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Effect of Combined Kinetic Therapy and Percussion Therapy on the Resolution of Atelectasis in Critically Ill Patients*

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Background: **Some critically ill patients have difficulty in mobilizing their respiratory secretions. These patients can develop pulmonary atelectasis that may result in hypoxemia. There are some data to show that atelectasis may be prevented by turning a patient from side to side utilizing special beds.**

Study objectives: **To determine the role of kinetic therapy (KT) combined with mechanical percussion (P) in the resolution of established atelectasis of the lungs and hypoxemia in critically ill, hospitalized patients. (KT was defined as rotation of a patient along the longitudinal axis of ≥ 40° to each side continuously.)**

Design: **Prospective and randomized study (2:1 test to control group).**

Patients: **Twenty-four patients with respiratory failure, either mechanically ventilated or spontaneously breathing, who demonstrated segmental, lobar, or unilateral entire lung atelectasis were studied.**

Setting: **Medical ICU and adult respiratory ward in a county hospital in New York.**

Interventions: **Seventeen patients were treated with KT combined with mechanical P using a KT system (Triadyne Kinetic Therapy System; KCI; San Antonio, TX). Seven patients received manual repositioning and manual P every 2 h. Both groups received similar conventional therapy with inhaled bronchodilators and suctioning.**

Results: **Partial or complete resolution of atelectasis was seen in 14 of 17 patients (82.3%) in the test group as compared with 1 of 7 patient (14.3%) in the control group. The median duration to resolution of atelectasis was 4 days in the test group. Bronchoscopy was performed in 3 of 7 patients in the control group, but in none of the patients in the test group. A cost of $720 was incurred per patient for utilizing the specialty beds for a mean duration of 4 days. An improvement in oxygenation index occurred in the test group (change in baseline Pao_2/fraction of inspired oxygen from 207.4 ± 106.7 mm Hg to 318 ± 100.7 mm Hg) at the end of therapy, while the control group showed a reduction over a similar duration of time (181.3 ± 96.3 mm Hg to 112 ± 21.2 mm Hg).**

Conclusions: **KT and mechanical P therapy resulted in significantly greater partial or complete resolution of atelectasis as compared with conventional therapy. There was a generalized trend toward statistical significance in the improvement of oxygenation and a reduced need for bronchoscopy in the group receiving KT and P therapy.** ***(CHEST 1999; 115:1658–1666)***

Key words: atelectasis; kinetic therapy; oxygenation; percussion

Abbreviations: APACHE = acute physiology and chronic health evaluation; DNR = do not resuscitate; KT = kinetic therapy; MICU = medical ICU; P = mechanical percussion; Pao_2/Fio_2 = ratio of partial pressure of oxygen in arterial blood to fraction of oxygen in inspired gas; VW = ventilator ward

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Critically ill patients, unable to move spontaneously, are nursed in the supine position for extended periods of time. This is in striking contrast to normal human beings who, even during sleep, change their position approximately every 11.6 min—a phenomenon described by Keane[1] as "minimum physiological mobility requirement." The deleterious effects of prolonged immobilization affect the heart, vascular system, musculoskeletal system, skin, and kidneys, despite repositioning every 2 h.[2–8]

Significant effects may also occur in the respiratory system. Nosocomial pneumonia, pulmonary thromboembolism, and hypoxemia may increase the patient's morbidity and mortality.[9,10] Another pulmonary complication of immobility is atelectasis. In the supine patient, the abdominal contents push in a cephalad direction, thereby decreasing the functional residual capacity. The alveoli in the dependent lung zones may close. Complete or partial closure of these alveoli will result in lowering of their compliance; thus, a greater level of opening pressure would be required to restore the patency of these alveoli. It has been shown that immobility may also result in accumulation of mucus in the dependent lung zones.[11,12] The most common segment of the lung to develop atelectasis is the left lower lobe, possibly due to compression by the heart in the supine position and its poor drainage.

Whatever the mechanisms involved, atelectasis results in development of a shunt with attendant hypoxemia. The pooled and stagnant secretions may act as a nidus for bacterial proliferation, culminating in nosocomial pneumonia.

