Early activity is feasible and safe in respiratory failure patients*

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Objective: **To determine whether early activity is feasible and safe in respiratory failure patients.**

Design: **Prospective cohort study.**

Setting: **From June 1, 2003, through December 31, 2003, we assessed safety and feasibility of early activity in all consecutive respiratory failure patients who required mechanical ventilation for >4 days admitted to our respiratory intensive care unit (RICU). A majority of patients were treated in another intensive care unit (ICU) before RICU admission. We excluded patients who required mechanical ventilation for ≤4 days.**

Patients: **Eight-bed RICU at LDS Hospital.**

Interventions: **We assessed patients for early activity as part of routine respiratory ICU care. We prospectively recorded activity events and adverse events. We defined three activity events as sit on bed, sit in chair, and ambulate. We defined six activity-related adverse events as fall to knees, tube removal, systolic blood pressure >200 mm Hg, systolic blood pressure <90 mm Hg, oxygen desaturation <80%, and extubation.**

Measurements and Main Results: **During the study period, we conducted a total of 1,449 activity events in 103 patients. The activity events included 233 (16%) sit on bed, 454 (31%) sit in chair, and 762 (53%) ambulate. In patients with an endotracheal tube in place, there were a total of 593 activity events, of which 249 (42%) were ambulation. There were <1% activity-related adverse events, including fall to the knees without injury, feeding tube removal, systolic blood pressure >200 mm Hg, systolic blood pressure <90 mm Hg, and desaturation <80%. No patient was extubated during activity.**

Conclusions: **We conclude that early activity is feasible and safe in respiratory failure patients. A majority of survivors (69%) were able to ambulate >100 feet at RICU discharge. Early activity is a candidate therapy to prevent or treat the neuromuscular complications of critical illness. (Crit Care Med 2007; 35:139–145)**

Key Words: respiratory failure; critical illness; exercise; ambulation; mobility

Critically ill patients often require lengthy mechanical ventilation (1). Outcomes in patients requiring mechanical ventilation have traditionally focused on hospital mortality or short-term physiologic end points (2–4). However, survivors of mechanical ventilation often experience poor physical outcomes (1, 5, 6), intensive care unit (ICU) readmission (7), institutionalization (8), and decreased health-related quality of life (9). A prospective study of 109 patients with acute respiratory distress syndrome showed significant physical disability 1 yr after hospital discharge, with approximately half of the patients unable to return to work due to persistent fatigue, weakness, and poor functional status (10).

Critically ill patients are frequently viewed as "too sick" to tolerate vigorous activity in the early phase of their illness, thereby incurring "unavoidable" prolonged immobilization. Prolonged immobilization may play a role in the development of neuromuscular abnormalities that complicate the clinical course of critically ill patients (11). We postulated that early activity, beginning at a point when the patient demonstrates physiologic stabilization and continuing through the ICU stay, might improve physical functioning to the point that most patients could ambulate by the time of ICU discharge. The purpose of this study was to determine whether early physical activity was feasible and safe in respiratory failure patients.

METHODS

Patient Selection. From June 1, 2003, through December 31, 2003, we assessed safety and feasibility of early activity in all consecutive respiratory failure patients who required mechanical ventilation for >4 days admitted to an eight-bed respiratory ICU (RICU) at LDS Hospital. We selected patients with >4 days of mechanical ventilation in order to include patients at risk to develop physical debilitation. We excluded patients requiring mechanical ventilation for ≤4 days. A majority of patients were admitted to the RICU from the medical ICU and shock trauma respiratory ICU. We collected patient demographics, etiology, comorbid disorders, length of stay, Acute Physiology and Chronic Health Evaluation II scores 24 hrs after admission to RICU (12), multiple organ failure scores (13), ventilator data, and hospital disposition data prospectively. The LDS Hospital Institutional Review Board approved this study and informed consent was waived.

