Effect of Air-supported, Continuous, Postural Oscillation on the Risk of Early ICU Pneumonia in Nontraumatic Critical Illness*

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Study Objective: **We hypothesized that continuous, automatic turning utilizing a patient-friendly, low air loss surface would reduce the incidence of early ICU pneumonia in selected groups of critically ill medical patients.**

Design: **Prospective, randomized, controlled clinical trial.**

Setting: **Medical ICU of a large community teaching hospital.**

Patients: **One hundred twenty-four critically ill new admissions to the medical ICU at Charity Hospital in New Orleans.**

Interventions: **Patients were prospectively randomized within one of five diagnosis-related groups (DRG)—sepsis (SEPSIS), obstructive airways disease (OAD), metabolic coma, drug overdose, and stroke—to either routine turning on a standard ICU bed or to continuous turning on an oscillating air-flotation bed for a total of five days.**

Measurements and Results: **Patients were monitored daily during the treatment period for the development of pneumonia. The incidence of pneumonia during the first five ICU days was 22 percent in patients randomized to the standard ICU bed vs 9 percent for the oscillating bed ($p=0.05$). This treatment effect was greatest in the SEPSIS DRG (23 percent vs 3 percent, $p=0.04$). Continuous automatic oscillation did not significantly change the number of days of required mechanical ventilation, ICU stay, hospital stay, or hospital mortality overall or within any of the DRGs.**

Conclusions: **We conclude that air-supported automated turning during the first five ICU days reduces the incidence of early ICU pneumonia in selected DRGs; however, this form of automated turning does not reduce other measured clinical outcome parameters.** ***(Chest 1993; 103:1543-47)***

Pneumonia is a common complication of critical illness that usually develops within the first five ICU days and is associated with excess ICU length of stay and mortality.[1] Although immobility has long been recognized as a risk factor in the pathogenesis of pneumonia, only recently have oscillating beds been developed that allow testing of the hypothesis that continuous turning is superior to periodic repositioning of critically ill patients. Continuous postural oscillation on a rigid platform has been demonstrated previously to reduce length of ICU stay, time receiving mechanical ventilation, and incidence of ICU pneumonia.[2-4] Although ideally suited for the multiply-traumatized patient in traction, the platform turning frame is unnecessarily cumbersome and uncomfortable to use for patients with medical illnesses. Additionally, the platform has not been demonstrated to reduce the incidence of pressure ulcers in this population.[5] Low air-loss surfaces, on the other hand, have proved to be effective in skin care management. We hypothesized that automatic turning of critically ill medical patients utilizing a patient-friendly, air-supported surface would reduce the incidence of early ICU pneumonia while improving other clinical outcomes, such as mortality and length of stay. Additionally, we hypothesized that the efficacy of this form of continuous, postural oscillation might vary across different diagnostic related groups (DRGs).

Methods

The protocol was approved by the Institutional Review Board of Louisiana State University Medical School in New Orleans. New admissions to the medical ICU at the Medical Center of Louisiana (formerly Charity Hospital of Louisiana) in New Orleans between July 1989 and January 1991 were eligible for enrollment into the study. Patients were excluded from the study if the admitting chest radiograph showed focal parenchymal infiltrates suggestive of pneumonia. Consenting patients were assigned within 24 h of admission to the medical ICU to one of five DRGs based on their clinical presentations:—sepsis (SEPSIS), obstructive airways disease (OAD), metabolic coma, drug overdose, and stroke. Patients were included in the SEPSIS DRG if on admission to the medical ICU all of the following criteria were met: clinical evidence of infection, temperature >38.3°C or <35.6°C, tachycardia, and tachypnea. All of the patients assigned to the SEPSIS DRG were receiving antibiotics at the time of study entry usually consisting of a third-generation cephalosporin and an aminoglycoside. Patients were included in the OAD DRG if they presented with signs and symptoms of chronic obstructive pulmonary disease or asthma and did not fit into the SEPSIS DRG. Patients were assigned to the metabolic coma DRG if they presented with altered mentation and hepatic failure, renal failure, or diabetic ketoacidosis. Assignment to the drug overdose DRG was based on history of drug overdose

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or toxicology findings obtained on presentation. The stroke DRG included all types of acute cerebrovascular disease.

