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apparatus and techniques

Effect of a rotating bed on the incidence of pulmonary complications in critically ill patients

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The risk of nosocomial pneumonia and atelectasis is high among critically ill immobilized patients. We hypothesized that continuous turning on the kinetic treatment table would reduce their incidence. Sixty-five critically ill patients, immobilized because of head injury or traction, were prospectively randomized for treatment in a conventional bed (n = 38) or the kinetic treatment table (n = 27). Patients were well matched for baseline demographic and pulmonary risk factors. Patients in the conventional bed group had a higher incidence of cigarette smoking. The combined incidence of significant atelectasis or pneumonia was higher (66%) in the conventional vs. kinetic treatment table (33%) groups ($p < .01$). Atelectasis, pneumonia, adult respiratory distress syndrome, requirements for ventilator treatment, for PEEP, and for an F_{IO_2} >0.50 were not significantly different, but tended to be higher in the control group. Survival and the incidence of decubitus ulcers were similar.
(Crit Care Med 1988; 16:783)

Nosocomial pneumonia and atelectasis are important causes of morbidity, mortality, and expense in critically ill patients (1–7). In a preliminary survey (unpublished observation), we found the incidence of pulmonary complications was approximately 45% in the first 6 days in our surgical ICU (SICU) patients who received suboptimal positioning because of head injuries or orthopedic injuries requiring traction.

The kinetic treatment table (1) rotates continuously on its long axis, through an arc of 124°, approximately every 7 min. Previously published evaluations (8–13) of this bed have not been controlled or randomized, thus leaving doubt regarding its efficacy in reducing pulmonary complications. We conducted a randomized, prospective study of patients immobilized by therapy for head injuries or orthopedic traction, comparing the effects of therapy in the kinetic treatment table with management in a conventional bed.

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PATIENTS AND METHODS

Patients with orthopedic injuries requiring traction, head injuries, or spinal injuries were randomized within the first 24 h after admission to be nursed in a conventional bed or the kinetic treatment table. After informed consent was obtained from the patient or next of kin, randomization was performed by drawing a randomizing card. Patients were evaluated daily. The active study period started with randomization and ended when the patient was allowed out of bed, died, or was discharged from the SICU. The follow-up period began when the patient was allowed out of bed and ended 4 days later. Other aspects of the patient's care followed routines established in the SICU. Patients randomized to the experimental group were placed on the kinetic treatment frame and nurses were instructed to leave the bed rotating except during recording of vital signs and treatments. Control patients were ordered to be turned in a conventional fashion every 2 h. If a patient treated in a conventional bed developed a pulmonary complication and inadequate positioning was felt to be a contributing factor, the patient was placed on a kinetic treatment table. If a patient developed a serious complication as a result of treatment on a kinetic treatment table, the patient was moved to a conventional bed.

Diagnostic Criteria

The diagnosis of bacterial pneumonia was based on the presence of all five of the following criteria: a) the presence of many WBC and many organisms on Gram stain of the tracheal aspirate; b) moderate to heavy growth of one or more organisms on bacterial cultures; c) the appearance of infiltrate in an area not showing infiltrate on the chest x-ray taken at the time of admission; d) a total WBC count >15,000 or <5000/mm^3 or

>15% immature segmented neutrophils; e) maximal core body temperature for 24 h, >38.5°C or minimal nonperioperative core temperature <36.5°C. The duration of pneumonia was the number of days on which the criteria for pneumonia were met. Undefined pneumonia was diagnosed when infiltrate, WBC count and temperature criteria were present with either purulence of tracheal aspirate or bacterial growth, but not both. Bacterial bronchitis was diagnosed when criteria a, b, d and e were present, but chest x-ray did not reveal infiltrate (criterion c).

The above criteria for pneumonias and bronchitis had to be present for at least 2 consecutive days. Patients who first satisfied the criteria for diagnosis of pneumonia or bronchitis later than 36 h after admission were considered to have developed a nosocomial pneumonia and were assigned as a pulmonary complication for the appropriate group. When pneumonia developed more than 36 h after completion of the active study period, it was not considered a complication for that group.

