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Effect Of Kinetic Therapy on Pulmonary Complications

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Effect of Kinetic Therapy on Pulmonary Complications

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• BACKGROUND *Optimal turning of critically ill patients is not well established. Kinetic therapy (systematic mechanical rotation of patients with 40° turns) may improve pulmonary function more than the improvement in function achieved via the standard of care (turning patients every 2 hours).*

• OBJECTIVE *To determine (1) if patients receiving mechanical ventilation who tolerate kinetic therapy have better pulmonary function than do patients treated with standard turning and (2) the cost-effectiveness of kinetic therapy.*

• METHODS *A prospective, randomized, multicenter study including 234 medical, surgical, and trauma patients (137 control patients, 97 patients receiving kinetic therapy).*

• RESULTS *Kinetic therapy significantly decreased the occurrence of ventilator-associated pneumonia and lobar atelectasis. The risk of pneumonia developing was lower (P = .002) in patients receiving kinetic therapy than in the control patients. The risk of lobar atelectasis developing was decreased (P = .02) for the patients receiving kinetic therapy. Lengths of stay in the intensive care unit and in the hospital did not differ between the groups. Charges for intensive care were less in the kinetic therapy group ($81 700) than in the control group ($84 958), but not significantly less. Twenty-one patients did not tolerate kinetic therapy and were not included in the analysis.*

• CONCLUSION *Kinetic therapy helps prevent ventilator-associated pneumonia and lobar atelectasis in critically ill patients. Costs to rent the bed may be offset by the potential cost reduction associated with kinetic therapy. (American Journal of Critical Care. 2004;13:376-383)*

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The concept of turning patients to prevent respiratory complications is almost as old as modern nursing. Unfortunately, the rationale for turning is not based on empirical research.[1] For example, a standard exists in nursing that patients should be turned at least every 2 hours to prevent respiratory complications. Yet the research to support this guideline is difficult to trace. Although the idea of turning immobile patients to prevent pulmonary complications seems self-evident, manually turning a patient has not been shown to alter pulmonary function.

Physical therapies have been developed to help treat acutely injured lungs and avoid pulmonary complications such as ventilator-associated pneumonia (VAP). These therapies involve turning patients at various angles to improve gas exchange, mobilization of secretions, and lymphatic drainage. The most aggressive turning approach is prone therapy. Technically difficult to do, placing patients prone improves gas exchange but not patients' outcomes (except perhaps in the more critically ill patients, such as those with P/F ratios <100 [where P stands for arterial oxygen pressures and F stands for fraction of inspired oxygen]).[2]

Less aggressive forms of turning include various rotational therapies such as kinetic therapy, in which patients are rotated from side to side in a turn of at least 40°, and continuous lateral rotation therapy (CLRT), in which patients are rotated from side to side in a turn of less than 40°.

Kinetic therapy has been available to intensive care units (ICUs) since the introduction of the Roto Rest bed in the 1970s.[3] However, the concept was used for decades before the introduction of this bed.[4] The Roto Rest system was one of the earliest forms of rotational therapy (encompassing kinetic therapy and CLRT). This bed allowed continuous turning up to 62° (124° arc).

Although several investigators examined the effects of rotation on pulmonary function, all the studies were limited by a lack of power (because of the small sample sizes). For example, in a randomized study[5] of 65 patients in a surgical ICU, patients receiving kinetic therapy had a lower combined incidence of atelectasis or pneumonia than did control subjects ($P < .01$). However, other variables such as individual occurrence of atelectasis, incidence of pneumonia and acute respiratory distress syndrome (or adult respiratory distress syndrome), fraction of inspired oxygen requirements, ICU days, survival, and formation of pressure ulcers did not differ significantly between the kinetic therapy group and the control group, although results tended to favor the kinetic therapy group. In this study,[5] the kinetic therapy group had a steep angle turn of 62°.

Fink et al[6] assessed kinetic therapy in 106 patients with blunt chest trauma. Kinetic therapy decreased the risk of pneumonia by 23% ($P < .01$) and of other lower respiratory tract infections by 32% ($P < .01$). The therapy also resulted in a 43% reduction in days of intubation ($P = .05$) and, among survivors, shortened the hospital length of stay by 54% ($P < .01$).