After consent was obtained, patients were randomized within each DRG using a system of shuffled, sealed envelopes to either a standard control hospital bed (CONTROL) on which they were turned to a new body position manually by nursing staff every 2 h or to an automatic oscillating air-flotation bed (OSCILLATION) (Biodyne, Kinetic Concepts, San Antonio) on which they were continuously turned through an arc of approximately 90° every 7 min by alternating inflation of air cells within the bed's support surface. The oscillating bed was connected to a turning clock that verified that patients were in the oscillating mode at least 18 h/d. If both a CONTROL and an OSCILLATION bed were available for randomization at the time of ICU admission, then the patient was admitted to the study. Treatment on the CONTROL and OSCILLATION beds lasted a total of five days after which all patients were assigned to CONTROL beds for the remainder of their hospitalizations. Patient care was dictated by independent physicians blinded to the nature of the study. Decisions to initiate or terminate mechanical ventilation, to admit or discharge from the medical ICU or hospital, and to start or stop antibiotic therapy were made by the primary care physicians without input from the investigators.

The primary outcome variable studied was pneumonia during the first five ICU days. Secondary outcome variables were days of required mechanical ventilation, length of stay in the ICU, length of hospital stay following randomization, and hospital mortality.

During the treatment period, anteroposterior chest radiographs were obtained daily and sputum cultures were obtained from all febrile patients with infiltrates. Early ICU pneumonia was defined by all of the following clinical parameters present within a single 24-h period during the first five ICU days: new focal radiographic infiltrate that persisted at least three days, temperature ≥38.3°C, grossly purulent sputum, and growth of one or more respiratory pathogens in all four quadrants on the culture plate of expectorated or suctioned sputum culture that contained less than ten squamous epithelial cells per low-power field. The chest radiographs of patients enrolled in the study were interpreted by a pulmonologist investigator blinded to treatment group. Randomization to the oscillating bed could not be distinguished from randomization to the standard bed by use of the chest radiograph since the x-ray cassette was placed between the support surface and the patient.

Days of required mechanical ventilation, length of stay in the ICU, and length of hospital stay following randomization were similarly calculated for all patients and for survivors. The APACHE II score, an index of severity of illness, was calculated as described by Knaus et al[6] from physiologic data obtained at the time immediately prior to bed randomization. Predicted mortalities for the two treatment groups were calculated by averaging predicted mortalities derived from the initial APACHE II score of individuals within each group using the following formula:

$$\ln(R/1-R) = -3.517 \pm (\text{APACHE II score} \times 0.146) \pm (0.603 \text{ if postemergency surgery}) \pm \text{"diagnostic category weight"}$$

where R is the predicted mortality of a patient and the "diagnostic category weight" was assigned from the ICU admitting diagnosis as described.[6]

Statistical Analysis

The patients were analyzed based on intention to treat. The outcome variables of incidence of pneumonia and mortality were analyzed using Fisher's exact test to determine if there was a significant effect due to bed type. This analysis was first carried out on all patients and then on the individual DRGs.

The length of time of required mechanical ventilation, the ICU length of stay, and the hospital length of stay were analyzed for effects due to bed type by carrying out an analysis of covariance. The initial APACHE II score was used as a covariate to take into account the initial severity of illness. Additionally, because the time variables and the APACHE II scores were skewed and nonnormal, the ranks of these variables were used in the analysis of the actual variables. The analysis of covariance was again carried out on all patients and then on the individual DRGs (Table 1).

Table 1—*Comorbid Risk Factors[7] for the Development of Nosocomial Pneumonia (Mean No./Patient ± SEM)**

	Control	Oscillating	p Value†
All patients	2.6±0.1	2.9±0.1	0.28
SEPSIS DRG	2.5±0.2	2.4±0.2	0.66
OAD DRG	2.9±0.1	3.5±0.2	0.01
MISC DRG	2.5±0.4	3.0±0.4	0.44

*DRG = diagnosis related group; OAD = obstructive airways disease; MISC = miscellaneous.
†p values correspond to analysis of variance.