The diagnosis of segmental or lobar atelectasis was based on chest x-ray. Atelectasis present at the time of randomization was not counted as a complication for the assigned group on the first day. Atelectasis developing any time after completion of the active study period was not considered a complication for that group.

Adult respiratory distress syndrome (ARDS) was defined as hypoxemia (Pa_{O_2}/F_{IO_2} ratio of <200 or a shunt fraction >0.20 or PEEP >5 cm H_2O) and poorly compliant lungs (peak inspiratory pressure [PIP] minus PEEP >35 cm H_2O when the ventilator delivered a tidal volume [VT] 12 ml/kg ideal body weight) and the presence of bilateral infiltrates on chest x-ray. The shunt criterion took precedence over the Pa_{O_2}/F_{IO_2} ratio when the former was available. All criteria had to be present on at least 2 consecutive days. The duration of ARDS was the number of days on which these criteria were met. Barotrauma was defined as the presence of pneumomediastinum, pneumothorax, or subcutaneous emphysema.

Data Collection

The following risk factors were recorded on admission: age; sex; blood alcohol level; smoking history; Glasgow Coma Scale (GCS) score; clinical evidence of aspiration of gastric contents; weight, height; presence or absence of fractured ribs; presence or absence of parenchymal pulmonary x-ray abnormalities; the use of steroids or antibiotics during the week preceding SICU admission; history of parenteral drug abuse; occupation; present and past illnesses; location of incisions and fractures; simplified acute physiology score (SAPS) (14); expected mortality as predicted from SAPS (14); and trauma score (15).

The following information was recorded daily: antibioties, muscle relaxants and their total daily dosage; maximal and minimal core body temperatures (rectal or pulmonary artery); tracheal aspirate for Gram stain and culture; total and differential WBC count; list of clinical diagnoses; GCS score; route of intubation; mode of ventilation; visual sputum description (amount, color, consistency); diagnostic or therapeutic procedures; PEEP; PIP; delivered V_T; F_{IO_2}; the site and grade of decubitus ulcers; miscellaneous complications of therapy; chest x-ray interpretation. In almost all cases, these films were taken with the x-ray cassette placed directly underneath the patient, rather than underneath the kinetic table. This prevented the bed frame from appearing on the x-ray, and thus blinded the interpreter to the group assignment of the patient.

Statistical Analysis

The two groups (38 patients in the control group and 27 in the experimental group) were compared for the categorical baseline variables, such as sex, smoking status, incidence of spinal cord injury, and traction using the Z-statistic for comparison of proportions. Next, continuous baseline variables (age, GCS score, SAPS, trauma score, blood alcohol level and number of fractured ribs) for the two groups were compared using the small sample *t*-test. Finally, the incidences of major pulmonary complications (pneumonia or major atelectasis), decubitus ulcers, bronchitis, ARDS, barotrauma and survival rate for the study period, SICU stay, and hospitalization were compared using the Z-statistic. Furthermore, average duration of stay in the SICU and hospital, average duration of pneumonia, ARDS, atelectasis, mechanical ventilation, F_{IO_2} >0.50, and PEEP >5 cm H_2O were compared using the *t*-test.

RESULTS

Patients in the control and experimental groups were similar for most demographic variables (Table 1). Patients in the control group were slightly, but not significantly, less ill, as measured by the GCS score, SAPS, and expected mortality (32.1%, vs. 44.2%) calculated from the SAPS, and trauma score. Only one patient received corticosteroids during the study. Antibiotics were administered to 86.8% of the control patients and to 74.1% of the kinetic table patients (not significantly different). Only antibiotics administered before the onset of pneumonia were considered in those who developed pneumonia, while antibiotics administered at any time during the study were counted in those not suffering this complication. One patient was removed from the kinetic treatment table during the second day because it was not possible to control elevated intracranial

TABLE 1. Baseline data (mean ± SD)