To overcome issues of sample size and get a better perspective on the effects of kinetic therapy, Choi and Nelson[7] performed a meta-analysis of 6 studies. In the combined 419 patients, kinetic therapy reduced the incidence of nosocomial pneumonia by 50% ($P < .002$) and atelectasis by 38% ($P < .03$). Moreover, kinetic therapy contributed to a 35% reduction in the incidence of intubation ($P < .04$) and a 24% decrease in ICU days ($P < .02$). Choi and Nelson found no differences in mortality, length of stay, or the incidence of pulmonary emboli or acute respiratory distress syndrome. Although hospital costs were reduced by $1200 for patients who received kinetic therapy, the difference was not statistically significant. Ultimately, Choi and Nelson recommended that a large, randomized study with adequate power be done to support their findings.

In a study[8] of 25 critically ill patients receiving mechanical ventilation, compared with conventional therapy (manual turning and percussion every 2 hours), the combination of kinetic therapy and percussion resulted in a significantly higher frequency of partial or complete resolution of atelectasis.

Several abstracts[9-12] and articles[13-15] have been published on the effects of kinetic therapy. In all of the studies, however, sampling techniques or sample sizes were inadequate. On the other hand, all the studies had evidence suggestive of a potential benefit of kinetic therapy.

CLRT has been investigated in a manner similar to kinetic therapy, but with fewer studies with generally smaller sample sizes. Results from these studies were inconclusive. Dolovich et al[16] studied mucus removal from the lungs after 90 minutes of CLRT in a nonrandomized sample of 13 patients in stable condition who were receiving mechanical ventilation. None of the patients had evidence of improvement.

Beds for kinetic therapy rotate in a turn of at least 40°, whereas those for continuous lateral rotation therapy rotate less than 40°.

Whiteman et al[17] examined the effects of CLRT at 30° on patients after liver transplantation. These researchers found no significant differences in resource utilization (mechanical ventilation or ICU length of stay), although they did find that the incidence of infections of the lower respiratory tract in the CLRT group was significantly lower than the incidence in the control (stationary bed) group.

MacIntyre et al[18] studied rotational therapy with 20° turns. They found no difference between the CLRT group and the standard care group in the incidence of infections of the lower respiratory tract. Patients receiving CLRT experienced increased anxiety and had a statistically significant reduction in urinary tract infections (11% vs 27%).

Nelson and Anderson[19] examined 10 patients with stable hemodynamic status who required mechanical ventilation for symmetric lung disease. On the basis of changes in PaO_2 values, the authors suggested that steep positioning (62° turning) may help reverse reduced PaO_2 values. No hemodynamic changes occurred during rotations of less than 4 hours.

In another study[20] of 10 patients, the patients with moderate lung injury responded better than did patients with acute lung injury (as indicated by a pulmonary severity Murray score of 2.5 or greater). The investi-

Table 1 Definitions of dependent variables

Variable	Definition
Ventilator-associated pneumonia (VAP)	The diagnostic criteria for VAP were modified from those established by the American College of Chest Physicians.[21] VAP was considered to be present when a new or progressive radiographic infiltrate developed in conjunction with one of the following: • Radiographic evidence of pulmonary abscess formation (ie, cavitation within preexisting pulmonary infiltrates) • Histologic evidence of pneumonia in lung tissue • Growth of microorganisms on culture of blood or pleural fluid • Two of the following: Fever, body temperature >38.3°C Leukocytosis, white blood cell count >10 x 10^9/L Purulent tracheal aspirate Samples of blood and pleural fluid could not be obtained for cultures within 48 hours before or after clinical findings suggestive of VAP. Microorganisms recovered from cultures of blood or pleural fluid also had to be identical to the microorganisms recovered from the cultures of the respiratory secretions. VAP complicating community-acquired pneumonia was considered to be present if new or progressive infiltrates developed at least 48 hours after the start of the mechanical ventilation and empiric antibiotic treatment. The previous infiltrates, attributed to the community-acquired pneumonia, were also required to be stable or improving in their radiographic appearance for at least 48 hours before the development of these new or progressive infiltrates.
Lobar atelectasis	Diagnostic criteria for lobar atelectasis included evidence of complete or near complete opacification of a lobe. This opacification had to be associated with direct or indirect signs of volume loss on radiographs.
Intrapulmonary shunting	Intrapulmonary shunting was measured by comparing arterial to inspired oxygen. This value (also called P/F) is obtained by dividing the arterial oxygen tension (Pa_{O_2}) by the fraction of inspired oxygen (F_{IO_2}).
Duration of mechanical ventilation	Duration of mechanical ventilation was defined as the number of hours a patient received mechanical ventilation, beginning at intubation and ending at extubation.
Intensive care unit (ICU) length of stay	ICU length of stay was defined as the number of days a patient was in the ICU, from admission until discharge from the unit.

gators[20] postulated that this finding might be due to pulmonary changes that limited the benefit of positioning in patients with severe lung injury (ie, ventilation-perfusion relationships could not be easily altered in these patients).