Results

One hundred twenty-four patients were enrolled into the study. Termination of the study due to fiscal constraints by the granting institution prior to use of all the cards resulted in unequal numbers of patients in the two treatment groups. Three patients randomized to the OSCILLATING group voluntarily withdrew during the early treatment phase of the study because of perceived discomfort associated with continuous oscillation but were analyzed with the OSCILLATING group based on intention to treat. No other recognizable physiologic complications were associated with continuous postural oscillation. Because of the small numbers of patients assigned to the metabolic coma (n=8), drug overdose (n=5), and stroke DRGs (n=5), these DRGs were combined into a miscellaneous DRG (MISC) for the analyses.

Risk factors for early ICU pneumonia at enrollment were similar for the CONTROL and OSCILLATING groups. The mean initial APACHE II score was lower in the CONTROL group than in the OSCILLATING group (16.8±1.0 vs 18.5±0.9, respectively), although this difference was not statistically significant

Table 2—*Incidence of Early ICU Pneumonia, n(%)**

	Control	OSCILLATING	p Value†
All patients	11/51 (22)	6/69 (9)	0.05
SEPSIS DRG	6/26 (23)	1/35 (3)	0.04
OAD DRG	3/15 (20)	4/22 (18)	1.0
MISC DRG	2/10 (20)	1/12 (8)	0.57
Ventilated	10/40 (25)	6/58 (10)	0.05
Not ventilated	1/8 (13)	0/10 (0)	0.44
Died<5 days	0/5 (0)	0/11 (0)	. . .
5-day survivors	11/46 (24)	6/58 (10)	0.07
All hospital survivors	9/37 (24)	3/41 (7)	0.06
SEPSIS survivors	5/17 (29)	0/18 (0)	0.02
OAD survivors	2/13 (15)	3/17 (18)	1.0
MISC survivors	2/7 (29)	0/7 (0)	0.46
All nonsurvivors	2/14 (14)	3/27 (11)	1.0

*DRG = diagnosis related group; OAD = obstructive airway disease; MISC = miscellaneous.
†p value from Fisher's exact test.

(p=0.15). Despite the lower mean initial APACHE II score for the CONTROL group, early pneumonia occurred significantly less frequently in the OSCILLATING group (Table 2). This treatment effect was greatest in those groups at highest risk for pneumonia: the SEPSIS DRG, patients requiring mechanical ventilation, five-day survivors, and hospital survivors. The dramatic reduction in early ICU pneumonia in the SEPSIS DRG was not due to differences in antibiotic use since all patients assigned to this DRG were receiving broad-spectrum antibiotics. The ICU day of appearance of infiltrates that ultimately fulfilled our case definition of pneumonia was not different between the two groups (2.5±0.5 vs 3.3±0.6 for CONTROL vs OSCILLATING, respectively; p=0.31). No early pneumonias were observed in patients who died within the first five ICU days. However, since the case definition required the infiltrate to be present for three days, this would have excluded virtually all such cases. Neither did intubation and mechanical ventilation account for the lower incidence of pneumonia in the OSCILLATING group. In addition to the APACHE II score, the following were considered risk factors for nosocomial pneumonia: age ≥65 years, obesity, chronic lung disease, congestive heart failure, diabetes mellitus, AIDS, systemic lupus, cancer, central nervous system diseases, seizures, head trauma, uremia, malnutrition, drug overdose, alcoholism, antibiotic therapy, antacids, H_2-blockers, steroids, cytotoxic drugs, mechanical ventilation, nasogastric tube, and major surgery.[7] The total number of risk factors for nosocomial pneumonia was retrospectively determined for each patient and the mean number for each DRG and treatment group and is listed in Table 1. Overall there were no significant differences in the number of pneumonia risk factors between the two groups. In the CONTROL group, 84 percent of patients required mechanical ventilation vs 86 percent of patients in the OSCILLATING group (p=0.8). However, within the OAD DRG, the OSCILLATING group had significantly more risk factors for pneumonia than the CONTROL group.

Days of required mechanical ventilation, length of ICU stay, and length of hospital stay were not significantly different between the CONTROL and OSCILLATING groups (Table 3). Since early mortality could confound interpretation of need for mechanical ventilation, length of ICU stay, and length of hospital stay, the data were additionally analyzed for hospital survivors only. The mean initial ICU APACHE II scores for the hospital survivors were 16.2±1.2 for the CONTROL group and 17.0±1.1 for the OSCILLATING group (p=0.43). Trends toward fewer ventilator and ICU days in hospital survivors of the OSCILLATING group did not reach statistical significance in this subanalysis.