	Control	Kinetic Table
Number	38	27
Sex (% male)	76.3	74.1
Pulmonary contusion (%)	18.4	14.8
Injury of spinal cord (%)	10.5	14.8
Cervical (%)	2.6	11.1
Thoracic (%)	7.9	3.7
Traction (%)	26.3	22.2
Cervical (%)	7.9	14.8
Femoral (%)	10.5	3.7
Tibial (%)	7.9	0.0
Smoker (%)	63.2[a]	29.6
Initial x-ray clear (%)	26.3	37.0
Age (yr)	35.1 ± 15.4	34.8 ± 20.6
Fractured ribs		
No. fractured[a]	1.0 ± 1.6	0.7 ± 2.3
With fractured ribs (%)	31.6	18.5
No. fractured[b]	3.0 ± 1.3	4.0 ± 4.1
Glasgow Coma Scale score	9.0 ± 4.9	8.1 ± 4.4
SAP score	15.0 ± 5.8	17.6 ± 5.6
Predicted mortality[c] (%)	32.1	44.2
Trauma score	12.0 ± 2.9	11.5 ± 3.1
Alcohol level >0 mg/dl (%)	55.3	33.3
Level (mg/dl)[b]	162 ± 102	159 ± 113

[a] Mean for entire group; [b] mean utilizing number with the factor as denominator; [c] mortality predicted from mean SAP for group (14); [d] $p < .05$.

TABLE 2. Pulmonary complications

	Control	Kinetic Table
Combined Major Pulmonary Complications	% N	% N
All patients	65.8 (38)[a]	33.3 (27)
Subgroups		
Smokers only	66.7 (24)[b]	25.0 (8)
Nonsmokers only	64.3 (14)	36.8 (19)
CNS insults	71.4 (21)[b]	36.8 (19)
No CNS insult	58.8 (17)	25.0 (8)
Chest injury	80.0 (10)	42.9 (7)
No chest injury	60.7 (28)	30.0 (20)
Specific Pulmonary Complications Considering All Patients		
Atelectasis	42.1%	18.5%
Segmental	36.8%	18.5%
Lobar atelectasis	7.9%	0%
Subsegmental atelectasis	89.5%	55.5%
Pneumonia	34.2%	18.5%
Bacterial pneumonia	21.0%	14.8%
Undefined pneumonia	26.3%	11.1%
Duration of pneumonia	4.0 ± 3.6	3.2 ± 1.3

[a] $p < .01$; [b] $.05 < p < .10$.

TABLE 3. Miscellaneous outcome variables (mean ± SD)

	Control	Experimental
ARDS	13.2%	11.1%
Ventilator days	10.0 ± 8.2	8.5 ± 5.3
PEEP >5 cm H_2O	34.2%	22.2%
Duration	6.0 ± 5.1	3.3 ± 3.1
F_{IO_2} >.5	42.1%	22.2%
Duration	3.0 ± 3.5	1.8 ± 1.0
ICU days	15.0 ± 15.6	16.8 ± 13.6
Decubitus ulcers	26.3%	29.6%
Survival		
Study	92.1%	92.6%
ICU	89.5%	81.5%
Hospital	86.8%	74.1%
Observed/expected	1.26	1.32

The durations of PEEP and F_{IO_2} were calculated by including only patients who received these therapies. The ratio of observed to expected death rate was calculated by obtaining the expected mortality rate for the average SAP for each group and dividing it into the observed value. A ratio >1.0 indicates survival better than predicted. None of the differences were significant.

pressure. His data were not included in analysis because of the short duration of study. Patients in the kinetic table group were in rotation for 13.4 h/day (n = 15).

The proportion of patients with the major pulmonary complications, either significant atelectasis or pneumonia, was significantly higher in the control group ($p < .01$). The incidence of major pulmonary complications was higher in the control group than in the experimental group among both smokers (67% vs. 25%) ($.05 < p < .10$) and among nonsmokers (64% vs. 37%); nonsignificant when considered separately (Table 2). The results were analyzed in the subgroup of patients who had suffered chest trauma as evidenced by three or more fractured ribs or pulmonary contusion with similar findings, i.e., the kinetic treatment table group had approximately 50% fewer major complications. The same was true of patients who had suffered CNS insults resulting in an admission GCS score of 7 or less.

