (PS, IMV, T-piece)																	Type wean (PS, IMV, T-piece)
PS Level																	PS Level
IMV rate																	IMV rate
Set TV																	Set TV
Pt. Response	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Pt. Response
HR 150																	150 HR
125																	125
100																	100
75																	75
50																	50
0																	0
RR 150																	150 RR
125																	125
100																	100
75																	75
50																	50
0																	0
SPONT. 500																	500 SPONT.
TV 400																	400 TV
300																	300
200																	200
100																	100
0																	0
Comments (Pt. Position, etc.)																	Comments (Pt. Position, etc.)

Figure 2 The weaning flow sheet. This multidisciplinary form is used to document patients' progress with weaning. It is approximately 76 cm (30 in) wide by 51 cm (20 in) high and is hung on the wall at the patient's bedside.

port), (2) the start and stop time of the weaning trial, (3) physiological parameters measured (eg, vital signs, tidal volumes) before and after weaning, (4) the reason for discontinuing the weaning trial, and (5) any additional comments (eg, presence of family members, activities, patient's response).

4. Any member of the ICU team could fill in the weaning board and flow sheet. In practice, the laboratory values on the weaning board were filled in by the nursing staff, and the weaning plan was filled in by the patient's nurse, respiratory therapist, or physician. Both nurses and therapists completed the weaning flow sheet.

5. The processes used to wean patients (eg, assessments, method of weaning, monitoring) were not manipulated during the intervention period. In both groups, decisions related to weaning were made by the multidisciplinary team (including respiratory therapists and nurses), with the ICU attending physician providing leadership and overseeing the process. The difference during the 2 periods was the method of communicating the weaning plan and patient's progress (Table 1).

The medical ICU had a long-established history of multidisciplinary care planning and a unit philosophy that emphasized collaboration and teamwork. This preexisting collaborative culture certainly influenced the ease with which a new type of communication tool was accepted and used.

Demographic data collected on patients in the study included age, sex, history of chronic lung disease, Acute Physiology and Chronic Health Evaluation II (APACHE II) scores,[15] diagnosis, and method of weaning used (eg, synchronized intermittent mandatory ventilation, T-piece, pressure support). Outcomes studied included (1) duration of mechanical ventilation, (2) length of stay in the medical ICU, and (3) cost of stay in the medical ICU. Cost data were obtained from the medical center's billing department and were based on standardized Medicare reimbursement rates for ICU care (room rates, nursing care). Using cost data rather than charges facilitates comparison with similar studies from other institutions.[4,9] Data were also collected on complications that may have arisen in association with the new weaning method (ie, prevalence of reventilation and need for

Table 1 Comparison of characteristics related to philosophy, care planning, and documentation before and after implementation of a collaborative weaning plan

Before implementation	After implementation
Collaborative philosophy governing all aspects of patients' care	Collaborative philosophy governing all aspects of patients' care
Multidisciplinary rounds every morning on all patients; attended by nurses, attending physician, house staff, respiratory therapists, pharmacists, dieticians, and other support staff as appropriate	Multidisciplinary rounds every morning on all patients; attended by nurses, attending physician, house staff, respiratory therapists, pharmacists, dieticians, and other support staff as appropriate.
Assessment of readiness to be weaned Standardized assessment tools or weaning protocols Assessment data (ie, arterial blood gases, end-tidal carbon dioxide laboratory values) available in the medical record	Assessment of readiness to be weaned No standardized assessment tools or weaning protocols Assessment data (ie, arterial blood gases, end-tidal carbon dioxide laboratory values) available in the medical record and on the weaning board
Method of weaning (eg, synchronized intermittent mandatory ventilation, pressure support) determined by team during rounds that were led by the attending physician; no use of weaning protocols	Method of weaning (eg, synchronized intermittent mandatory ventilation, pressure support) determined by team during rounds that were led by the attending physician; no use of weaning protocols
Documentation of weaning plan recorded in physician's orders	Documentation of weaning plan recorded in physician's orders and on white dry-erase weaning board at bedside
Documentation of weaning progress recorded by nurses, respiratory therapists, and physicians in medical record	Documentation of weaning progress recorded by nurses, respiratory therapists, and physicians in medical record and on multidisciplinary flow sheet hung on wall at patient's bedside

readmission to an ICU) and on mortality rates. Last, data were collected on a number of organizational variables that could affect patients' outcomes, namely, nursing and respiratory staffing patterns, years of experience of nurses and respiratory therapists, and management changes.

Continuous variables were compared by using the Student t test for normally distributed variables. The χ^2 test was used to compare categorical variables and variables that were not normally distributed. Statistical significance was set at *P* less than .05 for the primary outcome variable, duration of mechanical ventilation.