Analysis of DRG assignment of hospital survivors for the number of required days of mechanical ventilation, ICU length of stay, and hospital length of stay are also summarized in Table 3. Trends toward a reduction in ventilator requirements and in ICU length of stay in the OSCILLATING group were similar across the three DRGs but failed to achieve statistical significance in any one DRG. These trends were greatest in the OAD and MISC DRGs even though the greatest effect on early pneumonia was in the SEPSIS DRG. Hospital length of stay varied across the DRGs.

Despite the significantly lower incidence of pneumonia in the OSCILLATING group, mortality tended to be higher in the OSCILLATING group (39 percent) than in the CONTROL group (27 percent), although the differences were not statistically significant. There were also no significant mortality differences between the CONTROL and OSCILLATING groups when analyzed by DRG. The observed difference in mortality between the two treatment groups was largely explained by differences in initial APACHE II. Predicted mortalities from the APACHE II score were 24±3 percent for the CONTROL group and 32±3 percent for the OSCILLATING group.

Discussion

The results of this prospective, randomized, controlled trial demonstrate that air-supported, continuous, postural oscillation applied for the first five ICU days reduces the incidence of clinical ICU pneumonia

Table 3—*Utilization of Services**

	Control	Oscillating	p Value†
All patients			
Ventilator days	9.9±1.8	6.1±0.9	0.18
ICU days	10.8±1.4	7.8±0.8	0.24
Hospital days	18.5±1.9	17.0±2.2	0.26
All hospital survivors			
Ventilator days	9.7±2.2	6.1±1.3	0.33
ICU days	10.9±1.7	8.1±1.1	0.43
Hospital days	20.8±2.3	22.2±3.3	0.96
SEPSIS DRG hospital survivors			
Ventilator days	10.2±3.2	9.0±2.3	0.86
ICU days	12.8±2.8	11.1±2.2	0.35
Hospital days	21.4±3.7	30.4±6.6	0.33
OAD DRG hospital suvivors			
Ventilator days	10.4±4.5	4.5±1.0	0.53
ICU days	10.7±2.9	6.4±1.0	0.89
Hospital days	22.6±4.8	16.3±2.1	0.68
MISC DRG hospital survivors			
Ventilator days	7.1±4.1	2.1±0.7	0.63
ICU days	7.0±2.7	4.3±0.9	0.55
Hospital days	15.9±3.9	13.2±4.6	0.45

*DRG = diagnosis related group; OAD = obstructive airways disease; MISC = miscellaneous.

†p values correspond to analysis of covariance with initial APACHE II as covariate.

during this same period by 59 percent in all patients and by 71 percent in hospital survivors; but applied in such a manner, this therapy does not improve mortality. Prevention of pneumonia was greatest in patients presenting with a diagnosis of sepsis, in patients requiring mechanical ventilation, and in patients who ultimately survived. Trends toward fewer days of required mechanical ventilation and fewer ICU days were also observed, but these trends were least apparent in the patients presenting with sepsis despite the fact that pneumonia prevention was best in this group.

These data are consistent with previous prospective, randomized, controlled investigations of continuous postural oscillation on rigid turning frames.[2,3,5,8] In 106 critically ill victims of blunt trauma, Fink et al[3] reported that continuous postural oscillation on a kinetic treatment table reduced the incidence of pneumonia by 65 percent using a definition of pneumonia similar to the one used in our present study. Despite this impressive reduction in ICU pneumonia by the kinetic treatment table, mortality was unaffected (16.7 percent in the conventional therapy group vs 19.6 percent in the kinetic treatment table group). Kelley et al[8] randomized 53 bedridden patients with acute stroke to either a standard hospital bed or to a kinetic therapy bed. The risk of infectious complications (including pneumonias) was reduced by 51 percent in the kinetic therapy group, although again mortality was unaffected. Gentilello et al[5] reported that among a group of 65 critically ill patients immobilized because of head injury or traction, the risk of ICU pneumonia was reduced from 34.2 percent in patients randomized to a standard ICU bed to 18.5 percent in patients randomized to platform turning. As in the previous studies, mortality was similar between the two treatment groups.