Early Activity Protocol. We defined "early" as the interval starting with initial physiologic stabilization and continuing through the ICU stay. This interval is early compared with activity that usually begins after ICU discharge. *A priori* we selected three criteria for initiation of activity including neurologic criteria, respiratory criteria, and circulatory criteria. The neurologic criterion to begin activity was patient response to verbal stimulation. Activity was not started in comatose patients. The respiratory criteria to start activity were F_{IO_2}

***See also p. 311.**

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≤0.6 and positive end-expiratory pressure ≤10 cm H_2O. The circulatory criteria to start activity were the absence of orthostatic hypotension and catecholamine drips. For patients who did not fully meet the respiratory or circulatory criteria but who otherwise appeared ready for activity, we initiated a careful trial of activity with close monitoring for adverse events. All patients were assessed to determine whether they met early activity criteria within 24 hrs of RICU admission and daily thereafter.

The goal of the activity protocol was to ambulate >100 feet before RICU discharge. Each activity event required the participation of a physical therapist, respiratory therapist, nurse, and critical care technician. We attempted to increase progressively the patients' activity level (e.g., from sit in chair to ambulate) with each subsequent twice-daily physical therapy session. If activity was suspended for any reason, activity was reevaluated daily during team rounds until reinitiated. We attempted to circumvent any nonphysiologic activity barriers imposed by ICU equipment and processes, including endotracheal tubes.

A pre- and postactivity rest period with assist-control ventilation for 30 mins was employed as needed to support early activity. If the patient was intubated and able to participate in activity, the F_{IO_2} was increased by 0.2 before initiation of activity. We deferred ventilator weaning in support of activity, as necessary. Levels of F_{IO_2} and airway status were recorded before and during each activity event. Adequate oxygen was administered to prevent desaturation during activity. Oxygen saturation was monitored using continuous pulse oximetry before, during, and after each activity event. Blood pressure was measured immediately before and after activity.

Activity Events. A priori we defined three activity events: sit on the edge of hospital bed without back support, sit in a chair after transfer from the hospital bed, and ambulate with or without assistance using a walker and/or support from the RICU staff. During ambulation, a physical therapy technician with a wheelchair followed behind the patient in case of sudden fatigue or any adverse event. Patient movement to an upright position in bed or stroke chair and passive range of motion were not considered activities.

Feasibility. The RICU staff consists of nurses, respiratory therapists, physical therapists, and critical care technicians. The RICU staff was educated to work as a team to deliver twice-daily activity. This required a change in unit culture and teamwork habits during a prolonged prestudy period. The RICU staff is resourced similarly to other ICUs in our institution, with the exception of physical therapists who are assigned to work exclusively in the RICU compared with rotating assignments for other non-RICU physical therapists at our institution. However, total hours of physical therapy available to all hospital ICU patients at our institution were the same.

Table 1. Respiratory failure patients' medical data (n = 103)

Variable	Mean ± SD	Median	Range
Age, yrs	62.5 ± 15.5	63	18–91
Duration of mechanical ventilation, days	18.7 ± 15.4	13	5–88
Total ICU length of stay, days	22.7 ± 15.9	18	6–92
RICU length of stay, days	13.8 ± 11	11	1–50
Hospital length of stay, days	26.6 ± 17	22	6–94
Hospital to RICU admission, days	10.5 ± 9.9	8	0–57
APACHE II scores			
Highest value in any ICU	26 ± 4.9	26	13–.39
At initial ICU admission	21 ± 6.3	21	7–36
At RICU admission	17 ± 4.8	17	4–29
Multiple organ failure score (13)			
At initial ICU admission	4.5 ± 2.8	4	0–13
At RICU admission	4.5 ± 2.8	4	0–11
Highest F_{IO_2} in any ICU	0.87 ± 0.2	1	0.4–1
Lowest Pa_{O_2}, mm Hg, in any ICU	52.7 ± 11	52	32–85
Lowest Pa_{O_2}/F_{IO_2} in any ICU	97.8 ± 46.8	89	35–265

ICU, intensive care unit; RICU, respiratory intensive care unit; APACHE, Acute Physiology and Chronic Health Evaluation.

