Journal of
Critical Care

VOL 10, NO 3 SEPTEMBER 1995

Continuous Oscillation: Outcome in Critically Ill Patients

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Purpose: To compare turning by an oscillating bed to standard 2-hour turning. Outcomes were survival, length of stay (LOS), duration of mechanical ventilation, and incidence of pneumonia.
Methods: One hundred and three intensive care patients were randomly assigned to standard turning or turning by an oscillating bed. Data, collected at baseline, daily for 7 days, and then three times weekly until study discharge, included demographics, initial Acute Physiology and Chronic Health Evaluation (APACHE II) score, ventilatory/gas exchange parameters, indicators of pneumonia, nursing measures, and chest roentgenograph.
Results: There were no significant differences for LOS, duration of ventilation, nor incidence of pneumonia. Higher survival for subjects on the oscillating bed reached borderline significance ($P = .056$) for subjects with APACHE II greater than or equal to 20. Longitudinal data were analyzed using the random effects model. No differences in ventilatory or gas exchange parameters were identified. Among subjects who developed pneumonia there was a significantly higher respiratory score (nursing acuity scale) for subjects on the oscillating bed.
Conclusions: In selected critically ill patients oscillating therapy may improve survival and improve airway clearance. The frequency and degree of turning needed to prevent complications and improve outcome remains unclear. These newer beds should be used with discrimination so as to not increase hospital costs unnecessarily.

FREQUENT position changes are advocated as a means of preventing and/or treating pulmonary complications.[2,12,13,16] This recommendation is especially important in the critically ill, a population likely to be immobile. However, the frequency of position change needed to prevent complications is unknown. Nevertheless, one study in dogs found that turning intervals of 30 minutes were more effective in preventing hypoxemia and atelectasis than hourly position changes; hourly turning intervals were superior to immobility.[14]

In the recent past, there has been a dramatic rise in the development of special beds to assist in the turning of patients. These beds are capable of turning patients at intervals of less than 30 minutes. Much of the previous research on these special beds has been designed to study a platform type of bed with axial rotation that can accomplish up to a 60° turn to each side. The platform bed has been compared with either the supine position or "routine" care (routine often not defined), and the majority of the studies have evaluated patients with trauma, orthopedic, and spinal injuries.[3,5-7,15] Although some studies have shown no beneficial effect,[3] other studies have shown a decreased length of stay (LOS) in the intensive care unit (ICU)[6,17] and a reduction in the incidence of infection[10] and pneumonia.[6,7] A meta-analysis of six studies using the rotating platform bed found that

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Received August 20, 1994; accepted April 29, 1995.
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0883-9441/95/1003-0001$05.00/0

continuous turning was associated with a reduction in the incidence of pneumonia and atelectasis, decreased duration of intubation, and a shorter length of stay in the ICU; there was no effect on ICU cost, total LOS at the hospital, or survival.[1]

More recently, another type of bed that accomplishes turning by inflating and deflating compartments in the mattress has been developed. These beds, commonly called oscillating beds, have not been studied as extensively as the platform beds; one study[4] showed a reduced incidence of pneumonia in selected diagnostic groups. Therefore, we compared turning of critically ill patients manually at 2-hour intervals with turning accomplished by an oscillating bed. The major outcomes investigated were survival, LOS, number of ventilator days, and incidence of pneumonia.

MATERIALS AND METHODS

Admissions to the ICUs in two teaching hospitals (University Medical Center, Tucson, AZ, and Harborview Medical Center, Seattle, WA) were screened for entrance into the study. Both hospitals have large medical and surgical ICUs, and both are level I trauma centers. Exclusion criteria were developed to exclude patients for whom the oscillating bed was contraindicated and patients who were likely to have an ICU LOS less than 48 hours. Therefore, the following categories of patients were excluded: age less than 18 years; morbid obesity (weight/height ratio greater than 4.3 lbs/in); primary admitting diagnosis of burn, myocardial infarction, postcardiothoracic surgery, cardiac dysrhythmias, gastrointestinal bleeding, drug overdose; requirement for skeletal or cervical traction; requirement for elevation of the head of the bed to be greater than 30°; not screened for study entry within the first 24 hours after admission to the ICU; requirement for a specific type of oscillating/rotating bed; previous enrollment in the study (earlier ICU admission). Patients not excluded were then randomized to either the oscillating bed or to a standard bed. The final study sample was determined after day 2; patients enrolled but discharged from the ICU within that 2-day period were not included in the final study sample.