Results

A total of 137 patients met the criteria for entry into the study: 82 in the experimental group and 55 in the comparison group. It is unclear why the numbers of patients meeting the criteria in the 2 periods are so different. Perhaps the medical ICU service was simply busier in the later period than it had been in the previous year. Or perhaps the decrease in the number of ventilator days in the experimental group led to a faster turnover, and hence more patients could be seen.

Table 2 Demographic data and clinical characteristics of patients in comparison and experimental groups

Characteristic	Comparison group (n = 55)	Experimental group (n = 82)	*P*
Age, mean (SD), years	57.9 (19.6)	58.8 (15.8)	.77
Sex, % female	46	46	.95
APACHE II score, mean (SD)	24.1 (7.7)	26.1 (7.3)	.13
Chronic obstructive pulmonary disease, % of patients	35	27	.25
Days of ventilation before transfer to intensive care unit, mean (SD)	5.8 (7.0)	5.5 (6.8)	.87

Comparison group is from before implementation of the collaborative weaning plan; experimental group, from after implementation. APACHE II indicates Acute Physiology and Chronic Health Evaluation II.

Demographic Data

The control and experimental groups did not differ significantly with regard to age, sex, APACHE II scores, presence of chronic obstructive pulmonary disease, or days of mechanical ventilation before being transferred to the medical ICU (Table 2). Most patients in both the comparison and experimental groups were admitted to the medical ICU because of respiratory failure (comparison group, 87%; experimental group, 75%). Other diagnoses included sepsis, liver failure, neurological dysfunction, and recent cardiopulmonary arrest. The 2 groups did not differ significantly with respect to admitting diagnoses (*P* = .27; Table 3).

Forty-nine percent of patients in the experimental group were successfully weaned off the ventilator as compared with 33% of patients in the comparison group (*P* = .12). Most patients in both groups were weaned by using a combination of synchronized intermittent mandatory ventilation and pressure-support ventilation (comparison group, 94%; experimental group, 78%). The type of weaning method used did not differ significantly between groups (*P* = .42; Table 4).

Outcomes

The outcomes for the experimental and comparison groups are compared in Table 5. The median duration of mechanical ventilation ($\chi^2 = 6.1$, $P = .02$), median length of stay in the medical ICU ($\chi^2 = 9.1$, $P = .004$), and the median cost per stay in the medical ICU ($\chi^2 = 9.1$, $P = .004$) were all less in the experimental group than in the comparison group. The mortality rate did not differ significantly between the 2 groups. The prevalence of complications, including reventilation and readmission to the medical ICU, also did not differ significantly.

The number of years of experience of the nursing and respiratory therapy staff did not differ significantly between the 2 periods studied (Table 6). No changes in staffing patterns were made between the 2 periods. A system of primary nursing remained in place during both the control and experimental period. The medical staff and nursing director, as well as the clinical nurse specialist and respiratory specialist, remained the same throughout the 2 years of the study.

The process for care planning (ie, multidisciplinary morning rounds) was unchanged during the 2 study years. Before the study period, the medical center had instituted a number of strategies to decrease length of stay (eg, critical pathways, protocols, utilization review audits). None of the aforementioned strategies were directly related to the patients being weaned, and no new strategies were introduced into the ICU during the 2-year study period.

Discussion

Our results indicate improved outcomes for patients receiving mechanical ventilation for 7 days or

Table 3 Primary diagnoses of patients in comparison and experimental groups

	Comparison group (n = 55)		Experimental group (n = 82)	
Diagnosis	No. of patients	%	No. of patients	%
Respiratory failure	47	85	62	76
Cardiovascular failure	0	0	1	1
Trauma	0	0	1	1
Neurological problem	0	0	4	5
Drug overdose	0	0	0	0
Gastrointestinal bleeding	0	0	0	0
Sepsis	4	7	9	11
Recent cardiopulmonary arrest	2	4	0	0
Postoperative care	0	0	0	0
Liver failure	2	4	4	5
Other	0	0	1	1

Comparison group is from before implementation of the collaborative weaning plan; experimental group, from after implementation. Differences between groups are not significant ($\chi^2 = 8.67$, $df = 7$, $P = .27$). Twelve cells (75%) have expected cell count less than 5. The minimum expected count is 0.40.

Table 4 Method of weaning used in patients who were successfully weaned off mechanical ventilation

	Comparison group (n = 55)		Experimental group (n = 82)	
Method	No. of patients	%	No. of patients	%
Intermittent mandatory ventilation/pressure support	17	94	31	78
Pressure support	0	0	2	5
T-piece	0	0	2	5
Other (combination method)	1	6	5	12

Comparison group is from before implementation of the collaborative weaning plan; experimental group, from after implementation. Differences between groups are not significant ($\chi^2 = 2.80$, $df = 3$, $P = .42$). Six cells (75%) have expected cell count of less than 5. The minimum expected count is 0.62.

more who were managed by using a collaborative weaning plan. Duration of mechanical ventilation, length of ICU stay, and ICU costs were all significantly reduced after implementation of this innovative approach to improve communication among the multidisciplinary team members.