LDS Hospital multiple organ failure score is obtained by assigning a score of 1 for each organ system in failure including renal, cardiovascular, coagulation, hepatic, central nervous, gastrointestinal, and immunologic and summing the total number of organs that failed at least once after admission. Definitions of organ failure are as follows: renal = creatinine ≥3.5 mg/dL, dialysis, or urine output <25 mL/hr for 24 hrs; cardiac = cardiac index <1.8 L/min/m^2, systolic blood pressure <90 mm Hg with pressor drugs, or arterial-venous oxygen difference >7.0 mL of oxygen/dL; coagulation = platelet count <60,000/μL or prothrombin time or partial thromboplastin time >1.5 times control; hepatic = bilirubin >5 mg/dL or prothrombin time or partial thromboplastin time >1.5 times control; central nervous = Glasgow Coma Scale score <8 for 3 days; gastrointestinal = pancreatitis causing shock, ruptured necrotic/ischemic viscus or gastrointestinal hemorrhage requiring >2 units of packed red blood cells; immunologic = prednisone or equivalent of 50 mg/day for ≥7 days or ≥20 mg/day for ≥1 month, or other immunosuppressive agent, or known acquired immune deficiency syndrome (13).

Patient Safety. A priori we defined six activity-related adverse events: fall to knees, tube removal, systolic blood pressure >200 mm Hg, systolic blood pressure <90 mm Hg, desaturation of <80%, and extubation. The adverse events and associated complications were prospectively recorded by our physical therapists (RB, JJ).

Statistical Analysis. Descriptive statistics were carried out for demographic, medical, activity, and adverse events. Data are presented as mean ± SD and median.

RESULTS

Demographic and Medical Data. We prospectively enrolled 103 consecutive respiratory failure patients. Twenty patients had no comorbid disorders, 26 patients had one comorbid disorder, and 57 had multiple comorbid disorders. Table 1 shows medical data for the patients. Of the 103 patients, 57% were male. The median age was 63 yrs (interquartile range 50–75 yrs), and 49 (48%) of the patients were older (age >65 yrs). Table 2 shows the patients' primary diagnosis and comorbid medical disorders. Ninety-seven (94%) of our patients were admitted to another ICU at LDS Hospital before

Table 2. Primary diagnosis and comorbid disorders for the respiratory failure patients

Variable	No.
Primary diagnosis	
Sepsis	41
Pneumonia	20
Cardiovascular disease	10
Aspiration	7
Gastrointestinal bleed or liver failure	6
Trauma	6
Surgery	6
Chronic obstructive pulmonary disease exacerbation	4
Cancer	2
Asthma	1
Comorbid disorders	
Cardiovascular disease	39
Diabetes	31
Psychiatric disorders	23
Chronic obstructive pulmonary disease	21
Neurologic disease	15
Cancer	14
Congestive heart failure	11
Obstructive sleep apnea	10
Immunosuppression	6
Morbid obesity	6
Substance abuse	4
Cirrhosis	3
Other pulmonary disorders	3
Chronic renal failure	2

RICU admission (mean time to RICU admission 10.5 ± 9.9 days). Ninety-two (89%) patients were on mechanical ventilation at RICU admission. Five patients were not weaned from mechanical ventilation before RICU discharge: three had end-stage pulmonary disease, one had traumatic brain injury, and one was chronically ventilator dependent before hospital admission. During the 7 days before RICU admission, 17 patients received catecholamine drips, 24 received sedatives (>10 mg Ativan per day or any intravenous sedative drip), and 22 received both catecholamines and sedatives. Early activity started a mean of 0.31 ± 3.4 days (median 1 day) after discontinuation of catecholamines and a mean of 1.1 ± 2.1 days (median 1 day) after discontinuation of sedatives. After RICU admission only two patients received sedatives and nine received catecholamines while participating in activity.

Figure 1. A patient with exacerbation of chronic obstructive pulmonary disease and pneumonia on assist-control ventilation ambulating with the aid of the respiratory therapist on the right, physical therapist on the left adjacent to the patient, and a critical care technician following with a wheelchair in the background. The patient's nurse is outside of the photograph. Printed with permission.

The time to activity from initial ICU admission was 6.6 ± 5.5 days to sit on the edge of the bed, 8.8 ± 7.6 days to sit in chair, 11.3 ± 10.1 days to walk, and 12.4 ± 10.7 days to walk >100 feet. The time to activity for RICU admission was −2.9 ± 7.7 days to sit on the edge of the bed, −0.7 ± 7.5 days to sit in a chair, 1.5 ± 9.1 days to walk, and 2.9 ± 9.4 days to walk >100 feet. The negative numbers for time from RICU admission to sit on the edge of the bed and sit in a chair indicate that these activities were initiated before RICU admission.