Treatment of atelectasis usually involves frequent repositioning and suctioning of respiratory secretions, percussion (P) therapy, incentive spirometry, or intermittent positive pressure breathing in the spontaneously breathing patient. In the mechanically ventilated patient, suctioning is more effective; application of positive end-expiratory pressure is of doubtful efficacy. In patients with nonresolving atelectasis, bronchoscopic suctioning may be resorted to. Bronchoscopy is an invasive and expensive procedure that may sometimes necessitate intubation, especially in the severely hypoxemic patient with inspissated mucus.

It is easier to prevent atelectasis than to treat it. One of the newer modalities that has become available in the last few years is kinetic therapy (KT), which is defined as the continuous turning of a patient slowly along the longitudinal axis to $\geq 40°$ onto each side.[9] This therapy is delivered by using a specialized bed that rotates from side to side, utilizing the minimum degree of turn. Several studies have shown that KT can prevent the development of atelectasis in the setting of trauma, quadriplegia, and spinal cord injury.[13–16]

To our knowledge, no published studies have addressed the value of KT and P in the resolution of established pulmonary atelectasis. Addressing this question was especially important to us, since our medical ICU (MICU) and ventilator ward (VW) admit a significant number of patients with atelectasis and respiratory failure from the affiliated 1,000-bed geriatric center. The nurse to patient ratio of 1:7 to 10 in the VW does not usually allow frequent manual repositioning and P of our patients. Many of these elderly patients or their families do not allow bronchoscopy to help in the resolution of atelectasis.

Materials and Methods

The protocol was approved by the Institutional Review Board of Nassau County Medical Center, East Meadow, NY. New or previously admitted patients to the MICU or VW of Nassau County Medical Center between 1995 and 1997 were considered eligible if they had respiratory failure and evidence of atelectasis on chest radiographs. Patients could be breathing spontaneously or mechanically ventilated. Patients or their designees who gave written consent were randomized to either KT with P (test) or manual repositioning (control). A 2:1 test to control randomization was done using slips with either test or control written on them that were shuffled and sealed in envelopes.

KT was provided utilizing a KT system (Triadyne Kinetic Therapy System; Kinetic Concepts, Inc; San Antonio, TX). The angle of rotation was set to 45° on each side. A 5-min pause was given at each of the three positions—right side down at 45°, neutral position, left side down at 45°. The total number of complete rotations (neutral-right-neutral-left-neutral) was four per hour. A minimum duration of rotation was aimed at 18 h/24 h. The KT bed was programmed to administer P therapy at 9 beats/s. P was administered during the lateral rotation of the bed for a total duration of 20 min every 4 h. To initiate P therapy, the patient's nurse switched on the P control button at four hourly intervals. The control group was manually repositioned and received percussion therapy every 2 h by the nursing staff. Both groups received conventional therapy in the form of inhaled bronchodilators, suctioning as needed, and other medications, including antibiotics as deemed appropriate by the treating physicians. Suctioning in the nonintubated patients was performed using the nasotracheal Silastic catheters attached to the standard wall unit suction equipment.

The patients were followed up for the duration of time they stayed on the MICU or VW, up to a maximum of 2 weeks. If the patients were transferred from the MICU to the VW, they were followed up for the remaining duration of the 2 weeks. The primary variables monitored included the extent of atelectasis on a portable chest radiograph at baseline (day 0) and on days 3, 7, and 14. An independent chest radiologist who was blinded to the test and control groups reviewed each chest radiograph and determined atelectasis to be present using the following criteria: patchy or dense areas of consolidation, without air bronchograms, with evidence of loss of volume, following a segmental or lobar distribution, usually appearing abruptly or over 1 to 2 days in a manner more suggestive of atelectasis than pneumonia. In the case of entire lung collapse, the cutoff sign of the main bronchus was also looked for. The atelectasis was classified as segmental,

lobar, or unilateral whole lung. Resolution at each of the time points applicable (days 3, 7, and 14) was noted as complete if the entire area of atelectasis had resolved, partial if approximately half of the area of atelectasis had resolved, and none if less than one fourth of change in size was detected. After resolution of atelectasis, any recurrence was noted over the 2-week study period.

The other primary variable that was monitored was the Pa_{O_2}/fraction of inspired oxygen (F_{IO_2}) ratio at baseline and on days 3, 7, and 14 whenever possible. At least 30 min was allowed to elapse after making any changes in the inspired F_{IO_2} concentration before drawing an arterial blood gas sample. The arterial blood sample was transported by the research coordinator to the arterial blood gas analyzer within 5 to 10 min of drawing the sample.

