The use of positioning therapy has been advocated for the management of respiratory conditions in critically ill patients.1-4 This review is focused on a method of positioning patients that uses a programmable bed that turns on its longitudinal axes, intermittently or continuously, with the aim of preventing and/or treating respiratory complications in critically ill patients. The generic term commonly used for this therapy is continuous lateral rotation. If the degree of turn is 40º or greater to one side (80º total arc), the treatment may be referred to as Kinetic Therapy. Kinetic Therapy is a trademarked term and has been supported by the Centers for Disease Control and Prevention as a measurable method of turning.

Background
Immobility is associated with complications involving many body systems.

Objective
To review the effect of rotational therapy (use of therapeutic surfaces that turn on their longitudinal axes) on prevention and/or treatment of respiratory complications in critically ill patients.

Methods
Published articles evaluating prophylaxis and/or treatment were reviewed. Prospective randomized controlled trials were assessed for quality and included in meta-analyses.

Results
A literature search yielded 15 nonrandomized, uncontrolled, or retrospective studies. Twenty prospective randomized controlled trials on rotational therapy were published between 1987 and 2004. Various types of beds were studied, but few details on the rotational parameters were reported. The usual control was manual turning of patients by nurses every 2 hours. One animal investigation and 12 clinical trials addressed the effectiveness of rotational therapy in preventing respiratory complications. Significant benefits were reported in the animal study and 4 of the trials. Significant benefits to patients were reported in 2 of another 4 studies focused on treatment of established complications. Researchers have examined the effects of rotational therapy on mucus transport, intrapulmonary shunt, hemodynamic effects, urine output, and intracranial pressure. Little convincing evidence is available, however, on the most effective rotation parameters (e.g., degree, pause time, and amount of time per day). Meta-analysis suggests that rotational therapy decreases the incidence of pneumonia but has no effect on duration of mechanical ventilation, number of days in intensive care, or hospital mortality.

Conclusions
Rotational therapy may be useful for preventing and treating respiratory complications in selected critically ill patients receiving mechanical ventilation. (American Journal of Critical Care. 2007;16:50-62)
patients. The terms continuous lateral rotation and Kinetic Therapy are often loosely used in a similar context. The rotation of the patient on a bed is hypothesized to improve drainage of secretions within the lung and lower airways, to increase functional residual capacity by providing an increased critical opening pressure to the independent lung, and to reduce the risk of venous thrombosis and associated pulmonary embolism.5

It has long been recognized that immobility is associated with complications involving many body systems6-13 (Table 1). Rotational therapy may be effective in treating and preventing many of these complications; however, this review is limited to a discussion of the role of rotational therapy with respect to respiratory complications.

Respiratory complications experienced by patients in an intensive care unit (ICU) include ventilator-associated pneumonia (VAP), atelectasis, and acute respiratory distress syndrome (ARDS). Patients with VAP may spend longer in the ICU and have a higher mortality rate than patients without VAP.14 Guidelines for the prevention of pneumonia advocate a range of interventions that may be organizational, pharmacological, or physical.15-17 ARDS is associated with high morbidity and mortality.18 Current best practice is focused on ventilatory strategies to protect the lung.19 Rotation of patients on therapeutic beds is one of the interventions that may be useful in preventing and treating these respiratory complications.

Description of Beds

Use of special beds to turn critically ill patients has been a recognized intervention for many years. A study20 describing the RotoRest bed was published in 1967. Other early examples include the CircElectric bed, which could even turn a patient prone. Both beds were used as methods of mobilization for patients with spinal cord injuries, but rotation was often limited by those patients’ lack of vascular tone and compensatory response to gravitational shifts.21

Several manufacturers market a variety of therapeutic surfaces that are based either on a rotating rigid platform or an air-filled mattress. These beds vary in the degree and frequency of rotation, the method of rotation, and the inclusion of other therapies such as low air loss, pulsation, percussion, and vibration (Table 2). The RotoRest bed is based on a rigid platform and is indicated for patients with spinal injuries for which alignment must be maintained. For other patients, the RotoRest bed may prove to be cumbersome, and it may be uncomfortable for patients who are conscious. Air-filled mattresses were developed primarily for the prevention of pressure ulcers but now have been modified to provide automated turning.

