Effect of a collaborative weaning plan on patient outcome in the critical care setting

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Objective: **The process of weaning from mechanical ventilation can be complex, requiring collaborative care planning by members of the healthcare team. Improved outcomes have been demonstrated to result from collaborative decision-making processes (e.g., when ventilator teams were utilized). The purpose of this study was to evaluate the effect of a collaborative weaning plan (CWP) on length of time on mechanical ventilation, length of stay in the intensive care unit (ICU), and cost.**

Design: **A new, collaborative weaning plan in the form of a weaning board and flowsheet was introduced into a medical intensive care unit (MICU) setting. A pre- and post-quasi-experimental design using historical controls was used to test the hypotheses. Attempts to control for the effects of history were made by collecting data related to patient, staffing, and organizational variables that could independently effect outcome.**

Setting: **MICU in a west coast teaching hospital.**

Patients: **Critically ill patients receiving mechanical ventilation for 3 days or greater.**

Intervention: **Implementation of a collaborative weaning plan.**

Measurements: **Outcomes studied included length of stay in the MICU, length of time patients were mechanically ventilated in the MICU, cost per MICU stay, and the incidence of complications (e.g., reventilation, readmission to the ICU, and mortality rate.)**

Main Results: **The CWP decreased length of stay in the MICU by 3.6 days ($p = .03$) and length of ventilator time by 2.7 days ($p = .06$). There were no significant differences between groups related to cost or incidence of complications.**

Conclusions: **These results support the usefulness of collaborative structures (such as weaning boards/flowsheets) in decreasing ICU length of stay. (Crit Care Med 2001; 29:297–303)**

KEY WORDS: weaning; mechanical ventilation; collaboration; critical care planning

The process of weaning critically ill patients from mechanical ventilation is complex from both a physiologic perspective and from the standpoint of the healthcare system. The challenge is particularly great in situations when the patient requires prolonged ventilatory support or has underlying medical problems that complicate the weaning process. Given this complexity, the weaning process lends itself to the use of structures that promote collaborative decision making by members of the critical care team (1, 2).

Most research related to weaning has focused on the assessment of weaning readiness (3–10) and comparisons of various weaning methods (11–13). More recently, investigators have begun to examine patient care delivery systems with the potential to have a positive impact on the weaning process, such as computerized weaning programs (14–16), protocols (17–19), and a multidisciplinary ventilator management team (2). Despite the fact that collaborative, or team approaches to weaning have much commonsense appeal, structures and processes that promote such an approach have not been well tested.

The process of weaning from mechanical ventilation is unique in that it requires ongoing assessment and planning by multiple members of the critical care team. Physicians, nurses, respiratory therapists, and others all make unique contributions to the weaning process. Unfortunately, the mechanisms used to document and evaluate such collaborative endeavors as weaning are typically lacking in the intensive care unit (ICU) setting. The majority of flowsheets and care plans are generated and used exclusively by nursing staff, are not multidisciplinary in design, and are not readily available to all the members of the team. Hence, the individuals caring for a patient may not be aware of the plan or the patient's progress related to weaning. Our study examined the impact of an innovative, multidisciplinary approach on patient outcomes. We hypothesized that patients receiving an experimental, collaborative approach to weaning would have reduced length of time on mechanical ventilation, shorter lengths of stay in the ICU, and reduced cost of ICU care compared with patients in a care-as-usual comparison group.

MATERIALS AND METHODS

A pre- and post-quasi-experimental design was used to compare patient outcomes 1 yr before (July 1995 to June 1996) and 1 yr after (July 1996 to June 1997) the implementation of a new, collaborative approach to weaning. The appropriate Institutional Review Board granted approval for the study before its being conducted.

Because the nature of the intervention involved an organizational change that involved all patients in the unit, the human subjects protection committee granted an exemption from informed consent. Therefore, with the exception of key administrative and research personnel, the majority of healthcare providers, patients, and families were unaware of the specific outcome variables being assessed. The study took place in an eight-bed medical ICU (MICU) in a large, west coast medical center.