The need for bronchoscopy was determined by one of four pulmonologists who were aware of the protocol. Bronchoscopy was considered if the techniques utilized to bring about resolution of the atelectasis were not successful, if the patient's oxygenation was getting progressively worse (increasing the likelihood of intubation and mechanical ventilation), and if the patient or the family consented to the procedure. If present, "DO NOT RESUSCITATE (DNR)" orders were rescinded during and 24 h after the procedure, and complications of bronchoscopy were treated as needed.

Demographic data were collected on all patients. The Acute Physiology and Chronic Health Evaluation (APACHE II)[17] score was calculated at the time of randomization in the study. Other variables noted included WBC count and temperature on days 0, 3, 7, and 14. The need for mechanical ventilation during the study period and the lengths of stay in the MICU, VW, and hospital were recorded. The patient's final disposition (home, nursing home, or death) was also noted.

The costs incurred with the use of the specialty bed were obtained by multiplying the daily rental costs of the bed with the average duration of time that it took for resolution of atelectasis. The actual cost of performing a bronchoscopy was calculated from time spent by the attending physician, pulmonary fellow, and bronchoscopy nurse, and equipment and supplies used, in addition to cost of sterilizing the bronchoscope.

Statistical analysis was done using Fisher's Exact Test to compare the degree of resolution between the test and the control groups. Comparison of the Pa_{O_2}/F_{IO_2} ratio at baseline between the test and control groups, and with each of the other time points, was obtained utilizing the unpaired *t* tests. Within-group analysis was done utilizing one-way repeated measures analysis of variance. If the analysis of variance was significant, a Tukey's pairwise multiple comparison test ($p < 0.05$) was performed to determine which time points were significantly different from each other.

Results

A total of 32 patients were offered enrollment in the protocol. Two patients died before consent could be obtained, while three patients' relatives refused to give consent for the study (expressing concern at the degree of rotation). The remaining two patients upon intubation, at the time of enrollment in the study, demonstrated radiographic resolution of atelectasis. Twenty-five patients were considered eligible for the study. Of these, 17 were randomized to the test group and 8 to the control group. However, one patient in the control group died within 24 h of enrollment. Since a chest radiograph and follow-up arterial blood gas determination could not be obtained prior to this patient's death, she was not included in the final analysis.

The demographic data of the patients are summarized in Table 1.

No significant differences were discerned in the age, frequency of smoking, baseline WBC count, or Pa_{O_2}/F_{IO_2} ratio between the two groups. The APACHE II scores, calculated at the time of entry into the study, were higher for the test group as compared with the control group ($p < 0.02$). Thus, the patients in the test group may have been slightly sicker than the control group. The primary diagnosis of the patients referred to the major clinical problem of the patient during the 2 weeks of their enrollment period.

Data analysis showed more patients with neurologic problems (strokes, subdural hematomas, intracranial hemorrhage) in the test group as compared with the control group. Diagnoses included in the category of respiratory disorders were mainly COPD and pneumonia. No significant differences were seen in the medication usage, including antibiotics in the two groups, either before or during the clinical trial. The percentage of patients intubated and mechanically ventilated at day 0 in the test group (47%) was greater than when compared with the control group (28.6%). This was because two of the remaining five patients in the control group had advance directives

Table 1—*Baseline Patient Information

Patient Data	Control	KT With P	p Value
No.	7	17	
Sex, No. (%)			
Male	4 (57)	11 (65)	NS
Female	3 (43)	6 (35)	
Age, yr, mean ± SD	68 ± 19	66 ± 18	NS
Smoker, %	3	10	NS
Primary diagnosis, No. (%)			
Pneumonia/respiratory	2 (28.5)	3 (17.5)	
Sepsis/shock	1 (14.3)	2 (11.8)	
Stroke/neurologic	2 (28.5)	9 (52.9)	NS
Trauma	1 (14.3)	1 (5.9)	
S/P cardiopulmonary arrest	—	1 (5.9)	
Congestive heart failure	1 (14.3)	1 (5.9)	
WBC (day 0), cells/mm^3	12.3×10^3	10.8×10^3	NS
± SD	± 7.4	± 4.4	
Pa_{O_2}/F_{IO_2} (day 0) ± SD	181 ± 96.3	207.4 ± 106.7	NS
Intubated, No. (%)	2 (28.6)	8 (47.1)	NS
CPAP (nonintubated) (No. of patients/mean CPAP)	2/6.5 cm	3/7.3 cm	NS
APACHE II score ± SD	11 ± 5	16 ± 4	< 0.02
Glasgow Coma Scale ± SD	11.3 ± 2.9	8.8 ± 4.6	NS