Although some evidence supports the concept of kinetic therapy, the research to date has not been rigorous. The following statement by Sahn[15] may best describe the current general perception of kinetic therapy: "The data suggest that a multicenter study with accrual of a large number of patients to evaluate this form of therapy in a prospective, randomized study is necessary." We therefore evaluated the effects of kinetic therapy on pulmonary complications and cost in patients requiring mechanical ventilation.

Kinetic therapy decreases pulmonary complications, but the results are limited by small samples.

Materials and Methods

A prospective, randomized design was used. Patients were enrolled in the study at 6 hospitals (4 community and 2 university). Patients were eligible for the study if they had a P/F ratio less than 250, had a score less than 11 on the Glasgow Coma Scale, and required mechanical ventilation. Patients were not eligible if they had open abdominal wounds, were receiving hemodialysis or peritoneal dialysis, or were having intracranial pressure monitored. The main independent variable was degree of rotation: standard turning with pillows under the back or automated bed turning to 40°. The main dependent variables were VAP, lobar atelectasis, intrapulmonary shunting, ICU length of stay, and duration of mechanical ventilation (Table 1). Main financial variables were hospital operating costs, fixed costs, and variable costs.

Selection of Patients

Patients who met the entry criteria and agreed to participate in the study were enrolled by using an alternate month schedule; that is, one month patients were assigned to the kinetic therapy group and the next month patients were assigned to the control group.

Patients in the kinetic therapy group were placed on a low-air-loss specialty bed capable of delivering 40° bilateral rotation with an 80° arc, 40° to the right and then 40° to the left (TriaDyne II, KCI USA, San Antonio, Tex). The bed was set to rotate with pause times of 10 minutes on one side, 5 minutes in the supine position, and 10 minutes on the opposite side. Patients in the control group were placed on a standard ICU bed and were manually turned from one side to supine to the other side by the nursing staff every 2 hours.

Patients randomized to the kinetic therapy group who, because of anxiety or physiological changes, could not tolerate the rotation during the first 24 hours after randomization were given an additional 24 hours to establish a tolerance by using the bed's acclimation mode.

Data were collected on all patients by site coordinators. The site coordinators made daily rounds, identified candidates for the study, and collected demographic and clinical data.

Table 2 Categorical dependent variables

Variable	Standard of care	Kinetic therapy	P*
Ventilator-associated pneumonia			<.01
Yes	45	14	
No	92	83	
Lobar atelectasis			.02
Yes	42	16	
No	95	81	

*χ^2 test.

Data Analysis

The main outcome physiological criteria were VAP, lobar atelectasis, intrapulmonary shunting, ICU length of stay, and duration of mechanical ventilation. Categorical data (VAP, lobar atelectasis) were analyzed by using a Yates-controlled χ^2 single-table test. Continuous data (P/F ratios, ICU length of stay, and duration of mechanical ventilation) were analyzed by using the Kruskal-Wallis test for 2 groups. Financial outcome criteria were reported in terms of charges, broken into hospital and ICU costs and into fixed and variable costs. All financial information was obtained from the hospitals' billing departments. Differences in financial outcomes between the control and kinetic therapy groups were analyzed by using the Kruskal-Wallis test for 2 groups.

Human Subjects

Each hospital's human subjects committee approved the study. Informed consent was obtained from patients' families (the entry requirement of having a score of 11 or less on the Glasgow Coma Scale often precluded getting informed consent from the patient).

Staff Education

All nursing staff received instruction in the care of patients receiving kinetic therapy. Classes were supplemented by on-site resource nurses who attended a 4-hour training program on kinetic therapy. These nurses assisted staff nurses as questions about the therapy and specialty bed occurred. Nurses were trained on the basics of kinetic therapy and on assessing patients' ability to withstand or continue kinetic therapy by considering tolerance and hemodynamic issues. Nurses were instructed to use their own judgment about whether to continue or terminate rotation if a patient was having signs or symptoms of intolerance that were not relieved by use of the acclimation mode or by attempts to reduce anxiety. The nurses were to list the reasons and/or indications of intolerance in their notes. Study coordinators, as well as a clinical consultant from the study sponsor, were available on a 24-hour basis to help address questions and issues. In addition, through daily rounds, the principal investigator was available to resolve issues.

Definition of Kinetic Therapy

Kinetic therapy was defined as rotation of at least 40° for at least 18 hours per day. Rotation hours were measured daily by using the bed's therapy hour meter feature (the bed has a built-in timer that allows users to determine how long the bed was in the programmed positions). Time of rotation was measured for both kinetic therapy and subkinetic therapy (<40° turning).