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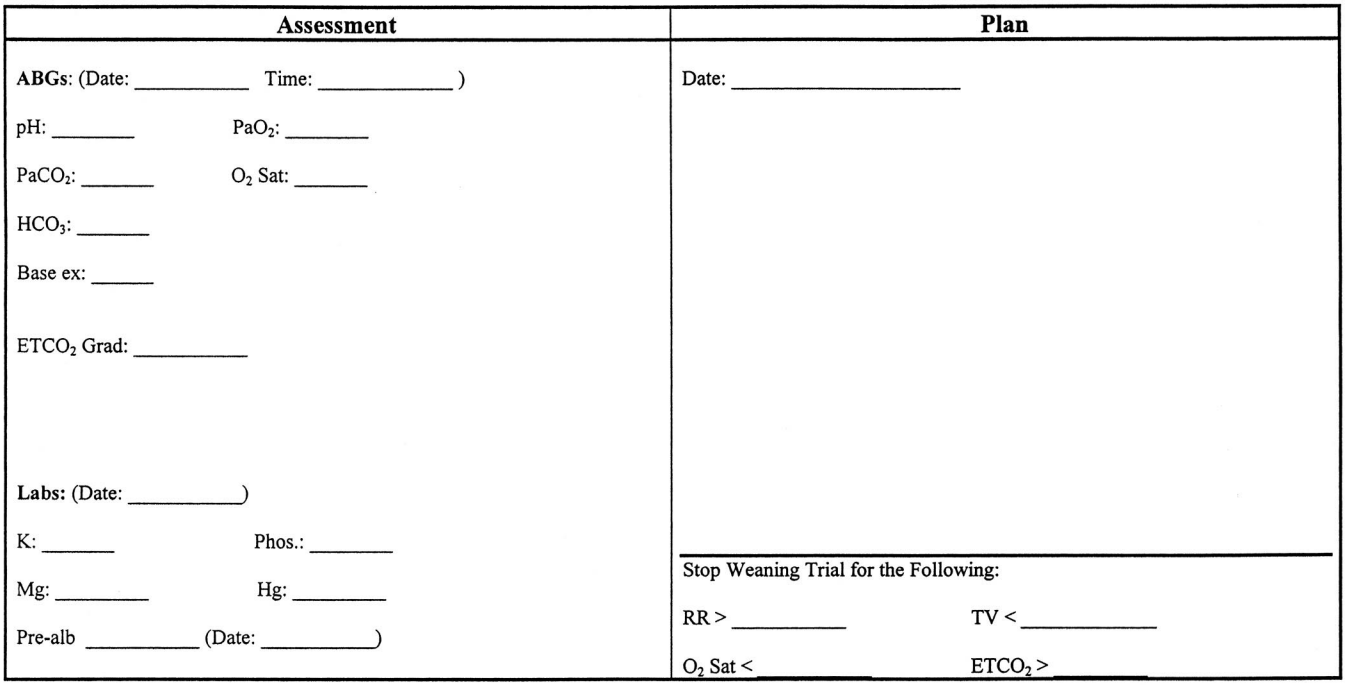

Figure 1. The weaning board. A white, dry-erase board approximately 8 by 24 inches, which is kept at the bedside of each patient.

All patients admitted to the MICU who received mechanical ventilation either via a tracheostomy or endotracheal tube for 3 or more days were included in the study. Patients were excluded from the study if weaning from the ventilator was not a goal (e.g., patient with neuromuscular disease requiring partial or continuous support). A power analysis using an alpha of 0.05, a moderate effect size, and a beta of 0.80 determined 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 the collaborative weaning plan. The multidisciplinary team developed this plan of care related to weaning during morning rounds. The team consisted of the nurses, physicians, respiratory therapists, and other support staff as appropriate (e.g., pharmacist, dietician, and other support staff). The plan was documented on a weaning board and a weaning flowsheet (Figs. 1 and 2). The weaning board was a large (18 inches high by 24 inches wide) white dry erase board that hung on the wall at the patient's bedside. The board was used to communicate to the team, patient, and family members important data related to assessing the patient's readiness to wean (e.g., blood gas results and other laboratory values) and the plan for weaning for the day. The multidisciplinary team devised the weaning plan during morning rounds. The weaning plan also included specific variables for when the weaning trial should be stopped (e.g., respiratory rates, tidal volumes, etc.)