*S/P = status post; CPAP = continuous positive airway pressure; NS = not significant.

categorically specifying that mechanical ventilation not be instituted in their individual cases.

The proportion of patients with atelectasis in the test and control groups was similarly distributed between the MICU and surgical ICUs and the VW. The extent of atelectasis was similar in the test and control groups at the initiation of the study (Table 2). There was a trend toward more frequent lobar atelectasis in the control group and entire lung atelectasis in the test group. The test group had complete or partial resolution of atelectasis in 14 of 17 patients (82.3%), while only 1 of 7 control patients (14.3%) demonstrated this resolution (Fig 1). The difference was highly statistically significant ($p = 0.004$). The median duration of resolution for the test group was 4 days. Since only one of the control patients underwent resolution, the numbers were too small to calculate a median duration for this group. The average length of time that KT and P were administered to patients was 7.3 ± 5.2 days. By comparison, patients in the control arm received conventional treatment for atelectasis for 9.5 ± 3.8 days. The difference in duration of therapy was not statistically significant.

None of the patients receiving KT and P required a bronchoscopy for resolution of the atelectasis. Of the three patients who failed to resolve their atelectasis with KT and P, bronchoscopy was not performed for the following reasons: refusal to give consent (one), refusal to rescind DNR (one), and no improvement with a prior bronchoscopy (one). In the control arm, three patients underwent a bronchoscopy, and one demonstrated resolution of atelectasis without a bronchoscopy. Three remaining patients did not undergo a bronchoscopy for the following reasons: refusal to consent to procedure (two) and refusal to rescind the DNR order prior to the procedure (one).

Table 2—*Atelectasis Data**

Atelectasis Data	Control n = 7		KT With P n = 17		p Value
Duration of atelectasis prior to enrollment, d, mean ± SD	1.5 ± 9		1.9 ± 1.7		NS
Extent of atelectasis					
Entire lung	1 (14.3%)		5 (29.4%)		NS
Lobar	6 (85.7%)		10 (58.8%)		
Segmental	0		2 (11.8%)		
Degree of resolution					
Complete	1		10		
Partial	0	14.3%	4	82.3%	0.004
None	6		3		
Days to resolution (median)	—		4		
Recurrence of atelectasis	1/1		3/4		NS
Bronchoscopy performed	3/7		0/17		< 0.02

*NS = not significant.

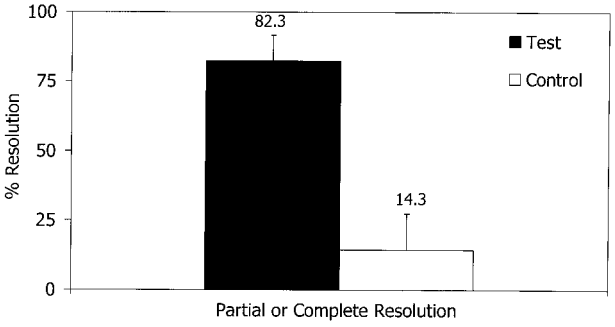

FIGURE 1. Comparison of resolution of atelectasis between the control and test group.

The actual cost of performing a bronchoscopy in our institution varies from $290 to $320. This takes into consideration the cost of disposable equipment and medications used, the 1-h compensation of one attending pulmonologist, and 1½ h of a pulmonary fellow and bronchoscopy nurse's time, and the cost of sterilizing the bronchoscope. While the cost in private hospitals may be considerably higher, the figures that we have quoted are fairly representative of the costs incurred in a county or city hospital.

An apparent and significant improvement was seen in the index of oxygenation of the test group patients over the control patients. The PaO_2/FIO_2 ratio was not statistically different between the control group and the test group at day 0. There was a significant difference between the test and control group at all of the other time periods (days 3, 7, and 14) as indicated in Figure 2.