In 2001, in an observational study22 of clinical practice during a single day in Canadian ICUs, researchers found that 3.1% of patients were on a rotational bed.

Methods

A literature search was conducted by using the PubMed database for articles published between 1966 and 2004. Relevant search terms included patient position, rotational and kinetic therapy, therapeutic bed and/or mattress, and the names of specific beds. Several manufacturers were contacted and invited to supply references. Reference lists of papers were scrutinized for details of other relevant publications.

All reports of studies in which rotational therapy was used to treat and/or prevent respiratory complications

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### Table 1 Hazards of immobility

<table>
<thead>
<tr>
<th>System</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>Pneumonia, atelectasis, pulmonary embolism</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Postural hypotension, cardiac muscle atrophy, deep vein thrombosis</td>
</tr>
<tr>
<td>Skin</td>
<td>Pressure ulcers</td>
</tr>
<tr>
<td>Renal</td>
<td>Calculi, nephritis</td>
</tr>
<tr>
<td>Hematological</td>
<td>Anemia</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Constipation and fecal impaction</td>
</tr>
<tr>
<td>Metabolic</td>
<td>Glucose intolerance, negative nitrogen balance</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>Osteoporosis, muscle atrophy, contractures</td>
</tr>
<tr>
<td>Neurological</td>
<td>Depression, psychosis</td>
</tr>
</tbody>
</table>

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### CE

Notice to CE enrollees:
A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Discuss respiratory complications associated with critically ill patients.
2. Discuss articles reviewed that investigated the use of rotational therapy for the prevention of respiratory complications.
3. Discuss findings of the meta-analysis on rotational therapy.

To read this article and take the CE test online, visit www.ajcconline.org and click “CE Articles in This Issue.”
and a 32% reduction in the duration of a patient’s cant decrease in the incidence of postoperative fever 24 hours after cardiac surgery resulted in a signifi-
standard of care.23 Manual turning every 2 hours for patient every 2 hours has long been an established usually includes regular repositioning. Turning of the 

dev (mean 10.6 turns).

were reviewed. From among these articles we selected those that reported a prospective randomized study. Data on severity of illness and basic information about patients, interventions, and outcomes evaluated in the studies or reviews were extracted. Quality was assessed by using guidelines published by the Scottish Intercolligate Guidelines Network (http://www .sign.ac.uk). A meta-analysis was performed on articles that fulfilled basic quality standards for which suf cient outcome data were available. Review Manager software (RevMan Version 4.2 for Windows; The Nordic Cochrane Centre, Copenhagen, Denmark) was used for these meta-analyses.

Results

Routine nursing management of ICU patients usually includes regular repositioning. Turning of the patient every 2 hours has long been an established standard of care.13 Manual turning every 2 hours for 24 hours after cardiac surgery resulted in a signi cant decrease in the incidence of postoperative fever and a 32% reduction in the duration of a patient’s stay in a surgical ICU.24 Schallom et al25 reported hourly observations of the positions of 284 critically ill tube-fed patients for 3 days between 8 AM and midnight. Patients in whom pneumonia developed were turned signi cantly less often (mean 8.7 turns) than were patients in whom pneumonia did not develop (mean 10.6 turns).

<table>
<thead>
<tr>
<th>Name</th>
<th>Rotation</th>
<th>Percussion</th>
<th>Vibration/pulsation</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCI Triadyne</td>
<td>45º</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Provena</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KCI RotoRest</td>
<td>62º</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>KCI Therapulse</td>
<td>30º</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>KCI BariAir</td>
<td>25º</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hill-Rom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respistar (V/QUE)</td>
<td>40º-45º</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hill-Rom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respicaire (Effica)</td>
<td>40º-45º</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Hill-Rom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TotalCare SpO₂RT</td>
<td>40º-45º</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Huntleigh ACER</td>
<td>40º</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*Other characteristics not detailed include the method of achieving rotation, the timing of the rotation, the capability of the bed to rest in certain positions and/or assume a chair position, and the material used for the mattress cover. The beds vary in the safe maximum weight they will support and whether or not they have safety features such as interlocking side rails. The details, when available, are those provided by the companies that manufacture the beds and have not been independently verified.