Results

Between June 2000 and June 2001, 255 patients were enrolled in the study, 137 in the control group and 118 in the kinetic therapy group. Twenty-one patients in the kinetic therapy group could not tolerate bed rotation and were not included in the analysis.

The incidences of lobar atelectasis and VAP were significantly lower in the patients receiving kinetic therapy than in the control patients (Table 2). The risk of VAP developing was lower in patients receiving kinetic therapy than in control patients. The risk of lobar atelectasis developing was lower for the patients in the kinetic therapy group than for patients in the control group.

Lengths of stay in the ICU and hospital did not differ significantly between the 2 groups (Table 3). Costs

Table 3 Continuous dependent variables

Variable	Standard care	Kinetic therapy	P*
Length of stay in intensive care unit	n = 137	n = 97	.47
Mean	13.64	13.46	
SD	11.33	13.21	
Duration of mechanical ventilation	n = 137	n = 97	.92
Mean	10.14	10.75	
SD	10.62	12.23	
Pulmonary function			
Day 1	n = 133	n = 96	.98
Mean	142.81	142.40	
SD	61.16	60.98	
Day 2	n = 111	n = 80	.07
Mean	171.85	190.73	
SD	81.31	82.22	
Day 3	n = 86	n = 54	.55
Mean	180.23	187.37	
SD	70.93	81.38	
Day 4	n = 70	n = 40	.71
Mean	184.06	191.18	
SD	74.25	84.01	
Day 5	n = 42	n = 30	.46
Mean	187.54	194.37	
SD	79.23	82.30	
Intensive care unit costs, US$	n = 86	n = 67	.50
Mean	84 958.22	81 740.19	
SD	71 807.89	76 352.33	

*Kruskal-Wallis test for 2 groups, assuming homogeneous variances and normal distribution.

in the kinetic therapy group ($81 740) were lower than costs in the control group ($84 958), but the difference was not statistically significant (Table 3). Lung function, as measured by P/F ratios, did not differ between the 2 groups.

Kinetic therapy decreased pneumonia and atelectasis but not length of stay in the ICU or in the hospital.

The 2 groups did not differ in clinical conditions, for example, congestive heart failure, chronic obstructive pulmonary disease, use of drugs (eg, steroids), albumin levels, or reintubation rates (Table 4). The kinetic therapy and control groups did not differ significantly in terms of age, sex, diagnoses, or scores on the Acute Physiology and Chronic Health Evaluation II (Table 5).

Table 4 Continuous demographic and clinical variables

Variable	Standard care (n = 137)	Kinetic therapy (n = 97)	P*
Sex			.77
Male	66	44	
Female	71	53	
Congestive heart failure			.60
Present	51	32	
Absent	86	65	
Chronic obstructive pulmonary disease			.93
Present	40	28	
Absent	97	69	
Death			.90
Present	58	41	
Absent	79	56	
Adult respiratory distress syndrome			.55
Present	11	5	
Absent	126	92	

*χ^2 test.

Discussion

The basis for supporting the current guidelines on kinetic therapy remains unclear. The assumption that kinetic therapy improves movement of secretions and prevents stasis of secretions empirically makes sense. However, research has been inadequate in evaluating frequency of turning, angle of turn, and duration of turn. In addition, lung models and the geometry of the tracheobronchial system suggest that simple turning will not effectively drain all lung segments because of the various geometric angles in the airways.

Despite these concerns, our findings support the benefits of kinetic therapy relative to pulmonary function. Previous studies were underpowered in terms of sample size, leaving to debate the applications and value of kinetic therapy. In addition, the control of turning angles, duration of turning, adherence to protocols, and required length of time patients received kinetic therapy varied in published research studies.

In our study, we were able to address some, but not all, of the limitations of the previous research. We had a large sample size and relatively good adherence to turning angles (40° rotation), duration of turning

Table 5 Categorical demographic and clinical variables

Variable	Standard care (n = 137)	Kinetic therapy (n = 97)	*P**
Age, years			.50
Mean	63.66	62.28	
SD	16.57	16.77	
APACHE II score			.73
Mean	27.31	27.16	
SD	7.31	6.66	

Abbreviation: APACHE, Acute Physiology and Chronic Health Evaluation.
*Kruskal-Wallis test for 2 groups, assuming homogenous variances and normal distribution

(10 minutes/5 minutes/10 minutes turning sequence), and days of rotation (5).