The weaning flowsheet was a large (18 inches high by 24 inches wide) sheet of paper that hung next to the weaning board. Data regarding the weaning process and patient's responses to each weaning trial that were recorded on the flowsheet included the following: 1) the method of weaning used (e.g., t-piece, pressure support, etc.); 2) the start and stop time of the weaning trial; 3) physiologic variables measured (e.g., vital signs, tidal volumes) before and after weaning; 4) the reason for discontinuing the weaning trial; and 5) any additional comments (e.g., presence of family members, activities, patient response).

Any member of the ICU team could fill out the weaning board and flowsheet. In practice, the laboratory values on the weaning board were filled in by the nursing staff and the weaning plan by the nurse, respiratory therapist, or physician. Both nurses and respiratory therapists completed the weaning flowsheet.

The process of weaning patients during the experimental and comparison periods was similar in many respects. The major difference during the two periods was the method of communicating the weaning plan and patient's progress. For example, the MICU had a long-established history of multidisciplinary care planning and a unit philosophy that emphasized collaboration and teamwork. This commitment to collaboration was clearly present during both study periods. In addition, the approach to weaning was unchanged during the two study periods. Decisions related to weaning were made by the multidisciplinary team (including respiratory therapists and nurses) with the ICU attending physician providing leadership and oversight of the process. During both the comparison and experimental periods, patients were managed on an individual basis, both for the assessment of weaning readiness and the method of weaning. There were no weaning protocols utilized during either the comparison or study period (Table 1).

Demographic data collected on patients in the study included age, gender, history of chronic lung disease, Acute Physiology and Chronic Health Evaluation (APACHE) II scores (20), diagnosis, and type of weaning utilized. Outcomes studied included the following: 1) length of time the patients received mechanical ventilation in the MICU; 2) length of stay in the MICU; and 3) and cost of the MICU stay. Cost data were obtained from the hospital 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 (2, 18). Data were also collected on complications that may have arisen secondary to the new weaning method, that is, mortality rates, incidence of reventilation, and need for readmission to *any* ICU in the hospital.

Lastly, data were collected on a number of organizational variables that had the potential to effect patient outcomes, namely, staffing patterns, years of experience of nursing and respiratory therapy staff, or management changes.

Descriptive statistics were used to characterize the two groups. Baseline characteristics