The oscillating bed used has multiple inflatable cushions that are programmed to inflate and deflate to turn the patient from side to side. (Biodyne, Kinetic Concepts, Inc, San Antonio, TX) The bed was programmed to provide maximal turning (up to 40° in each direction) and was set to rotate with a 5-minute pause on the left side, 10 minutes supine, and 5 minutes on the right side. Subjects on the standard bed were to be turned manually every 2 hours according to the standard ICU protocols at both hospitals.

Baseline data, including demographics, gas exchange parameters, and ventilator settings, were obtained at the time of ICU admission; also included in the baseline data were the Acute Physiology and Chronic Health Evaluation (APACHE II) score,[11] calculated at 24 hours, and admission chest roentgenographic (CXR) findings. Subsequently, gas exchange parameters, ventilator settings, white blood cell count (WBC), bacteriologic culture reports, vital signs, nursing acuity scores, and CXR were recorded daily for 7 days, and then three times a week until the patient was discharged from the study.

The nursing acuity tool used at both sites was the copyrighted Critical Care Patient Classification Tool developed by D.J. Sullivan and Associates (Ann Arbor, MI) for use at Harborview Medical Center, Seattle, WA. The tool lists a variety of nursing interventions/activities weighted according to the amount of nursing care time required. The activity score is then multiplied by the frequency of the activity. For example, suctioning an endotracheal tube is 1 point; if the tube was suctioned 10 times within a 24-hour period, then there is a total of 10 points for that intervention. The tool contains items ranging from hygiene measures and medication administration to specific technical skills and thus was used as a method of determining overall nursing care time required by subjects. Within the tool is a respiratory score; the components of the respiratory score include points for clinical assessment, nasal oxygen, ventilator, suctioning, deep breathing and coughing, tracheostomy care, and chest tubes.

Turning frequency for patients on the standard bed protocol was determined from the nursing notes/flow sheets. For patients on the oscillating bed the degree of rotation accomplished was recorded daily. The chest radiographs were read by a pulmonologist who did not know the patient's group assignment. The opacity score could range from 0 to 4, with 0 being normal; +1, opacity less than lobar; +2, lobar opacity; +3, opacity greater than lobar but unilateral; and +4, bilateral lobar opacification. New cases of pneumonia were defined by the following variables: a temperature greater than 38.5° centigrade, a WBC greater than 12,000/mm^3, and an increase of one point or more in the chest radiograph opacity score. All three of the criteria had to have been met within the time span of three successive data measurement points.

For each subject, study discharge occurred when one or more of the following criteria were met: (1) patient was out of bed more than 3 h/d; (2) a specific type of bed was ordered (patients on standard bed placed on oscillating bed, or patient on oscillating bed placed on a standard bed; the latter included patients who requested transfer off the oscillating bed); (3) patient on oscillating bed was rotating less than 12 h/24-hour period; (4) patient died; or (5) patient was transferred out of the ICU. Exit data collected at hospital discharge included LOS in the ICU, hospital LOS, and outcome (death, transfer to another institution, or discharge home).