Eighteen (17%) patients died before hospital discharge, with 16 deaths in the RICU and two deaths after RICU discharge. The survivors' discharge dispositions were 34 who returned home, 25 went to a skilled nursing facility, 20 went to a rehabilitation unit, four went to a long-term acute care facility, and two went to hospice.

Activity Events. Figure 1 shows a patient ambulating while on assist control ventilation with a high level of ventilatory support (450 mL tidal volume, F_{IO_2} 0.6, positive end-expiratory pressure 16; printed with permission). We conducted a total of 1,449 activity events in 103 patients between June and December 2003. Of the 1,449 activity events, 233 (16%) were sit on bed, 454 (31%) were sit in a chair, and 762 (53%) were ambulate. Figure 2 shows preactivity F_{IO_2} levels. In 75% of activity events, the preactivity F_{IO_2} was ≤0.4. In 8% of mechanically ventilated patients, preactivity F_{IO_2} was ≥0.7. Airway status during activity is shown in Figure 3. Patients with nasal or oral endotracheal tubes underwent 593 (41%) activity events, of which 249 (42%) were ambulation (Fig. 1).

On the last full day of RICU admission, the median distance ambulated by survivors was 200 feet (mean 212 ± 178 feet, range 0–600 feet). These data include an assigned ambulation distance of zero feet for all patients whose activity level was sit on bed, sit in chair, or no activity. By activity category, the survivors' activity level on the last day of RICU admission was as follows: 2.4% had no activity, 4.7% sat on the bed, 15.3% sat in a chair, 8.2% ambulated ≤100 feet, and 69.4% ambulated >100 feet. Table 3 shows activity in these categories subdivided by age <65 vs. ≥65 yrs of age, indicating that older age did not preclude participation in activity. The distance ambulated by survivors on their last full day of RICU admission varied by their disposition destination. The mean distance ambulated in patients who went home was 337 ± 130 feet (median = 400 feet), to a skilled nursing facility was 293 ± 124 feet (median = 270 feet), to rehabilitation

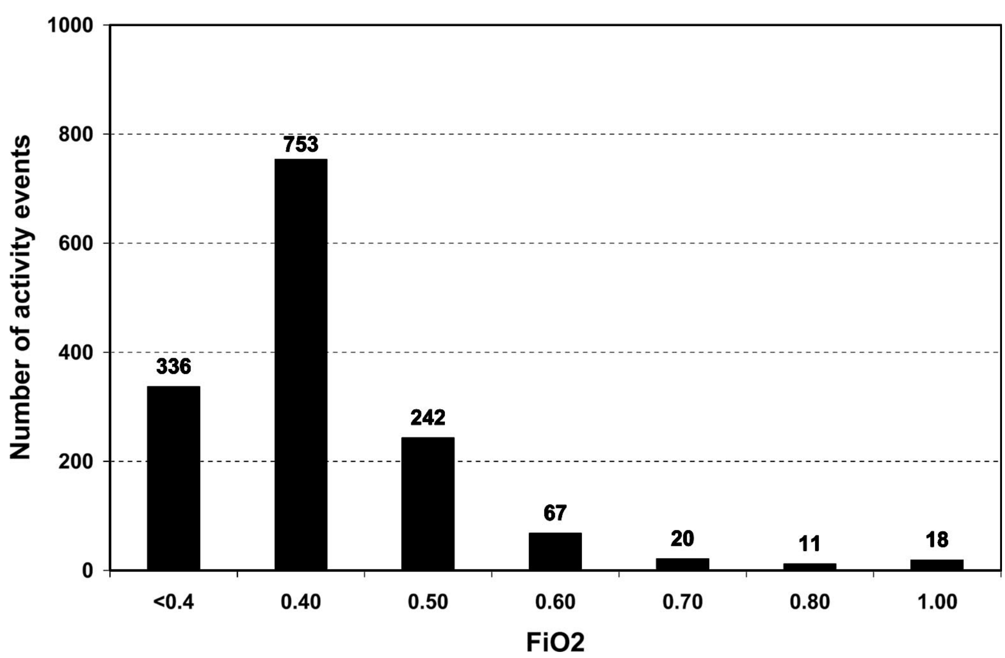

Figure 2. Preactivity F_{IO_2} levels.