Nonrandomized, Uncontrolled, or Retrospective Studies

These studies include medical ICU patients,26 a mix of critically ill patients,27 and patients with spinal cord injuries28-30 and trauma.31-33 Results of some of these studies suggest that rotational therapy prevents respiratory complications28-32 or is useful in their treatment.26,31,33,34 In a retrospective study, Takiguchi et al35 compared 2 types of bed, the Restcue (Support Systems International, Inc, Charleston, SC) and the Biodyne (Kinetic Concepts, Inc [KCI], San Antonio, Tex), and 2 different protocols, one aimed at preventing respiratory complications (with the Restcue) and the other targeted at treating patients with established complications (with the Biodyne). Both beds are based on air-inflated rotational mattresses, though the beds di er in their design and the mechanics of rotation. The preventive strategy was signi cantly more successful than was the strategy aimed at treating patients with established complications.

Reviews

Sahn35 reviewed the results of 4 prospective randomized studies36-39 and 2 retrospective analyses.28,29 Sahn tentatively concluded that the early use of rotational therapy in comatose or immobile patients decreased the incidence of infection of the lower respiratory tract, including pneumonia, during the rst 7 to 14 days of intensive care. In that article,35 Sahn suggested that a large randomized prospective trial was necessary. Choi and Nelson40 performed a meta-analysis on the studies36-39 reviewed by Sahn and 2 unpublished presentations, one by Narayan et al41 and the other by Nelson.42 Nelson and Choi43 later published an article that appears to present the results of that meta-analysis. All the studies looked at critically ill adult patients randomized to the RotoRest or to conventional surfaces with manual turning by nursing staff. The analysis showed that the incidence of pneumonia, atelectasis, number of hours intubated, and length of ICU stay were signi cantly reduced in the treatment group. No signi cant di erence was found in other outcomes, including hospital stay and mortality. Reviews published in 199344 and 199445 summarized the same 4 main studies.36-39

The Centers for Disease Control and Prevention (CDC) and the Healthcare Infection Control Practices Advisory Committee have published guidelines for the prevention of healthcare-associated pneumonia.15

Referencing one review46 and 6 articles about rotational beds,7,39,47-49 the guidelines describe the use of rotating beds as an “unresolved issue.” The conclusion was that “no recommendation can be made for the routine use of turning or rotational therapy, either by
that “clinicians [should] consider the use of kinetic beds.”

In an excellent article on the prevention of VAP, Dodek et al.7 reviewed the strategies of having the patient semirecumbent, positioning the patient prone, and using rotational bed therapy. A treatment was recommended “if there were no reservations about endorsing an intervention” and should be considered “if the evidence supported an intervention but there were minor uncertainties about the benefits, harms or costs.” It was concluded that no recommendation could be made for the prone position and that the semirecumbent position, with a goal of 45°, should be recommended in patients without contraindications. The evidence on rotational bed therapy was from 7 level 2 trials37,39,47,49,51 and a level 3 trial.48 The conclusion was that “clinicians [should] consider the use of kinetic beds.”

Meta-analysis suggests that rotational therapy decreases the incidence of pneumonia but has no effect on duration of mechanical ventilation, number of days in intensive care, or hospital mortality.

Prospective Randomized Controlled Trials

A literature search for the years 1987 through 2004 yielded 20 reports36,39,43,47,61 of prospective randomized controlled trials in which treatment on a turning bed was compared with a control. A variety of beds were used, most commonly the RotoRest. Details are sparse on the intended or achieved therapeutic parameters such as degree of rotation, number of rotations per hour, and duration of rotation. None of the studies showed any statistically significant differences in mortality between patients treated with rotation and control subjects.

One study45 was in neonates who were receiving mechanical ventilator support at 24 hours of age. They all weighed more than 1500 g and were predicted to need at least 24 additional hours of mechanical ventilation. Infants were randomized to a control group, whose members were turned from one side to the other every 12 hours, or a treatment group, whose members were continuously rotated to 40° on each side every 3.5 minutes on a P-30 Pediatric Kinetic Treatment Table (KCI). The study was started when the infant was 24 hours old and completed after extubation and when supplemental oxygen was no longer required. The only significant difference found was that the treatment group required oxygen for a shorter time than did the control group.