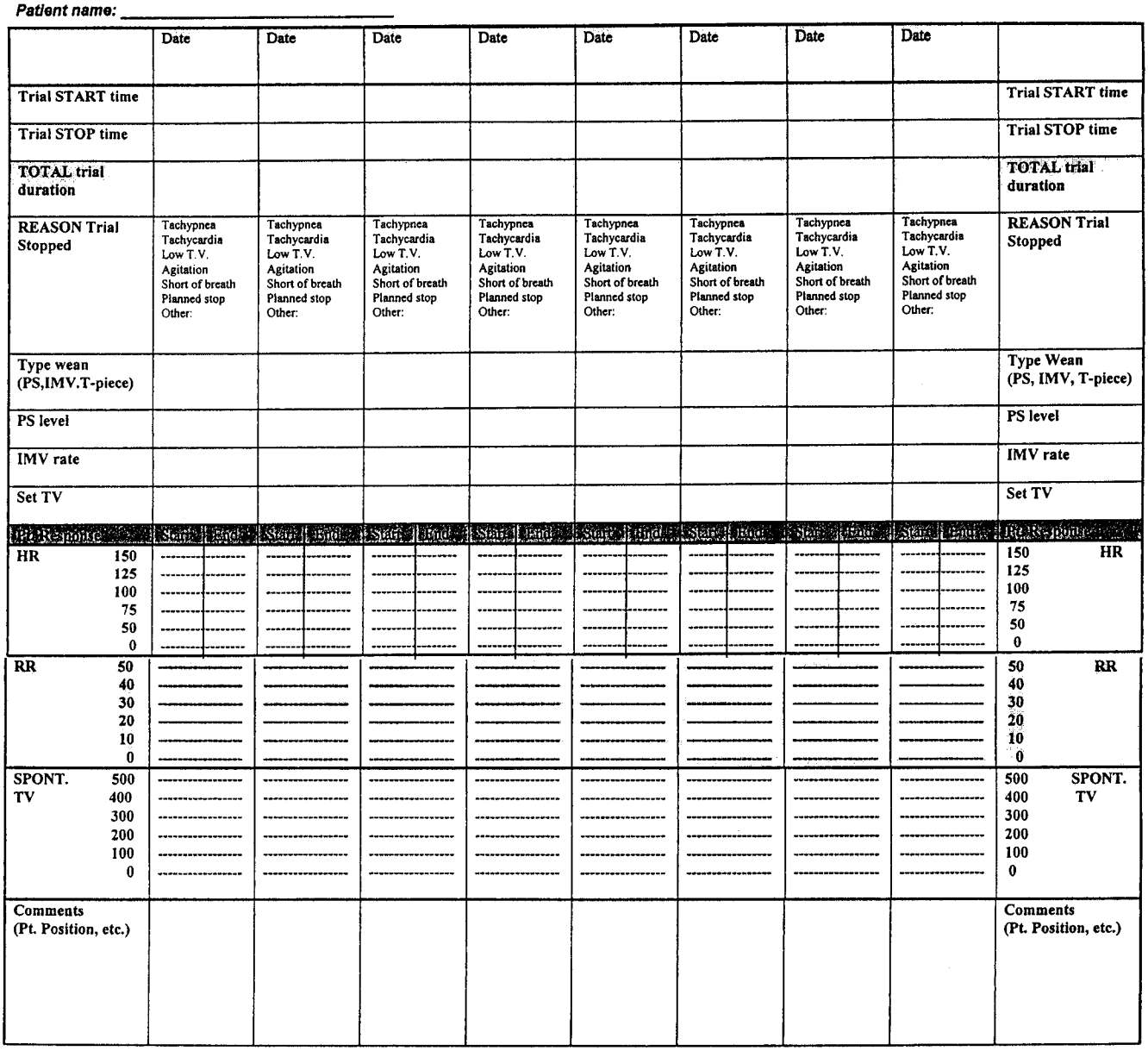

Figure 2. The weaning flowsheet.

of the two groups and clinical outcomes were compared using chi-square for ordinal data and independent *t*-tests for interval data. Significance was set at $p < .05$.

RESULTS

A total of 207 patients met the criteria for entry into the study. Six outliers (three per group) were excluded from data analysis because they represented a significant deviation from the rest of the patients based on an analysis of the frequency distribution, as recommended by Weissman (21). These patients represented 3% of the total sample. Their length of ventilator time and ICU stay were skewed to the right, ranging from 3.2 days to 47.5 days and 3.9 days to 75.3 days, respectively. The final data set consisted of 201 patients (comparison group, n = 77; experimental group, n = 124).

In order to provide a comprehensive representation of patient outcomes, median values for the entire patient population (including outliers) has been noted in parentheses in the "Results" section.

Demographic Data. There was no difference between the control and experimental groups with regard to age, gender, presence of chronic lung disease, or APACHE II scores (Table 2). The majority of patients in both the control and experimental groups were admitted to the MICU for respiratory failure (comparison group, n = 67 [87%]; experimental group, n = 90 [72%]). Other diagnoses included sepsis, liver failure, neurologic dysfunction, and postarrest states. There were no significant differences between groups with respect to admitting diagnoses ($p = .20$) (Table 3).