STATISTICAL ANALYSIS

The data analyzed were those from subjects who were enrolled in the study for more than 48 hours. When a subject was discharged from the study before ICU discharge because of transfer from one type of bed to another, that subject was analyzed as part of the group to which they were initially assigned after the intention to treat principle. To assess similarity between the two institutions and between the oscillating group versus standard bed groups at the time of admission, comparisons were made for the baseline characteristics by institution and by group assignment. Tests for differences between the two groups included chi squared analysis for categorical data and student's *t*-test for continuous data. Outcome data were analyzed to determine differences between the oscillating and standard bed groups. Because we found that the distributions for LOS and ventilator days were skewed, nonparametric statistics were used to evaluate those differences. Because of the special problems presented by the differences in number of data points per subject, the random effects model (REM) was used to analyze the longitudinal data for differences between groups over time. The basic REM fits a polynomial curve to the population data and simultaneously fits a similar polynomial to the deviations from the population curve. The name "random effects" is derived from the method whereby the within subject parameter estimates are assumed to be random; all subjects do not have to have the same slope. The recent modification by Jones and Boadi-Boateng[8] was used in this analysis. The modification includes a first-order autoregressive covariance structure within subjects. This procedure can be used to analyze serial data where the subjects may have unequally spaced observations and where observations can be at different times for different subjects. This analysis (REM) can be performed using SAS procedure PROC MIXED.[9]

RESULTS

One hundred thirty-seven potential subjects were enrolled in this study; 34 of the potential subjects were omitted from the final sample because they were discharged from the study before the minimum time criteria of 48 hours. Data were obtained from 103 subjects who were enrolled in the study for more than 48 hours. Forty-four were randomized to the oscillating group and 59 to the standard turning group.

Comparisons between the subjects admitted at the two institutions are shown in Table 1. There was a significant difference between the patients at the two institutions at baseline for APACHE II score with subjects in the Tucson group having significantly higher scores. However, when the baseline characteristics of the oscillating and standard bed groups were compared, after combining the data from both institutions, there were no differences for gender, age, diagnostic category, frequency of mechanical ventilation within 24 hours of admission, or mean APACHE II score (Table 2).

Of the 59 subjects randomized to the stan-

Table 1. Admission Characteristics: Comparison of Centers

	Tucson	Seattle
No.	49	54
% Male	55.1	64.8
Age, years (mean ± SD)	55.4 ± 20	56.4 ± 19.6
% Medical diagnosis*	59	48
APACHE II score† (mean ± SD)	21.3 ± 7.3	16.8 ± 5.3
% Ventilated	89.8	88.7
% Infiltrate	80	77.3
% Randomized to oscillating bed	46.9	38.9

*Subjects without trauma, surgical intervention, neurosurgical diagnosis.
†Difference significant at $P = .001$.

dard turning group, two were placed on special beds before being discharged from the ICU. Of the 44 patients on the oscillating bed, eight were moved to a standard bed before discharge, with five of the changes being caused by patient or nurse request; of the eight moved, only two had spent less than 6 days on the oscillating bed. An additional three subjects on the oscillating bed were moved when they met the study discharge criteria of being out of bed more than 3 h/d. During the total of 332 data collection days for those subjects on the standard turning protocol, subjects were turned every 1 to 2 hours 67% of the time; at 24% of the data points, subjects were turned at an interval of every 3 to 4 hours. For the subjects on the oscillating bed, the mean angle of rotation attained was 25.5° (40° was the objective).

There were no statistically significant differences between the two groups for survival, LOS in the ICU, number of days of mechanical ventilation required, or total hospital stay (Table 3). The difference in incidence of pneumonia, 18% (8 subjects) in the oscillating group and 29% (17 subjects) in the standard group, did not reach statistical significance ($P = .21$).

To further explore the influence of severity of illness on the outcome criteria, the two study groups were further divided into high and low APACHE II score groups. Those in the high groups had APACHE II scores greater than or equal to 20; those in the low groups had APACHE II scores less than 20. For subjects in the low APACHE II groups (oscillating and standard), there were no differences between groups for survival, total hospital LOS, or ICU LOS. However, the two high APACHE II score groups showed a trend for a difference between the two groups for survival. There were 18 subjects in the oscillating group and 19 subjects in the standard group with high APACHE II scores. The survival in the oscillating group was 77.8% compared with 47.4% in the standard group ($P = .056$) (Table 4).

Table 2. Admission Characteristics: Comparison of Groups

	Oscillating	Standard
No.	44	59
% Male	63.6	57.6
Age, years (mean ± SD)	52.8 ± 19.5	59.1 ± 20.3
% Medical Diagnosis	47.7	57.6
APACHE II score (mean ± SD)	19.8 ± 7.2	18.2 ± 6.3
% Ventilated	88.4	89.8
% with Infiltrate on CXR	81	77

Note: There were no significant differences between groups.