The p values for the four time periods are as follows: $p = 0.58$ (baseline); $p = 0.001$ (day 3); $p = 0.0007$ (day 7); and $p = 0.03$ (day 14). A within-group analysis determined that the PaO_2/FIO_2 was relatively flat over time for the control group ($p = 0.42$). However, for the test group, the PaO_2/FIO_2 rises steadily with time with an overall p value of $p = 0.0002$.

No significant differences were observed in the length of stay of patients in MICU, VW, or the hospital. The mortality rate was not significantly different between the test group and the control group.

DISCUSSION

This study suggests that a significantly higher rate of partial or complete resolution of atelectasis may be achieved in critically ill patients who receive both KT and mechanical P. An improvement in oxygenation that was maintained over the study duration of 2 weeks and a reduced need for bronchoscopy were

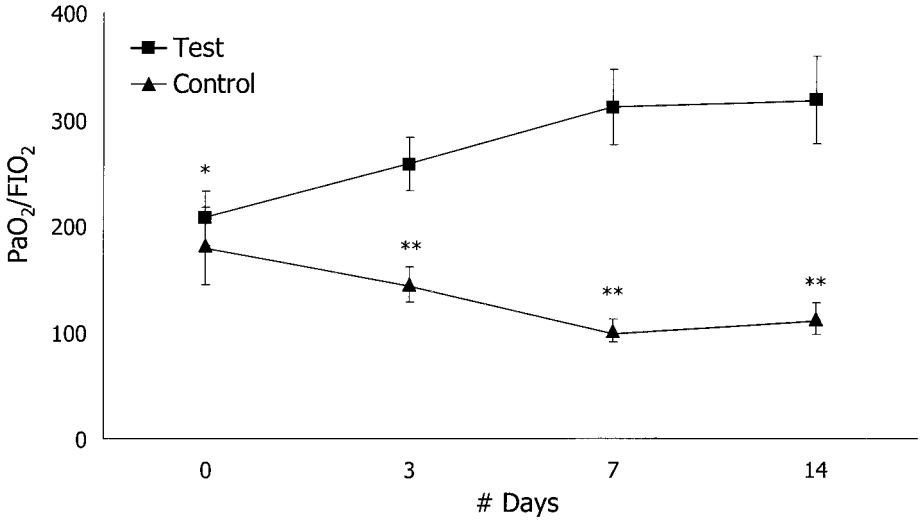

FIGURE 2. Comparison of oxygenation index between the control and test group over a 2-week study period.

also seen. To our knowledge, this is the first study looking at KT and P as a treatment modality for radiographically evident atelectasis.

The critically ill patient who is unable to move or cough effectively has multiple reasons to develop atelectasis and impaired mucociliary clearance.[3,18–21] Atelectasis has been reported in 74% of patients with acute spinal cord injury,[22–24] 85% with neuromuscular diseases,[25] up to 90% of patients who have undergone cardiac surgery, and 20 to 30% of patients after upper abdominal surgery.[26–29]

Atelectasis may be visible radiographically as segmental, lobar, or entire lung. Alternately, it may not be detected radiographically—a condition referred to as microatelectasis.[30,31] It has also been postulated, although not proven, that atelectasis may predispose to pneumonia.[32–34]

It has been observed that when air bronchograms are seen in the atelectatic lung, resolution is delayed.[35] Atelectasis persistent beyond 48 h usually necessitates aggressive therapy.[34] The usual treatment modalities include positioning for postural drainage, manual P, suctioning, incentive spirometry, maximal lung inflation,[36] intermittent positive pressure breathing,[37] and bronchoscopy.[38–40] Two other less widely used techniques, one deploying a curved-tip catheter to suction the upper lung lobes[41] and another selectively insufflating air intrabronchially in collapsed segments to expand them,[42,43] have been described.

The efficacy of chest physical therapy for resolving atelectasis, positioning postural drainage, P, suctioning, and lung inflation for resolving atelectasis parallels that of bronchoscopy.[35,38,44,45] Dettenmeier et al[46] showed an improvement in the oxygenation indexes, and radiographic findings of patients with atelectasis who received both chest physiotherapy and KT as compared with those who received only KT. Stiller et al[47] demonstrated improvement in the rate of resolution of lobar atelectasis when positioning and vibrations were combined with hyperinflation and suctioning (as compared with hyperinflation and suctioning alone). Based on this information, we chose to use both KT and P to treat atelectasis in our patient population.