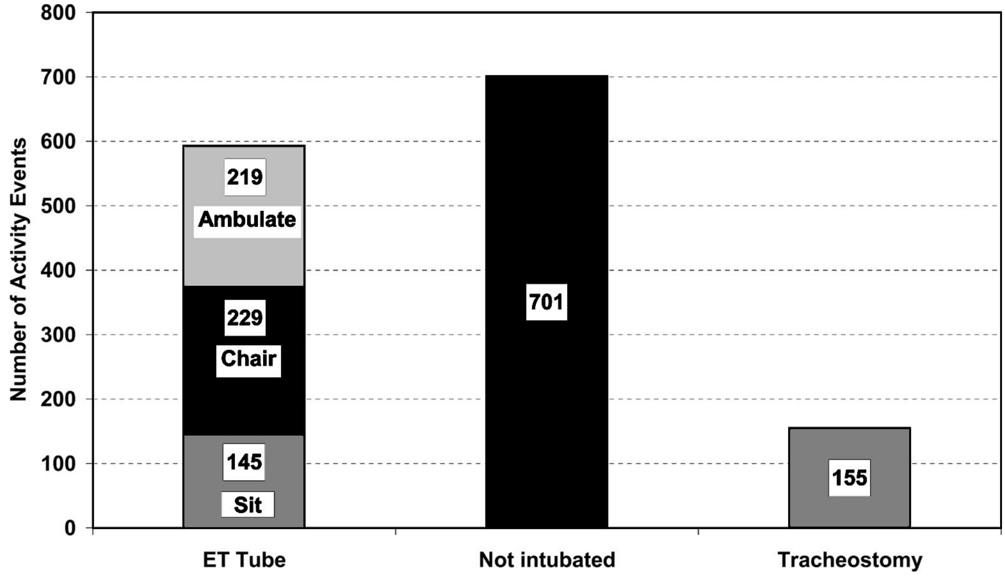

Figure 3. Airway status during activity. Type of activity (sit on the edge of the bed, sit in a chair, and ambulate) is shown for patients with an endotracheal (*ET*) tube.

Table 3. Activity level in survivors on the last full day of respiratory intensive care unit admission

Activity	Total Group (n = 85)	Age <65 Yrs (n = 49)	Age ≥65 Yrs (n = 36)
No activity	2 (2.4)	0	2 (5.6)
Sit on bed	4 (4.7)	2 (4.1)	2 (5.6)
Sit in chair	13 (15.3)	5 (10.2)	8 (22.2)
Ambulate ≤100 feet	7 (8.2)	6 (12.2)	1 (2.8)
Ambulate >100 feet	59 (69.4)	36 (73.5)	23 (63.8)

Data are subdivided by age <65 years and age ≥65 years. Values are n (%).

was 271 ± 168 feet (median = 230 feet), and to a long-term acute care facility was 138 ± 13 feet (median = 140 feet). Figure 4 shows the percentage of patients who underwent activity by normalized RICU day (e.g., day 1 is the first RICU day for each patient) for the first 30 days on the unit. On RICU day 1 (the day of admission), 71% of patients participated in activity. Overall, respiratory failure patients completed a daily activity on 88% of their RICU days. Forty-two patients completed an activity on 100% of their RICU days, 42 patients completed an activity on 75–99% of their RICU days, 13 patients completed an activity on 50–74% of their RICU days, and six patients completed an activity on <50% of their RICU days. Patients missed activity when they were off the unit due to procedures, had medical complications such as bleeding, or developed new physiologic instability.

Figure 5 shows the length of time from initial ICU admission until a patient was able to ambulate >100 feet as a function of the number of underlying comorbid disorders. Increasing numbers of comorbid conditions did not increase the time until a patient was able to ambulate. Most patients were able to participate in activity regardless of age, multiple organ failure, intubation, number of comorbid disorders, or (in a few patients) high FIO_2 needs (Tables 1–3, Figs. 4 and 5).