To our knowledge, this present study is the first report on the efficacy of air-supported turning. Furthermore, it is the first study of continuous, postural oscillation to use turning angles of only 90° (compared with 124° possible with rigid turning frames). Mortality in our present study was 29 percent in those patients who developed pneumonia within the first five ICU days and 35 percent in those patients who did not ($p=0.64$). Although it has been reported previously that pneumonia is an important risk factor for mortality in critically ill patients,[9] pneumonia prevention by postural oscillation or by selective decontamination of the digestive tract has not been demonstrated to reduce mortality.[4,10] One possible explanation for this dichotomy may lie in our case definition of pneumonia. We used a clinical definition of pneumonia that could overestimate the true incidence of pneumonia. The incidence of early ICU pneumonia in our CONTROL group was 22 percent, a figure consistent with other series of critically ill patients.[9,11,12] It has been suggested that only approximately 40 percent of pulmonary infiltrates in the febrile ICU patient are pneumonias as defined by quantitative culture techniques using the protected specimen brush or protected bronchoalveolar lavage catheter, the remainder being areas of parenchymal congestion or atelectasis.[13,14] It is possible that continuous postural oscillation preferentially decreases only noninfectious causes of parenchymal infiltration and therefore does not impact on survival. If this were the case, automatic oscillation would still seem to be a worthwhile endeavor since it would preclude the need to evaluate such cases with invasive, expensive procedures.[13] The cost of air-supported, continuous, postural oscillation in approximately $125/day. When used for five days as in the present study, the cost for pneumonia prophylaxis would be $4,808 per case of pneumonia prevented. This therapy could prove both to be cost-effective and have a favorable risk/benefit ratio when compared with bronchoscopic quantitative culture techniques and empiric antibiotic therapy.

Another explanation for the disparity between pneumonia prevention and survival in our present study is that mortality in critically ill patients is more closely related to severity of the underlying disease than to the presence or absence of nosocomial pneumonia. In our present study, we found that the initial APACHE II score was a better predictor of mortality than early ICU pneumonia. The mean initial APACHE II scores were 16.6 ± 0.8 in survivors and 20.4 ± 1.1 in nonsurvivors ($p=0.005$), but the incidences of early ICU pneumonia were nearly identical in survivors and nonsurvivors (15 percent and 12 percent, respectively, $p=0.64$). The lack of correlation between ICU pneumonia and mortality has been reported previously.[15]

We randomized patients within three broad DRGs in an attempt to determine if continuous postural oscillation would benefit all critically ill patients equally. The SEPSIS and OAD DRGs were selected since these were the most common admitting diagnoses for critically ill patients admitted to our medical ICU. Other admitting diagnoses occurred too infrequently to permit analysis of any other homogenous group of patients; thus, all other patients were assigned to the miscellaneous DRG. Prevention of pneumonia with postural oscillation was most apparent within the SEPSIS DRG and least apparent within the OAD DRG. Within the OAD DRG, the significantly higher number of pneumonia risk factors in patients randomized into the OSCILLATING group may, in part, account for the lack of treatment effect in the OAD DRG.

This new technology is most likely to be cost-effective if applied only to patient populations where pneumonia prophylaxis has been demonstrated and

for periods of time limited to pneumonia risk. The concept that only subsets of patients could benefit from continuous, automated turning is not without precedent. We have shown previously that platform postural oscillation shortened ICU length of stay in patients with sepsis, OAD, and drug overdose, but not metabolic coma or stroke.[2] Because treatment effects in this previous study were greatest during the first five ICU days and the incidence of ICU pneumonia is greatest during this period,[1] in the present study, we opted to treat patients for only the first five ICU days.

Although the differences observed between the OSCILLATING and CONTROL groups for days of required mechanical ventilation and ICU length of stay were not statistically significant, the magnitude and direction of these differences were very similar to those previously reported for platform turning.[2,3] It is possible that longer treatment and/or longer surveillance could have had a greater effect on the outcomes studied.

Conclusions

We have shown that air-supported, automatic, continuous postural oscillation applied for the first five ICU days reduces the risk of pneumonia during this same period in selected patients with nontraumatic critical illness, but applied in such a fashion, this therapy does not alter mortality. These data support and extend the findings of previous investigations of this mode of therapy and provide a rational basis for its selected application.

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