It is recommended that chest physiotherapy be carried out at least every 2 h in critically ill patients with atelectasis.[36,48] Animal experiments, further, showed that turning intervals of 30 min were more effective in preventing hypoxemia and atelectasis than hourly position changes. Hourly position changes were found to be better than no mobilization.[3]

However, a protocol of manual repositioning and P every 1 to 2 h has several drawbacks. It blocks off a significant segment of nursing time in the critical care areas. Nursing time accounts for 44% of costs incurred in caring for patients in the MICUs.[49] Back injuries are occasionally sustained by the nursing staff in the process of positioning patients. In addition, many of our ICU patients who fail to respond to weaning and are otherwise in hemodynamically stable condition, are sent to the VW. Some of these patients develop atelectasis. In the VW, where the

patient to nurse ratio is 7:1, a labor-intensive protocol for treating atelectasis is practically not feasible. Hence, we were interested in evaluating the new specialty beds that have the capability of providing KT and P to our patient population.

Since its introduction in 1939, the rigid Stryker frame beds were used widely until 1980 for acute spinal cord injury patients. Refinements of this bed followed with the development of a kinetic treatment table. The kinetic treatment table rotates a patient from side to side by $\geq 40°$ along the longitudinal axis at a speed of rotation of half a degree per second. This slow speed of rotation prevents stimulation of the vestibular apparatus.[50] The angle of rotation needs to be monitored carefully. In the study of Traver et al,[51] no significant difference in length of stay, duration of ventilation, or incidence of pneumonia was discerned. One of the plausible explanations put forth was that a mean angle of rotation of 25.5° was achieved in the ICU patients. In our protocol, we used an angle of rotation of 45° on each side. The duration of rotation per day is not well defined. Most of the studies using these specialty beds used a duration of rotation of at least 10 to 16 h/d.

There is very little information regarding the appropriate frequency and duration of P therapy. Imle[52] recommended frequencies ranging from 1.7 to 6 cycles per second. Others have proposed slower or faster frequencies, depending on their own personal experience. Although the frequency of P was assuredly different between the test and control groups, the purpose was to study the effects of manual and mechanical P in a real-life situation—where it would be difficult to regulate the exact frequency of the manual Ps. How frequently to administer P remains equally nebulous. In the physiotherapy regimen used by Stiller et al,[47] P was administered on an hourly basis to patients with lobar atelectasis. However, since P has to be switched on manually each time, we chose an interval of 4 h that we believed was more practical in our setting.

The patients in the test group had a higher APACHE II score and may have been sicker than the control subjects. Since the Pao_2/Fio_2 ratio was similar between the test and control groups, it may be inferred that the test group had more severe nonpulmonary disorders. Although the former demonstrated a trend toward more frequent intubation and mechanical ventilation, statistical significance was not achieved. Suctioning can be carried out more effectively in the intubated patients. However, we do not believe that this was the major reason for greater resolution of atelectasis in the test group.

The distinction between atelectasis, pleural effusion, and pneumonia on chest radiographs may be difficult to make. The sign on chest radiograph given most credence was that of volume loss. On occasions, patients demonstrated both loss of volume on chest radiographs and had concomitant fever and/or leukocytosis. Prior studies have demonstrated that fever may be an accompaniment of atelectasis.[25,53] In such cases, the rate of development or resolution of pulmonary infiltrates was used to decide if atelectasis was more likely than pneumonia or vice versa.

Most of the patients receiving conventional treatment and KT and P developed lobar atelectasis. Complete lung atelectasis and segmental atelectasis together accounted for $< 50\%$ of the cases in each group. Complete resolution of atelectasis occurred in 10 of 17 patients (58.8%) in the KT and P group as compared with 1 of 7 in the control group (14.3%). An additional 4 of 17 patients (23.5%) receiving KT and P showed partial resolution of atelectasis. Thus, significant improvement in atelectasis was seen in $> 80\%$ of patients receiving KT and P in contrast to $< 20\%$ of patients who received conventional therapy.