Similar reductions in days of mechanical ventilation were reported by Cohen et al,[4] who described the beneficial effect of a multidisciplinary ventilator management team on outcomes of ICU patients. The goals of their ventilator team were similar to those in our study, including communicating the weaning plan to all staff and promoting unitwide coordination.

Efforts to improve outcomes for patients receiving long-term ventilation have primarily been implemented outside of the ICU. Special units have been developed both within acute care hospitals[2] and at regional weaning centers.[13] These centers were successful in weaning patients who could not be weaned at other facilities. The strategies used in these studies typically included the implementation of a more multidisciplinary and holistic approach to patient care.

A collaborative approach to patients' care has much commonsense appeal but has not been well tested. The essence of collaboration is shared decision making. Collaboration allows all members of the healthcare team to participate fully in care delivery by bringing their unique expertise to the process. According to organizational theorist Peter Senge,[16] the more complex the process, the more collaboration is needed. For example, the extubation of a patient after heart surgery is not generally a complex process. As such, a standard or protocol guiding the process of rapid weaning to extubation is probably sufficient. On the other hand, the weaning of a patient who is recovering from severe respiratory failure or who has multiple underlying medical problems is more complex and requires thoughtful consideration by all members of the team.

A collaborative approach to weaning can be introduced into an ICU in several ways. For example, Cohen et al[4] successfully used a collaborative approach to weaning with their ventilator "team." Unfortunately, the use of specialized teams may not be embraced in this cost-conscious era of healthcare. Our approach, using a weaning board and a flow sheet, may be more

Table 5 Outcomes of patients in comparison and experimental groups

Outcome in medical intensive care unit	Comparison group (n = 55)			Experimental group (n = 82)			*P*
	Overall	1st quartile*	3rd quartile*	Overall	1st quartile*	3rd quartile*	
Days of ventilation, median	16.3	9.8	25.5	11.4	7.9	18.7	.02
Length of stay, median, days	17.1	12.1	28.8	12.6	8.8	21.9	.004
Cost, median, $US	50462	35707	84988	37330	25968	64700	.004
Mortality, % of patients	61.8	NA	NA	57.3	NA	NA	.36
Reventilation, % of patients†	1.8	NA	NA	3.7	NA	NA	.47
Readmission to unit, % of patients‡	0	NA	NA	4.9	NA	NA	.12

Comparison group is from before implementation of the collaborative weaning plan; experimental group, from after implementation.
*NA indicates not applicable.
†Reventilation indicates percentage of patients requiring mechanical ventilation to be reinstituted within 48 hours of the patient having mechanical ventilation discontinued.
‡Readmission to unit indicates percentage of patients readmitted to any intensive care unit within 48 hours of having mechanical ventilation discontinued.

feasible because it uses existing personnel but gives them new structures that foster improved communication and collaborative decision making.

Others have had success using an "outcomes management" approach. This model uses a team of highly motivated persons who develop standards and track variables related to the weaning process. Members of these teams are not necessarily involved in "hands on" care but are integral to the process of evaluating patients' outcomes and promoting strategies for improvement.[17,18]

A limitation of our study was the use of a historical comparison group. Because of this design, the outcomes of the 2 study periods could be the result of events other than the intervention. We attempted to control for this limitation by comparing patients' demographics and organizational characteristics during the 2 study periods. Because the groups were similar, we have greater confidence in our findings.

Despite its limitations, our results are important because they suggest that significant improvements in patients' outcomes can be achieved by using interventions aimed at improving communication among members of the healthcare team. Although our target group was patients being weaned off mechanical ventilation, most likely any group of patients with complex needs

Table 6 Years of experience of the nursing and respiratory therapy staff during the experimental and comparison periods

Staff	Comparison period (1995-1996)		Experimental period (1996-1997)		*P*	SE of difference	95% CI for difference
	Mean	SD	Mean	SD			
Nurses	4.3	2.7	5.4	2.8	.82	0.82	-2.81, 0.49
Respiratory therapists	9.5	6.5	8.8	7.4	.63	1.38	-2.06, 3.41

Comparison group is from before implementation of the collaborative weaning plan; experimental group, from after implementation.

(eg, pain management) would benefit from such an intervention. Further study in this area with use of other types of creative communication methods is certainly warranted.

Caring for critically ill patients with complicated, long-term needs deserves increased attention. The "cost" of caring for patients receiving long-term mechanical ventilation is high not only for the organization but also for the patient, the patient's family, and the staff. Collaborative care planning with use of a weaning board and a flow sheet offers a practical and cost-effective method of improving outcomes for this complex population of patients.

ACKNOWLEDGMENTS

This work was supported by a grant from the Stein-Oppenheimer Foundation. We thank the members of the University of California, Los Angeles, medical intensive care unit team for their commitment to collaborative planning for patients' care.

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