Feasibility. We were able to provide a higher level of activity using the same resources that exist in other ICUs at our facility. The higher activity level occurred because of unit reorganization to facilitate patient activity as a priority of care. The nurse to patient ratio remained 1:2 in the RICU, and early activity did not increase hours of nursing care. The RICU had 18 hrs of critical care technician support per day (3.15 full-time equivalents), which is 8 hrs less than the 24 hrs of critical care technician support (4.2 full-time equivalents) in the other ICUs in our institution. Our physical therapists work as part of the RICU team with no increase in physical therapy staffing. Respiratory therapists cared for ventilator patients in a 1:4 therapist to patient ratio, which was the same as other ICUs in our facility.

Patient Safety. Nine patients had adverse events, four of whom were >65 yrs of age. Six patients had one adverse event, two patients had two adverse events, and one patient had four adverse events for a total of 14 adverse events. Adverse events were infrequent, occurring in 14 of 1,449 (0.96%) activity events. Adverse events included five falls to the knees without injury, four systolic blood pressure <90 mm Hg, three oxygen desaturation <80%, one nasal-small bowel feeding tube removal, and one systolic blood pressure >200 mm Hg. Oxygen desaturation was immediately corrected with additional oxygen therapy. The four hypotensive episodes were orthostatic and were corrected by having the patient lie down. Adverse events did not result in extubation, complications that required additional therapy, additional cost, or longer length of hospital stays.

DISCUSSION

Our respiratory failure patients were able to participate in progressive "early" activity, where early refers to the time interval beginning after initial physiologic stabilization and continuing through the ICU stay. For activity to begin, a patient must be able to participate neurologically (no coma or heavy sedation), maintain a blood pressure when upright, and maintain adequate oxygen

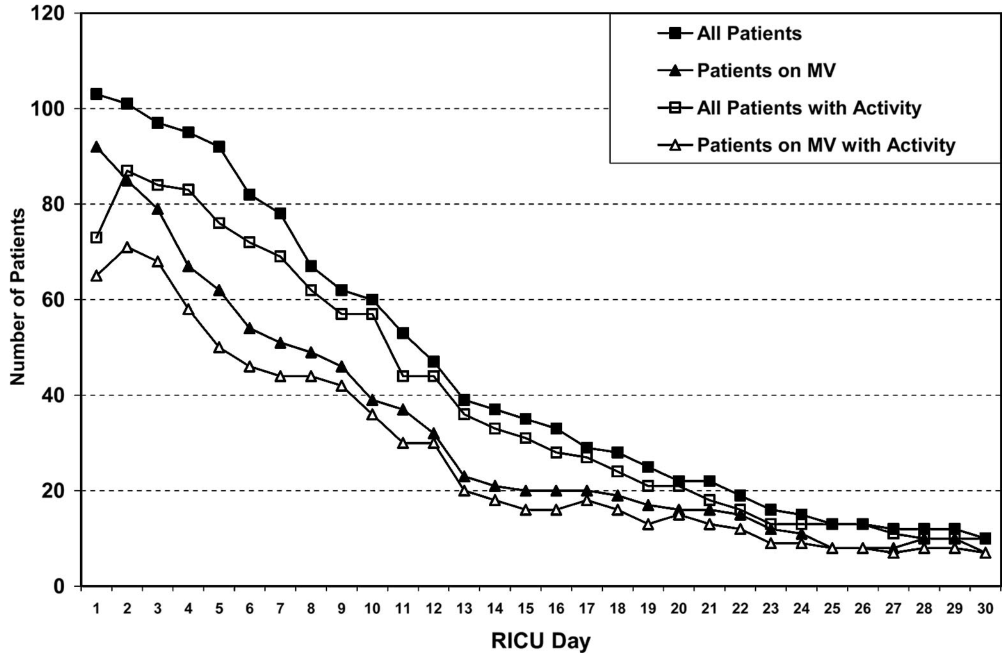

Figure 4. The number of respiratory failure patients, the number of patients with mechanical ventilation (*MV*), and the number who participated in activity for the total group and with MV shown by normalized respiratory intensive care unit (*RICU*) day (e.g., day 1 is the first RICU day for each patient).