Table 3. Patient Outcomes

	Oscillating (N = 44)	Standard (N = 59)
Survival (%)	72.7	67.8
Survivors (N)	32	40
Nonsurvivors (N)	12	19
	Median/range	Median/range
Hospital LOS (d)	17.5 (3-98)	17.0 (3-74)
Survivors	20.5 (6-98)	20.0 (4-70)
Nonsurvivors	12.5 (3-71)	10.0 (3-74)
ICU LOS (d)	7.0 (2-43)	5.0 (2-53)
Survivors	6.0 (2-37)	5.0 (2-53)
Nonsurvivors	9.0 (3-43)	6.0 (3-21)
Days on ventilator	3.0 (0-28)	3.0 (0-24)
Incidence of pneumonia (%)	18 (N = 8)	29 (N = 17)

Note: There were no significant differences between groups.

Table 4. Patient Outcomes: APACHE II Score Greater than or Equal to 20

	Oscillating (N = 18)	Standard (N = 19)
Survival (%)*	77.8	47.4
Survivors (N)	14	9
Nonsurvivors (N)	4	10
	Median/range	Median/range
Hospital LOS (d)	16.5 (5-58)	12.0 (4-41)
Survivors	20.0 (6-58)	18.0 (4-41)
Nonsurvivors	10.5 (5-13)	8.5 (4-17)
ICU LOS (d)	6.5 (2-37)	6.0 (2-26)
Survivors	6.5 (2-37)	7.0 (2-26)
Nonsurvivors	6.5 (4-11)	5.5 (3-16)
Days on Ventilator	4.0 (0-25)	5.0 (0-24)
Incidence of Pneumonia, %	28 (N = 5)	37 (N = 7)

*$P = .056$.

Longitudinal analysis (REM) of the measures related to pulmonary status, such as ratio of alveolar to arterial oxygen tension and lung-thorax compliance measurements, showed no significant differences between the two groups, after controlling for study site and APACHE II score. Data from the nursing care acuity tool also were subjected to the REM technique. The total nursing care acuity score showed no differences between groups, but the respiratory subscore did. The respiratory subscore is based on those activities related to respiratory care with the major component of the score derived from the points allotted to the frequency with which the patient was suctioned and/or coughed; the higher the score, the more suctioning and coughing the patient required. The respiratory score over time did not vary between the entire oscillating and standard groups, but there was a significant difference between the two groups in the 25 subjects who developed pneumonia. Of the items composing the score, the only components that showed variability between the two groups were the airway care items. The REM analysis is shown in Table 5. As indicated by the bed × day and bed × day^2 terms in the REM, the oscillating group with pneumonia had higher respiratory scores from day 2 to day 20 as compared with the subjects who developed pneumonia and received traditional turning (Table 5 and Fig 1). Those patients with pneumonia and who were on the oscillating bed also had higher respiratory scores than did the total population.

Table 5. Random Effects Model (REM) in Subjects Developing Pneumonia (N = 25)

	Coefficient	±	SEM
Constant	21.53		5.64*
Day	1.04		1.67
Day^2	−0.07		0.09
Bed	−3.27		2.51
Bed × day	1.38		0.60*
Bed × day^2	−0.06		0.02*

Note: In the model, the oscillating bed was assigned a value of 1 and the standard bed a value of 0. The significant Bed × day and Bed × day^2 coefficients indicate that the respiratory scores for patients on the oscillating bed were higher than those on the standard bed on days 2 through 20. The significant constant coefficient indicates that the respiratory scores for the entire population are greater than 0.

*Indicates $P < .05$.