Examining the subset of patients with entire lung atelectasis, there was complete resolution seen in three of five patients in the test group and one of one patient in the control group. The chest radiograph of a patient in the test group showing entire lung atelectasis is depicted in Figure 3, *top, A*. A follow-up chest radiograph, obtained 24 h after the institution of KT and P, demonstrates partial resolution of atelectasis (Fig 3, *bottom, B*). Those in the test group who showed complete resolution of atelectasis took a mean of 3 days for resolution. Thus, if complete resolution was to occur, it was likely to occur relatively early in the course of treatment. A plausible explanation may be that most of these patients had a mucus plug in the central airways, which, with positioning and P, could be suctioned out or dislodged. Indeed, four of five patients in the test group and the one patient in the control group with entire lung atelectasis showed a bronchus cutoff sign. For the patients in the KT and P arm with lobar atelectasis, complete resolution was seen in six patients within a mean duration of 4.8 days. In this same subgroup, partial resolution occurred in one patient.

Patients receiving KT and P who developed recurrence of atelectasis during the study period tended to be older (mean age, 72.6 years), had a higher Glasgow Coma Scale (mean value, 13), demonstrated atelectasis for a longer duration of time before enrollment (mean, 8.3 days), and had excessive respiratory secretions from underlying pulmonary disease (COPD and pneumonia). In contrast to patients with entire lung atelectasis or segmental

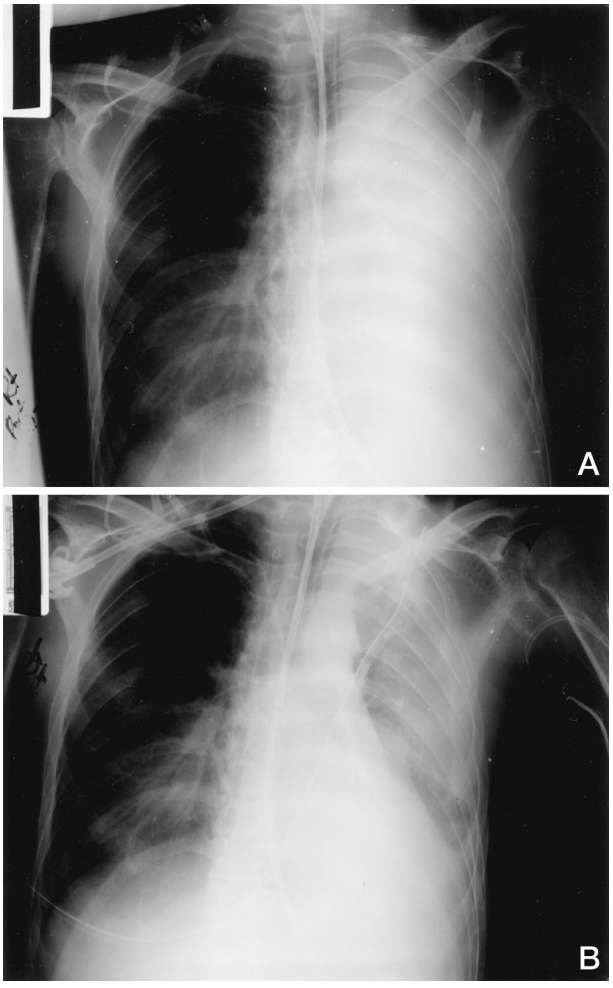

FIGURE 3. *Top, A:* left lung atelectasis in a patient in the test group on day 0. *Bottom, B:* repeated chest radiograph of the same patient 24 h after administration of KT and P. The radiograph demonstrates partial resolution of atelectasis.

atelectasis, all three patients in the test group who failed to show significant resolution had lobar atelectasis. Two of the three patients whose conditions failed to improve were not intubated.