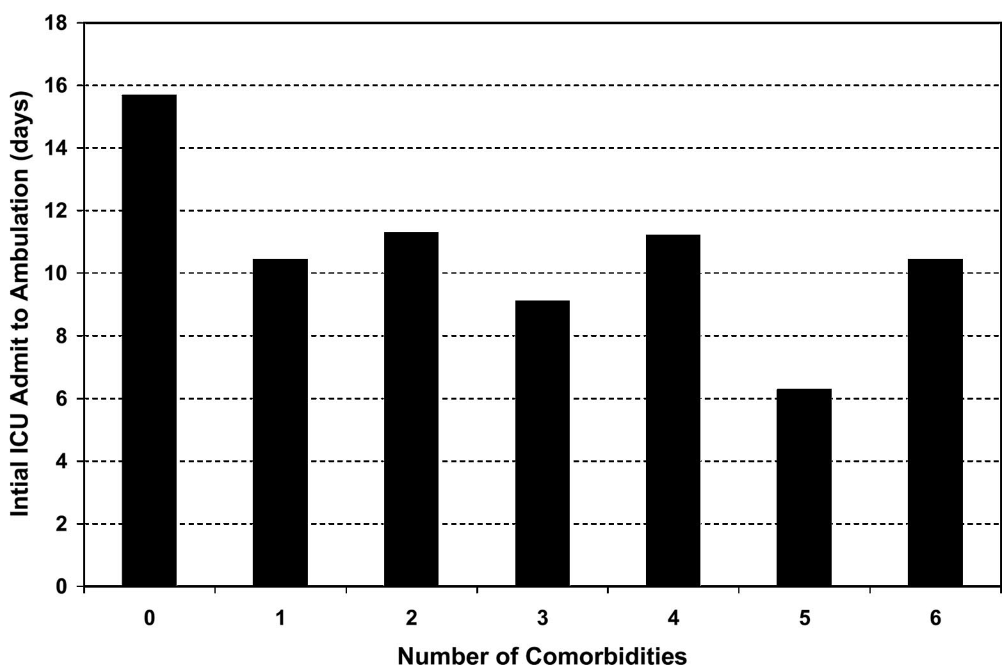

Figure 5. Length of time from initial intensive care unit (*ICU*) admission until the patient was able to ambulate >100 feet as a function of the number of underlying comorbid disorders.

saturation during activity. As a counter example, a hypotensive patient in septic shock has not achieved initial physiologic stabilization and therefore would not yet be eligible for the early activity protocol. Few patients were able to participate while sedated or on catecholamines. These criteria may be met relatively early in a patient's ICU course, well before ICU discharge. The neurologic criterion was absolute, as no patient ever underwent activity when unconscious. Some patients were able to tolerate activity despite not meeting all of the respiratory and circulatory criteria. This flexible approach did not lead to safety problems.

Another way to view early activity is that patients received both full ICU care and simultaneous rehabilitation-like physical therapy. This contrasts with traditional ICU care, where physical therapy and activity are often delayed until after ICU discharge (14). In the study by Martin et al. (14), this delay was associated with severe physical debility (100% of patients were bedridden at ICU discharge) that subsequently responded well to activity, suggesting that the later activity initiation after ICU discharge is associated with debilitation that responds to activity.

Our patients had acute critical illness with elevated Acute Physiology and Chronic Health Evaluation II scores and significant respiratory failure (Table 1). The duration of mechanical ventilation in our patients (mean 19 days, median 13 days) is consistent with acute to subacute respiratory failure. In contrast, most of our patients did not meet the criteria for chronic or prolonged mechanical ventilation (>21 days) established by a recent consensus conference (15). Such prolonged mechanical ventilation is more characteristic of patients seen in long-term acute care settings or chronic ventilatory rehabilitation units as opposed to our patients in the RICU. For example, a group of patients with chronic mechanical ventilation first began their rehabilitation activity after completing 18 days of mechanical ventilation (14), whereas our patients were ending their ICU-based physical therapy roughly during this same time frame. Therefore, our study results may not be applicable to chronic respiratory failure patients.