Staudinger et al.40 compared gas exchange and hemodynamics in 26 patients with nontraumatic ARDS who were receiving mechanical ventilation and were either placed prone or continuously rotated. Respiratory measures did not differ significantly between the prone group and the rotated group during the first 72 hours of treatment.

Davis et al.39 used patients as their own controls to assess cardiorespiratory variables and sputum production. The patients had ARDS, were in hemodynamically stable condition, and did not have severe injuries of the head or spine. Patients were randomized to have 4 turning and secretion management regimens in a random sequence during a 24-hour period. These regimens were as follows: (1) manual turning every 2 hours from one lateral side to the other, (2) turning every 2 hours with 15 minutes of manual percussion and postural drainage, (3) continuous rotation of the bed with a 2-minute pause in the lateral position, (4) continuous rotation of the bed with a 2-minute pause in the lateral position and 15 minutes of percussion provided by the bed every 2 hours, 60 to 90 minutes into the every-2-hour turning regimen. The only statistically significant differences were an increased volume of sputum in patients receiving the 2 treatments involving bed rotation (regimens 3 and 4).

The study in baboons undertaken by Anzueto et al.56 provides some of the most objective evidence for the efficacy of rotational therapy. The animals were sedated, paralyzed, and supported via mechanical ventilation for 11 days with a tidal volume of 12 mL/kg. Peak inspiratory pressures at day 11 were 28 cm H2O in controls compared with 20 cm H2O in the treatment group. In addition, although none of the animals receiving rotational therapy showed any abnormalities on radiological images, 6 of the 7 control animals had patchy atelectasis apparent on a chest radiograph. The ratio between PaO2 and the fraction of inspired oxygen (PaO2/FiO2) at day 11 was lower in the controls. The percentage of neutrophils obtained by bronchoalveolar lavage at days 7 and 11 was much higher in the controls. A quantitative measure of consolidation was higher in the controls (11%) than in the animals that were rotated (<0.6%).

This leaves 12 prospective randomized studies36,39,41,47,51,53,58 focused on the prevention of respiratory complications and 4 studies2,24,37,64 focused on the treatment of established complications (Tables 3 and 4). Four of the papers9,47,49 reported significant benefits to patients.
in the prevention of respiratory complications. Among the other studies, Demarest et al\(^\text{19}\) reported a lower incidence of atelectasis and pneumonia in the sub-group of patients who had normal findings on chest radiographs at the start of the study. Gentilello et al\(^\text{37}\) combined atelectasis and pneumonia into a single group called major pulmonary complications and found a lower incidence in the rotational therapy group. Kelley et al\(^\text{36}\) found that rotational therapy decreased the incidence of infection, pneumonia, sepsis, and urinary tract infections, and reduced the likelihood of multiple infections. In a large, well-conducted study by MacIntyre et al\(^\text{47}\), the only significant finding was a lower incidence of urinary tract infections (11% vs 27%). Summer et al\(^\text{18}\) found that rotational therapy was associated with fewer ventilator days for patients with chronic obstructive airways disease and shortened the ICU stay for patients with sepsis and chronic obstructive airways disease.\(^\text{8}\)

Shapiro and Keegan\(^\text{54}\) investigated the treatment of respiratory complications in patients with pulmonary contusions. In that study,\(^\text{54}\) outcomes did not differ between the control group and the study group. However, the groups were poorly matched because control patients had injuries that were less severe, with a mean injury severity score of 29.0 compared with 45.1 for the treatment group. McLean\(^\text{52}\) looked at 35 patients with trauma and a PaO\(_2/\text{FIO}_{2}\) less than 225 mm Hg and an injury severity score greater than 16. In that prospective, prophylactic study,\(^\text{52}\) the end point was an increasing impact on lung function, defined as an increased ventilation requirement. McLean concluded that “aggressive rotational therapy has a positive impact on lung function.” Reports of 2 other studies\(^\text{57,61}\) showed that rotational therapy was beneficial in the treatment of patients with respiratory complications.