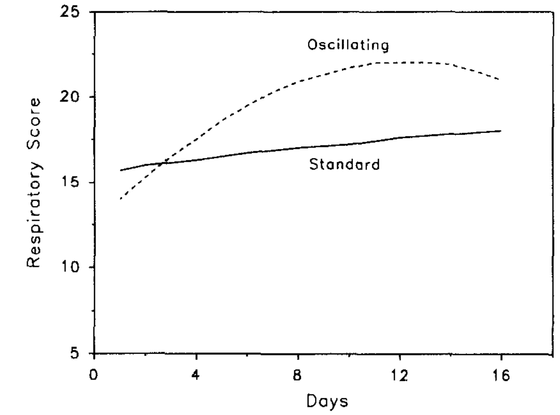

Fig 1. This plot shows the mean respiratory scores over time for the patients who developed pneumonia (N = 25). The mean scores for subjects on the oscillating bed are depicted by the dashed line; the solid line depicts scores for subjects on the standard bed. The mean curves were computed using the results of the longitudinal REM analysis presented in Table 5. After day 2, the amount of airway care (respiratory score) required by subjects on the oscillating bed was consistently higher than for subjects on the standard bed.

DISCUSSION

The present study randomized a wide variety of ICU patients to either a standard protocol of manual turning or turning by a special oscillating bed. In those subjects who had more severely impaired physiological function, defined as an APACHE II score of 20 or more, the difference in survival between the standard turning and oscillating groups reached borderline statistical significance ($P = .056$) with the oscillating group tending to have improved survival.

The longitudinal data showed that nursing staff provided more respiratory care (higher respiratory score) to patients who had pneumonia and who were on the oscillating bed versus those with pneumonia receiving standard turning. One interpretation is that the oscillating bed facilitated mucociliary transport so that a higher frequency of suctioning was required to clear secretions. Although the criteria used to determine need for suctioning are not known and there may have been omissions in charting, any biases would have influenced both groups of patients; the same nurses cared for patients in both groups and nursing staff were not aware of the specific evaluations being made.

The increased frequency of turning accomplished by the oscillating bed may have influenced the trend toward improved survival in those patients with high severity of illness scores. Although the bed accomplished frequent turning, it did not achieve a full 40° turn in most cases. It was noted by nursing staff that the patients required frequent repositioning in the bed; when the patient was not correctly positioned, a maximal turn was not attained. It is possible that a greater degree of turn is required to attain maximal benefit. Although the oscillating bed may not have accomplished the degree of turn desired, for those caring for patients in the critical care area, it is also obvious that the critically ill patient is often difficult to turn manually at frequent intervals because of the demands of care and cardiovascular instability. The chart review technique used in this study to determine frequency of turning over a 24-hour period is fraught with problems so that it is impossible to state with precision whether the standard bed patients with high severity of illness were manually turned at less frequent intervals. Also, the degree of turn accomplished with the manual technique was not measured.

No differences were found for the duration of mechanical ventilation, LOS in the ICU, and total time in the hospital between the two protocols. Nor could differences in ventilator time or LOS be shown between turning groups in those who had an APACHE II score greater than or equal to 20. Costs were not directly measured in this study. Nevertheless, because there was no difference in the LOS and rental of special beds is an additional cost, it is reasonable to assume that indiscriminate use of continuous oscillation does not reduce hospital costs and may actually increase cost. However, our data suggest that in severely ill ICU patients, these beds may improve overall outcome and thus justify the additional expense in selected cases, especially when frequent manual turning is not being accomplished.

In conclusion, this study was unable to show statistically significant differences between the standard and oscillating bed groups for ventilator days, incidence of pneumonia, LOS, or survival. The important clinical questions of how to accomplish the frequent turning of critically ill patients and how much rotation must be accomplished when turning the patient remain. The oscillating bed accomplishes more frequent turning than is possible without such technology. However, the cost of using such technology must also be considered. In situations where the patient is not being turned frequently because of lack of personnel time or high severity of illness, oscillation therapy should be considered. The oscillating bed evaluated in the present study was most effective (borderline significance for improved survival) for patients with high APACHE II scores and may improve airway clearance in patients with pneumonia. Future studies of the relationship between turning and pulmonary complications should include documentation of the frequency and degree of turn accomplished by manual techniques as well as by oscillation therapy.

ACKNOWLEDGEMENTS

The authors thank K. Buhlig-Bocchini and D. Davis for their assistance with data collection, and S. Nadella, S. Bapat, and W. Kaltenborn for help in data analysis.

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