Lack of tolerance to turning and variations in maximal turning duration may have affected results.

We found clear evidence of a benefit of kinetic therapy in pulmonary function. VAP and lobar atelectasis were markedly reduced in the kinetic therapy group. We also found that although baseline P/F ratios did not differ significantly between the 2 groups, by the second day, the improvement in P/F ratios for the kinetic therapy group indicated an early improvement in pulmonary function with kinetic therapy.

This potential improvement in pulmonary function did not appear to lead to shorter durations of mechanical ventilation or shorter hospitalizations. The improvement in pulmonary function may or may not be related to kinetic therapy. Although the randomization procedures should have controlled for differences in care practices of physicians and nurses (eg, weaning from mechanical ventilation, extubation, sedation practices, and ICU discharge), practices varied within and between hospitals and may have influenced ICU length of stay more than kinetic therapy did. The assumption is that if pulmonary function improves in one group of patients, the patients would be treated differently. This assumption may not be accurate. It is difficult to evaluate how much physicians' and nurses' care practices influenced the ICU length of stay and the duration of mechanical ventilation. Avoidance of VAP and lobar atelectasis might be expected to lead to a reduced time in the ICU. The lack of this result in our study could be attributed to differences in clinical decision making. Other factors that may have skewed the calculation of length of stay include early mortality being reflected as a short length of stay and having patients who were no longer critically ill, at least in terms of pulmonary status, remain in the ICU because of comorbid conditions or convenience.

Length of stay can also be affected by weaning from mechanical ventilation, sedation, and local care practices.

Cost is particularly relevant in the use of kinetic therapy. The cost to a hospital to use a specialty bed, such as the bed used for kinetic therapy, can be substantial. This cost can be offset if kinetic therapy reduces the time patients are in the ICU or are receiving mechanical ventilation. That result did not occur in our study, but we did find a difference in ICU charges between the 2 groups, although the difference was not statistically significant. The reason for the difference is unclear. On the basis of this information, the cost of kinetic therapy may be at least partially, if not completely, offset by the reduction in ICU charges.

Survival rates did not differ between the 2 groups, although both groups had high mortality rates (42.2% in the kinetic therapy group, 42.3% in the control group). The high mortality rate is consistent with the high scores on the Acute Physiology and Chronic Health Evaluation II (27.1 in the kinetic therapy group, 27.3 in the control group). It is also consistent with a score of 11 or less on the Glasgow Coma Scale, a criterion for entry into the study.

We found that the use of a score of 11 or less on the Glasgow Coma Scale severely limited the number of patients who might benefit from kinetic therapy. A follow-up study that includes sedation of patients to improve tolerance of the bed rotation should be done. Such a study will also need standardized plans or protocols for sedation and weaning from mechanical ventilation to control for the effects of clinicians' care practices.

The inability of some unsedated patients to tolerate turning was an important factor. The score of 11 on the Glasgow Coma Scale was selected in an attempt to find patients who would tolerate kinetic therapy. Unfortunately, tolerance truly was not known until rotation began. The reluctance of clinicians to sedate patients for kinetic therapy and the inability of some of the unsedated patients to tolerate kinetic therapy also limit the study findings. Ideally, neurologically depressed patients or patients sedated specifically for kinetic therapy should be considered for this type of treatment.

Nurses' compliance with bed rotation was a potentially confounding factor. Many patients did not receive the full 18 hours of rotation indicated in the study design. Rotation was often stopped for reasons that varied from a nurse's lack of comfort with how the patient looked to nurses' turning the bed off for a procedure and forgetting to turn it back on. The mean time spent in rotation was more than 12 hours but less than the ideal 18 hours. We assume that some patients would have had better outcomes if the correct angle of rotation had been used for the full 18 hours. Investigators for any follow-up study of this type should ensure the commitment of the nursing staff to the protocol so that patients will not be removed from rotation unless they truly cannot tolerate it.

Optimal turning frequency, angle, and duration are unknown.

Conclusion

Kinetic therapy appears to be effective in preventing VAP and lobar atelectasis in critically ill patients. We recommend using kinetic therapy for critically ill patients who can tolerate the therapy, although some patients may require increased sedation. Although the individual differences, such as reduced ICU stay and duration of mechanical ventilation, were not statistically significant, the differences between the 2 groups supported the use of kinetic therapy. Intolerance may limit the types of patients for whom kinetic therapy might be used, but patients should be evaluated on a case-by-case basis, and a judiciously applied sedation protocol may assist clinicians in this regard. Our data support and extend the conclusions of previous investigations of kinetic therapy and provide a rational basis for its selected application.

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