The study by Ahrens et al\(^\text{61}\) is by far the largest, with 234 subjects, and is the most recent. Because rotational

### Table 3  Summary of randomized prospective studies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Type of patients</th>
<th>Intervention</th>
<th>Number of patients</th>
<th>Type of bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kelley et al(^\text{16})</td>
<td>1987</td>
<td>Stroke; drowsy, stuporous, light coma</td>
<td>Prophylaxis</td>
<td>43</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Gentilello et al(^\text{17})</td>
<td>1988</td>
<td>Trauma</td>
<td>Prophylaxis</td>
<td>65</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Summer et al(^\text{18})</td>
<td>1989</td>
<td>Medical ICU</td>
<td>Prophylaxis</td>
<td>83</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Demarest et al(^\text{19})</td>
<td>1989</td>
<td>Trauma unit</td>
<td>Prophylaxis</td>
<td>30</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Fink et al(^\text{20})</td>
<td>1990</td>
<td>Surgical ICU, nonpenetrating trauma</td>
<td>Prophylaxis</td>
<td>99</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Clemer et al(^\text{21})</td>
<td>1990</td>
<td>Head injury</td>
<td>Prophylaxis</td>
<td>49</td>
<td>Kinetic Treatment Table (KCI)</td>
</tr>
<tr>
<td>Nelson and Choi(^\text{33})</td>
<td>1992</td>
<td>Surgical ICU, trauma</td>
<td>Prophylaxis</td>
<td>100</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>Shapiro and Keegan(^\text{44})</td>
<td>1992</td>
<td>Surgical ICU</td>
<td>Treatment</td>
<td>32</td>
<td>RotoRest (KCI)</td>
</tr>
<tr>
<td>deBoisblanc et al(^\text{47})</td>
<td>1993</td>
<td>Medical ICU</td>
<td>Prophylaxis</td>
<td>124</td>
<td>Biodyne (KCI)</td>
</tr>
<tr>
<td>Whiteman et al(^\text{48})</td>
<td>1995</td>
<td>Liver transplant ICU</td>
<td>Prophylaxis</td>
<td>69</td>
<td>Restrue Dynamic Air Therapy Bed (Support Systems International)</td>
</tr>
<tr>
<td>Traver et al(^\text{51})</td>
<td>1995</td>
<td>ICU admission and in study for &gt;48 hours</td>
<td>Prophylaxis</td>
<td>103</td>
<td>Biodyne (KCI)</td>
</tr>
<tr>
<td>Raoof et al(^\text{57})</td>
<td>1999</td>
<td>Medical ICU or ventilator ward</td>
<td>Treatment</td>
<td>24</td>
<td>Triadyne (KCI)</td>
</tr>
<tr>
<td>MacIntyre et al(^\text{48})</td>
<td>1999</td>
<td>ICU</td>
<td>Prophylaxis</td>
<td>104</td>
<td>Restrue Bed (Support Systems International)</td>
</tr>
<tr>
<td>McLean(^\text{52})</td>
<td>2001</td>
<td>Trauma (ISS $\geq$16) and PaO(<em>2/\text{FIO}</em>{2}) &lt;225 mm Hg</td>
<td>Treatment</td>
<td>35</td>
<td>Triadyne (KCI)</td>
</tr>
<tr>
<td>Kirschenbaum et al(^\text{60})</td>
<td>2002</td>
<td>Long-term mechanical ventilation</td>
<td>Prophylaxis</td>
<td>37</td>
<td>Effica (Hill-Rom)</td>
</tr>
<tr>
<td>Ahrens et al(^\text{61})</td>
<td>2004</td>
<td>Multicenter ICUs</td>
<td>Treatment</td>
<td>234</td>
<td>Triadyne (KCI)</td>
</tr>
</tbody>
</table>

Abbreviations: FIO\(_2\), fraction of inspired oxygen; GCS, Glasgow Coma Scale; ICU, intensive care unit; ISS, injury severity score.
therapy may not be tolerated in conscious patients, only those with a score of less than 11 on the Glasgow Coma Scale were eligible. Thus the results from that study may not be relevant to patients who are sedated and receiving mechanical ventilation. The main respiratory outcomes, VAP and lobar atelectasis, were both significantly less common in the group given rotational therapy. However, no information was provided on the incidence of pneumonia or atelectasis upon entry to the study or when these complications occurred. The control patients received mechanical ventilator support for a mean of 10.1 days and were in the ICU for a mean of 13.6 days. The figures for the intervention group were 10.8 days of mechanical ventilation and 13.5 days in the ICU. Mortality was 42% in both groups.