Outcomes. Fifty percent (n = 62) of patients in the experimental group successfully weaned off the ventilator as compared with 40% (n = 31) of patients in the comparison group. The vast majority of patients in both groups were weaned using a combination of synchro-

Table 1. Summary of ventilator weaning management strategies used in comparison and experimental groups

Comparison Group	Experimental Group
Multidisciplinary rounds every morning on all patients. Rounds attended by nurses, attending physician, house staff, respiratory therapists, pharmacists, dieticians, and other support staff as appropriate.	Multidisciplinary rounds every morning on all patients. Rounds attended by nurses, attending physician, house staff, respiratory therapists, pharmacists, dieticians, and other support staff as appropriate.
Assessment of readiness to wean: • no standardized assessment tools/weaning protocols • assessment data (i.e., ABGs, end-tidal CO_2 lab values) available in the medical record	Assessment of readiness to wean: • no standardized assessment tools/weaning protocols • assessment data (i.e., ABGs, end-tidal CO_2 lab values) available in medical record and summarized on weaning board
Method of weaning determined by team during rounds that were led by the attending physician. No weaning protocols utilized.	Method of weaning determined by team during rounds that were led by the attending physician. No weaning protocols utilized.
Documentation of weaning plan recorded in physician orders.	Documentation of weaning plan recorded on weaning board at bedside and in physician orders.
Documentation of weaning progress recorded by nurses, respiratory therapists, and physicians in medical records.	Documentation of weaning progress recorded by nurses, respiratory therapists, and physicians in medical record and on multidisciplinary flow sheet at patient's bedside.

ABGs, arterial blood gases; CO_2, carbon dioxide.

Table 2. Comparison group and experimental group—demographic data and clinical characteristics

	Comparison Group (n = 77)	Experimental Group (n = 124)	*p* Value
Age[a]	58.2 ± 18.4	59.2 ± 16.4	.70
Gender—female n (%)	33 (43)	60 (48)	.45
APACHE II Score[a]	24.3 ± 8.6	26.5 ± 7.9	.08
COPD–n (%)	26 (34)	31 (27)	.60

APACHE, Acute Physiology and Chronic Health Evaluation; COPD, chronic obstructive pulmonary disease.

[a]Data reported as mean ± SD.

Table 3. Comparison and experimental groups by primary diagnoses (reason for admission to the intensive care unit)

	Comparison Group (n = 77)		Experimental Group (n = 124)	
	n	%	n	%
Respiratory failure	67	87	90	73
Cardiovascular failure	0	—	1	1
Trauma	0	—	1	1
Neurologic	1	1	7	6
Drug overdose	0	—	0	—
Gastrointestinal bleeding	0	—	0	—
Sepsis	5	7	13	11
Post-arrest	2	3	1	1
Post-op	0	—	0	—
Liver failure	2	3	9	7
Other	0	—	2	2

—, not applicable.

No significant differences between groups (chi-square, $p = .20$).

nized intermittent mandatory ventilation (SIMV) and pressure support ventilation (comparison group, n = 30 (96.8%); experimental group, n = 56 (86.1%) (Table 4).

The length of time patients received mechanical ventilation in the experimental group was 10.3 ± 9.0 days (median 9.0) compared with 13 ± 10.7 days (median 11.8) in the comparison group ($p = .06$). The length of stay in the MICU was 12.0 ± 9.8 (median 9.0) in the experimental group and 15.6 ± 13.3 days (median 12.8) in the comparison group ($p = .03$). The average cost per MICU stay was $42,213 in the experimental group (median $26,559) and $52,789 in the comparison group (median $37,920) ($p = .16$) (Table 5).

The mortality rate was not significantly different in the control and experimental groups. The incidence of reventilation and readmission to the MICU was slightly higher in the experimental group, but not significantly (Table 5).