The patients in the test group showed a very significant improvement in their oxygenation as compared with the control group. The index of oxygenation chosen was the PaO_2/FIO_2 ratio. This index is simple to calculate, takes inspired oxygenation in consideration, and remains accurate, unless there are large fluctuations in the $PaCO_2$. Most of the patients had relatively small variations in the $PaCO_2$ in our series. The PaO_2/FIO_2 on day 0 was not statistically different between the test and control groups. An improvement in the PaO_2/FIO_2 was noted as early as day 3 in the test group and was sustained until day 14. A significant improvement in the PaO_2/FIO_2 ratio was seen in the test group at each of the follow-up points (days 3, 7, and 14) when compared with the baseline PaO_2/FIO_2 ratios. The values for P/F ratio for control and test respectively were as follows: day 3: 144.6 ± 42.6 vs 257.8 ± 103.4; day 7: 101 ± 21.9 vs 311.1 ± 93.0; and day 14: 112 ± 21 vs 318 ± 100. In addition, at each of the time points indicated above, the P/F ratio was significantly higher for the test group as compared with the control group. These data conform to the existing data showing a significant improvement in the oxygenation indexes with KT.[54–56] The greatest improvement in the oxygenation index was observed at about 24 h after radiographic partial or complete resolution of atelectasis. In a study by Bein et al,[57] 10 patients with severe, acute respiratory failure and mean PaO_2/FIO_2 of 169 ± 7 mm Hg were placed on a rotational bed (RotoRest) and studied. The ventilation/perfusion ratio was determined using multiple inert gas techniques. It was concluded that KT reduces ventilation/perfusion mismatch in patients with acute lung injury.[57] In another prospective study by Hörmann and colleagues,[58] 12 patients with severe ARDS were rotated by 62° on each side using KT. The FIO_2 requirement decreased from 0.8 at baseline to 0.35 on day 6 of the study. Concomitantly, the PaO_2 increased from a baseline of 99 mm Hg to 110 mm Hg. In a study done in the pediatric population, Jaimovich et al[59] studied five children with acute respiratory failure requiring mechanical ventilation and $FIO_2 \geq 0.5$. Such patients were assigned to continuous KT (up to 40° angle on each side). They demonstrated an improvement in PaO_2 that allowed them to reduce to FIO_2 to < 0.5 within 40 h of hospital admission. Murai and Grant,[60] utilizing an oscillating bed, found a significant reduction in the duration of oxygen supplementation in newborn infants with different respiratory disorders.

It was not possible to do a cost analysis on our patient population. Excluding one outlier, our patients had an average length of stay in the hospital of 47.1 ± 44.9 days in the test group and 18.7 ± 8.4 days in the control group. These patients had multiple medical problems and thus had protracted hospital stays. Nonmedical issues, such as delay in placement of patients in nursing homes, also influenced the length of stay of four of the test patients. Therefore, addressing an acute problem that developed in this patient population for up to 2 weeks was not likely to bring about significant cost savings.

Bronchoscopy for atelectasis is resorted to in our hospital if there is failure of resolution of atelectasis in 2 to 3 days with conservative measures (suctioning, physical therapy including manual P, and inhaled bronchodilators) or the development of hypoxemia from the atelectasis necessitating high FIO_2 concentrations. The need for bronchoscopy was determined by one of the pulmonologists who followed

these broad indications. However, he was aware of the protocol. This may have introduced a bias in his decisions. In our study, none of the 17 test patients underwent a bronchoscopy, in contrast to 3 of 7 control patients who required a bronchoscopy. Bronchoscopy was considered in the three test patients whose atelectasis failed to resolve with KT and P. However, for the reasons outlined earlier, it was deferred. Assuming that a bronchoscopy is done in all patients with nonresolving atelectasis, it can be projected from our data that in 100 patients with atelectasis, roughly 68 bronchoscopies may be avoided by utilizing KT and P.

One of the observations made during our study was that manual repositioning and physical therapy were not carried out in the non-ICU areas every 2 h as ordered. Nonadherence to physicians' orders for frequent treatment or therapeutic interventions has been commonly reported.[61] Therefore, it is possible that the rate of resolution of atelectasis may have been higher in the VW if strict compliance with the protocol was enforced. However, we were more interested in finding out what happens in a real-life situation.

In summary, we report beneficial effects on the resolution of atelectasis, improvement of oxygenation, and reduced need for bronchoscopy in critically ill patients. We recommend using KT and P therapy in comatose patients without severe hypoxemia. It may also be considered a noninvasive treatment modality in patients with atelectasis and severe hypoxemia who refuse a bronchoscopy or will not allow intubation during a bronchoscopy if a complication were to arise.

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Effect of Combined Kinetic Therapy and Percussion Therapy on the Resolution of Atelectasis in Critically Ill Patients

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