Meta-analyses were performed when suitable data were available on the incidence of pneumonia, the number of ICU ventilator days (mean and SD), number of days in the ICU (mean and SD), and hospital mortality. Most of the articles did not provide enough details for us to determine whether control groups had regular turning and whether the intentions of the intervention were achieved (Table 4). Because of the nature of the intervention, the studies were not double blinded. Methods of randomization were not always stated, and in some studies patients were randomized to groups by month or order of admission. One study had a mismatch between control and treatment groups; that study was not included in the analysis. Another article provided details on the incidence of pneumonia in the study but did not define the diagnosis; that article was excluded from the pneumonia meta-analysis. The meta-analyses showed no difference between control and intervention groups in days of mechanical ventilation, days in the ICU, or mortality (Figures 1-3). The analysis did suggest a benefit from rotational therapy with respect to the incidence of pneumonia (Figure 4).

<table>
<thead>
<tr>
<th>Study entry</th>
<th>Rotation or study end</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 24 hours of admission</td>
<td>Bed confinement ended</td>
</tr>
<tr>
<td>Within 24 hours of admission</td>
<td>Out of bed, died or discharged</td>
</tr>
<tr>
<td>Within 24 hours of ICU admission</td>
<td>Patient request or extubation</td>
</tr>
<tr>
<td>Normal findings on at least 50% of fields on chest radiograph</td>
<td>7 days</td>
</tr>
<tr>
<td>Within 24 hours of admission</td>
<td>Discharge from ICU</td>
</tr>
<tr>
<td>24 to 48 hours of ICU admission</td>
<td>Weaned from ventilator and transferred, or after 10 days, or death</td>
</tr>
<tr>
<td>Within 16 hours of admission</td>
<td>Hospital discharge or death</td>
</tr>
<tr>
<td>Blunt chest trauma and hypoxemic</td>
<td>Removed from bed because of instability, need to increase mobility, or patient's request</td>
</tr>
<tr>
<td>Within 24 hours of admission</td>
<td>5 days</td>
</tr>
<tr>
<td>Mechanical ventilator support if GCS score ≤11, 24 hours after admission</td>
<td>Able to be out of bed for 3 days, or unable to rotate for &gt;10 hours/day for 3 days, or transferred from ICU</td>
</tr>
<tr>
<td>After 2 days in ICU</td>
<td>Out of bed &gt;3 hours day, or transferred to different bed, or rotating less than 12 hours/day or transferred or died</td>
</tr>
<tr>
<td>Respiratory failure and atelectasis</td>
<td>Transfer or up to 2 weeks</td>
</tr>
<tr>
<td>Supported with mechanical ventilation with no clinical evidence or findings on chest radiograph indicative of respiratory infection</td>
<td>Development of lower respiratory tract inflammatory syndrome (see article for definition)</td>
</tr>
<tr>
<td>Within 24 hours of injury</td>
<td>Not stated</td>
</tr>
<tr>
<td>Admitted to ICU</td>
<td>Discharge from ICU</td>
</tr>
<tr>
<td>PaO₂:FIO₂ &lt;250, GCS score &lt;11, ventilated</td>
<td>Intolerance</td>
</tr>
</tbody>
</table>

www.ajcconline.org
Dolovich et al62 used a radiolabeled aerosol to examine the effect of rotation on mucus transport in 13 patients receiving mechanical ventilation while on Biodyne beds. The intervention consisted of 90 minutes of 30º rotation to both sides preceded and followed by a control period. Although clearance of mucus may have differed between the left and right lungs, rotation to this angle for this brief period did not affect overall clearance.