Years experience of nursing and respiratory therapy staff were not significantly different between the two time periods studied (Table 6). The MICU leadership group and medical staff remained the same throughout the 2 yrs of the study. A system of primary nursing remained in place during both the control and experimental period. The process for care planning (i.e., multidisciplinary morning rounds) was unchanged during the 2-yr study period. Before the study period the medical center had instituted a number of strategies to decrease length of stay (e.g., critical pathways, protocols, utilization review audits). However, no new strategies were introduced during the 2-yr study period.

DISCUSSION

The results of this study demonstrated the effectiveness of a collaborative weaning plan, using a weaning board and flowsheet on length of patient stay in an ICU setting. There was a statistical trend related to a reduction in ventilator time. Although the reductions in length of ventilator time and cost were not statistically significant, they were clinically important.

We hypothesized that both ventilator length of stay and time in the ICU would be reduced with the intervention. One possible explanation is that our sample size may have been too

small to detect a statistically significant difference in length of ventilator time. We had based our power analysis and sample size determination on Cohen's study (2), which utilized a more homogeneous sample population. It is possible that our nonsignificant findings can be explained by the larger variance found in our patient population as compared with that of Cohen.

Another possible explanation for the differences in ventilator time and length of stay was that the intervention provided increased communication and collaboration among the healthcare providers working in the unit. It may be, however, that the intervention had a broader effect in increasing communication over additional patient care issues such as nutritional issues, rehabilitation, and discharge planning. Staff frequently used the weaning board to record patient issues unrelated to weaning (e.g., tests planned for that day).

There was a slight increase (although not significant) in reventilation and readmission rates during the experimental period. However, our reventilation rates are similar to (12), or lower (13) than the reintubation rates reported in other studies. In those studies reintubation was used as the criteria for failed weaning as opposed to reventilation, which was used in our study. It is possible that an increased focus on weaning led to slightly more aggressive management and hence earlier discontinuing of mechanical support with a greater chance of weaning "failure," requiring the reinstitution of mechanical ventilation.

Our findings support those of other researchers (2), who have demonstrated improved outcomes in mechanically ventilated patients managed with a collaborative approach. Cohen and colleagues evaluated the impact of a multidisciplinary ventilator management team on ICU patient outcomes. Their goals were similar to ours, and included communicating the weaning plan to all staff and promoting unit wide communication. They reported a significant reduction in length of ventilator days for patients weaned using this approach as compared with historical controls.

Of note is that in Cohen's study, the length of ICU stay was not reduced significantly despite the decrease in ventilator days. This may have resulted from the

Table 4. Experimental and comparison groups by type of weaning utilized in patients successfully weaned from ventilator

	Comparison Group (n = 31)		Experimental Group (n = 62)	
	n	%	n	%
SIMV/pressure support	30	97	56	86
Pressure support	0	—	3	5
T-piece	0	—	1	2
Other (combination method)	1	3	2	3

SIMV, synchronized intermittent mandatory ventilation; —, not applicable.
No significant differences were observed between groups (chi-square, $p = .50$).

Table 5. Comparison of clinical outcomes in comparison and experimental groups

	Comparison Group (n = 77) Mean SD	Experimental Group (n = 124) Mean SD	*p* Value	SE of Difference	95% Confidence Interval of Difference
MICU ventilator days[a]	13.0 ± 10.7	10.3 ± 9.0	0.06	1.40	(−.10, 5.44)
LOS—MICU[b]	15.6 ± 13.3	12.0 ± 9.8	0.03	1.64	(.32, 6.79)
Cost—MICU ($)[c]	52,789.70 ± 52,113.82	42,213.24 ± 53,457.10	0.16	7557.02	−4323.00, 25475.92

	n	%	n	%	*p* Value
Weaned	31	40	62	50	0.18
Mortality—MICU	37	48	52	42	0.40
Reventilation[d,e]	2	6	6	10	0.90
Readmission ICU[e,f]	2	6	6	10	0.90

[a]MICU ventilator days: total number of days spent on mechanical ventilation while patient was in the medical intensive care unit (MICU).
[b]LOS—MICU: Number of days spent by the patient in the MICU.
[c]Cost—MICU: Total costs incurred during the patient's stay in the MICU.
[d]Reventilation: Number of patients requiring reinstitution of mechanical ventilation within 48 hrs of the patient having mechanical ventilation discontinued.
[e]The total numbers of patients successfully weaned includes the figures for patients who later required reventilation and readmission.
[f]Readmission—ICU: Readmission to any ICU within 48 hrs of being discharged from the MICU.