We found it feasible to conduct early progressive activity in respiratory failure patients. Early activity was done without increases in usual ICU staffing. Early activity required the development of a coordinated multidisciplinary team, whose members share a cultural expectation of early activity for all patients (after initial physiologic stabilization). Before the development of this team, it was unusual for ICU patients in our institution to participate in early activity.

Early activity in our respiratory failure patients was safe. The number of adverse events was low, and no event was serious. Early activity had a low risk (<1%) of complications even though a majority of activity events occurred when patients had an artificial airway in place (Fig. 3). Adverse events did not result in extubation, complications that required additional therapy, additional cost, or longer length of hospital stays.

There are few data in the literature to which we can compare our patients' functional outcomes. After an average of 18 days on mechanical ventilation and acute ICU care, the patients of Martin et al. (14) were able to ambulate zero feet, compared with our patients, who after an average of 19 days of mechanical ventilation were able to ambulate 212 feet. The patients of Martin et al. improved substantially after intensive therapy, but their final ambulation distance of 52 ± 18 feet by the time of rehabilitation discharge remained less than our patients achieved by the time of acute ICU discharge. It is possible that delaying activity until after discharge from the acute ICU admission may limit the ultimate performance level that a patient may achieve.

Our older patients were able to participate in activities in a similar fashion to our younger patients (Table 3), demonstrating that older age does not preclude participation in progressive early activity. Martin et al. (14) also reported that older ventilator-dependent patients (mean age of 58 yrs) were able to participate in a rehabilitation program. Their older patients responded to physical therapy with a significant increase in upper and lower extremity strength, many were able to ambulate, and most increased their Functional Independence Measurement scores (14).

One strength of our study was the prospective application of an activity protocol to all respiratory failure patients admitted to our ICU. We achieved high rates of activity participation (Fig. 4) despite the inevitable procedures, tests, and episodes of new physiologic instability that occur in critically ill patients.

Another strength of our study was the number of patients who ambulated before RICU discharge. When our critically ill patients are asked what is most important to them regarding their treatment and recovery from critical illness, a frequent response was that they "just want to go home" (i.e., return to their pre-illness activities). Patients considered ambulation to be important to meet their goal of returning home. Patients who went home ambulated farther (mean of 337 feet) than patients who went to a skilled nursing facility (293 feet), to rehabilitation (271 feet), or to a long-term acute care facility (138 feet).

One limitation of our study is that we did not administer objective measures of muscle strength. We chose instead to look at a functional outcome (ambulation >100 feet). We do not know if early activity improved functional outcomes after hospital discharge. We also do not know if the effects of early activity are long lasting. Since 1–2 yrs after ICU discharge only 77% (16), 69% (17), and 56% of mechanically ventilated patients (18) returned to their pre-illness activity levels, it is important to study such outcomes to develop treatments that can improve long-term physical function.

Our lack of a control group prevents us from demonstrating that early activity improves hospital discharge or long-term outcomes. However, this study was intended to be a preliminary investigation to demonstrate the safety and feasibility of this approach, a necessary step before considering a study with a control group. Nonetheless, a large majority of our patients met our goal that they ambulate >100 feet at ICU discharge, despite critical illness requiring mechanical ventilation.

Clinical studies are lacking regarding early mobilization practices and their relationship to complications and long-term functional outcomes. Studies should focus on interventions that can reduce complications due to immobility and neuromuscular weakness and improve health-related quality of life (2, 19, 20). Angus and colleagues (21) stressed the importance of the effect of ICU therapies and interventions on quality-adjusted survival, suggesting that therapies that improve morbidity and functional outcomes in critically ill patients may be as valuable as therapies that decrease mortality. Early activity is one such candidate therapy, since it is feasible and safe in respiratory failure patients and results in a high rate of ambulation by ICU discharge.

CONCLUSION

We conclude that early activity is feasible and safe in respiratory failure patients. A majority of patients treated using the early activity protocol were able to ambulate >100 feet at the time of ICU discharge. Early activity is a candidate therapy to prevent or treat neuromuscular complications of critical illness. Further studies are needed to demonstrate that early activity improves physical outcomes at and beyond hospital discharge.

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