Using the average SAPS for each group, the ratio of observed to expected survival (14) was 1.26 for control vs. 1.32 for the experimental group. Thus, the experimental group survival experience was at least as good as that for the control group when corrected for severity of illness as estimated by the SAPS.

The incidence of ARDS, duration of ventilator treatment, number of days during which >5 cm H_2O of PEEP was required, and mean duration of PEEP requirement were lower in the experimental group, but the differences were not statistically significant (Table 3). The sample size is small enough that there is a significant chance of having missed a significant difference in these complications.

DISCUSSION

Gravity can supplement the effectiveness of the mucociliary escalator apparatus in removing pulmonary secretions if the patient is properly positioned. Conversely, critically ill patients will be more susceptible to retention of secretions when treatment requires immobilization. Adequate removal of secretions aided by positional therapy should lead to a reduction in atelectasis and pneumonia. Kinetic treatment tables are prescribed, based on the hypothesis that continuous positional changes are superior to intermittent turning. However, there is a lack of convincing clinical data.

Green et al. (8) reported a 6% mortality rate in 162

spinal cord injury patients treated on the kinetic treatment table and a 6% incidence of atelectasis. These results were compared with a 1973 review (16) of experience treating patients with spinal cord injury, who had an incidence of pulmonary complications of 90% to 100%, and mortality of 40%. This group was treated in a general hospital, rather than a spinal cord unit, and those morbidity and mortality rates no longer reflect the expected outcome of such patients.

Brackett and Condon (12) retrospectively compared the incidence of pulmonary complications among two groups of patients, 14 of whom were treated on a Stryker frame, and 17 on the kinetic treatment table. The incidence of pulmonary complications on the Stryker frame vs. the kinetic treatment table was 69% (nine of 13) vs. 25% (three of 12), and the respective mortality rates were 28.6% vs. none. However, 64% of the Stryker frame group had cervical as opposed to thoracic spine injuries, compared to 47% with cervical injuries among the kinetic treatment group. Thus, in the absence of randomization, any generalizations from the data are questionable.

Trammell et al. (13) retrospectively compared 20 patients treated on a kinetic treatment table with 19 patients treated on a Foster frame. The incidence of atelectasis was 20% among the kinetic treatment group vs. none for the Foster frame group. The total incidence of pulmonary complications was 20% vs. 21%. They concluded that either bed was acceptable, but the lack of randomization weakens this conclusion.

In contrast to the above studies, the present study was a randomized, prospective comparison of two groups of similar patients immobilized for a variety of reasons. Our criteria for making the diagnosis of pneumonia were quite stringent, but were derived from similar criteria used in other studies (4–7, 17, 18). Tobin and Grenvik (1) stressed the many potential errors inherent in relying on any single criterion in establishing the diagnosis of pneumonia. Cultures of airway secretions may be false-positive or negative (19, 20). Fever and leukocytosis are nonspecific and may be related to underlying trauma or other infectious or noninfectious processes. In the study by Andrews et al. (18) of nosocomial pneumonia in patients with acute lung injury, x-ray consolidation was found in only 57% of patients with histologically defined pneumonia, and 30% of patients without pneumonia had x-ray consolidation. Thus, we required the presence of multiple criteria to make the diagnosis of pneumonia. Despite these precautions, it is possible that we had significant false-positive and false-negative rates utilizing these criteria, but they were applied uniformly to both groups in a prospective fashion.

An interesting area for further study would be to define the number of hours during which continuous rotation is necessary in order to retain its effectiveness. This line of investigation has implications with respect to the rationale for conventional orders to "turn every hour." While we attempted to leave the patients in continuous rotation except as needed to render other therapy, they were rotated only slightly more than 50% of the time. It is possible that less than continuous rotation would be just as effective and more comfortable for the patient, especially those who are awake.

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