Table 6. Comparison of years experience in the experimental and comparison periods for nursing and respiratory therapy staff

	Comparison Period (1995–1996)		Experimental Period (1996–1997)				
	Mean	SD	Mean	SD	*p* Value	SE of Difference	95% Confidence Interval for Differences
Nursing staff	4.3	2.7	5.4	2.8	.82	0.82	−2.81, 0.49
Respiratory therapy staff	9.5	6.5	8.8	7.4	.63	1.38	−2.06, 3.41

These results support the usefulness of collaborative structures (such as weaning boards/flowsheets) in decreasing intensive care unit length of stay.

narrow (albeit appropriate) focus on the ventilator management team on the patient's ventilatory status as opposed to the patient's overall condition. In our study, the collaborative plan was determined by a team involved in all aspects of the patient's care. Hence, decisions about ventilator management made have been balanced against other considerations, which may have ultimately expedited the patient's transfer out of the ICU.

Cohen's study highlighted the need for improved coordination of weaning and demonstrated a positive impact on patient outcomes using a multidisciplinary team. However, the use of specialized teams may not be embraced in this cost-conscious era of health care. Our approach may be more feasible because it utilizes existing personnel, but gives them new structures that foster improved communication and collaborative decision making.

Collaborative or multidisciplinary approaches to care have long been promoted by professional organizations as key to optimizing patient outcomes (22, 23). Despite this, few studies have systematically examined the impact of collaborative decision-making processes on patient outcome (24–26). The results of these studies suggest, however, that structures that promote coordination, interaction, and shared decision making have a positive effect on outcomes.

Current methods of care planning in the ICU setting have two major drawbacks. The first is that the structures available to clinicians are typically noncollaborative in nature. Each discipline characteristically performs its own assessment and from this assessment derives a plan of care. For example, a physician may develop a plan, which is then written in a clinical note, and sections of the plan are conveyed via the physician's "orders." The nurse and respiratory therapist also conduct a patient assessment and develop a plan, which is recorded in their own notes, flowsheet, or care plan. With the exception of physician orders, it is questionable whether any of these records are used for cross-disciplinary communication.

The other problem with our current documentation system is its focus on short-term outcomes and goals. Most interventions and patient responses in the ICU setting are assessed over minutes or hours. Processes that span days to weeks, such as weaning from mechanical ventilation, require a perspective beyond what is typically available on a 24-hr flowsheet. Structures that support long-term decision making are desperately needed. The weaning board/flowsheet is an example of a device that can facilitate the complex process of weaning.

This study is not without limitations. The use of a historical comparison group is problematic in that it is possible that the outcomes that occurred between the two study periods resulted from events other than the intervention. Attempts were made to control for history by comparing patient demographics and organizational characteristics during the two time periods. Because the groups were similar, we are more confident in our findings. Although a randomized design would have been preferable, in reality, it would have been impossible to carry out such a scheme in our small eight-bed unit without significant contamination. We also considered using another ICU in our medical center as a control unit, but the populations were so different that it was not deemed appropriate.

It is becoming increasingly evident that there is no single best method of weaning. Experts have suggested that the real "magic" behind successful weaning lies not in the use of any particular method, but rather in the use of a coordinated, consistent approach by members of the weaning team with careful monitoring of patient responses (27). Efforts must be directed at creating the best environment for weaning through the use of structures and processes, which support a collaborative weaning process. A collaborative weaning plan using a weaning board and flowsheet offers clinicians this type of structure.

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