In another study63 of 10 deeply sedated patients with acute lung injury, ventilation-perfusion ratios were measured after 20 minutes of rotational therapy and compared with the ratios that had been obtained with the patient resting supine. Intrapulmonary shunt was significantly decreased and PaO₂/FIO₂ improved during rotational therapy. The improvement in PaO₂/FIO₂ was seen in patients with “mild to moderate” lung injury but not in patients with late or progressive ARDS.

The hemodynamic effects of lateral rotation were investigated in 12 patients with severe respiratory failure who were receiving infusions of inotropic agents.64 They were positioned supine, left dependent, and right dependent, pausing for 15 minutes in each position. Cardiac index, intrathoracic blood volume, and right ventricular end-diastolic volume increased significantly.
in the left-dependent position compared with supine. In the right position, arterial pressure and right ventricular end-diastolic volume decreased. Other investigators have failed to find a significant cardiovascular effect associated with steep lateral positioning.

**Complications and Other Issues**

Complications associated with rotational therapy include disconnection of intravascular catheters, intolerance of patients to the rotation, adverse effects on intracranial pressure, and arrhythmias. In a study of 10 patients with head injuries, Gonzalez-Arias et al. found that rotational therapy did not have any significant effect on intracranial pressure.

**Cost Analysis**

Few relevant data on the cost of rotational therapy are available. Choi and Nelson stated that the charges incurred in the ICU (with kinetic therapy) were no different than the charges for control patients. Ahrens et al. found that ICU costs were lower in patients who were on the rotational therapy bed ($81 740) than in patients who were not ($84 958), but this difference was not statistically significant.
Implementing Rotational Therapy

Several examples of guidelines for the use of rotational therapy are available. One set of guidelines suggests that rotation should be 40° or greater for at least 18 hours a day.69 Appropriate patients included those with a PaO2/FIO2 less than 300 mm Hg, an FIO2 greater than 0.5, a positive end-expiratory pressure greater than 10 cm H2O, those at risk for development of ARDS, or those with pneumonia, atelectasis, or infiltrates visible on radiograph. Apart from those with spinal cord injury, agitated patients and patients not receiving mechanical ventilation were unsuitable because of their inability to tolerate aggressive rotational therapy.

Discussion

From a physiological perspective, rotational therapy should have a beneficial effect on the prevention and treatment of respiratory complications in critically ill patients. Authors of several case reports and reports of uncontrolled studies have claimed that positioning therapy has beneficial effects on pulmonary function.
### Figure 3: Meta-analysis of hospital mortality: rotation versus control

<table>
<thead>
<tr>
<th>Study or subcategory</th>
<th>Proportion of patients who died</th>
<th>Odds ratio (fixed)</th>
<th>Weight, %</th>
<th>Odds ratio (fixed)</th>
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<tr>
<td>Ahrens et al[61]</td>
<td>41/97</td>
<td>27.24</td>
<td>100.00</td>
<td>1.00 (0.59, 1.69)</td>
</tr>
<tr>
<td>Clemmer et al[53]</td>
<td>3/23</td>
<td>4.01</td>
<td>0.63 (0.13, 2.99)</td>
<td></td>
</tr>
<tr>
<td>Demarest et al[50]</td>
<td>8/16</td>
<td>3.14</td>
<td>1.33 (0.32, 5.64)</td>
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<tr>
<td>Fink et al[39]</td>
<td>10/51</td>
<td>6.50</td>
<td>1.22 (0.44, 3.40)</td>
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<tr>
<td>Gentilello et al[37]</td>
<td>7/27</td>
<td>3.02</td>
<td>2.31 (0.65, 8.27)</td>
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</tr>
<tr>
<td>Kelley et al[36]</td>
<td>6/18</td>
<td>2.74</td>
<td>2.00 (0.50, 8.00)</td>
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<tr>
<td>MacIntyre et al[58]</td>
<td>15/53</td>
<td>10.04</td>
<td>1.04 (0.44, 2.46)</td>
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<tr>
<td>McLean[52]</td>
<td>0/15</td>
<td>6.99</td>
<td>0.05 (0.00, 0.90)</td>
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<tr>
<td>Nelson and Choi[43]</td>
<td>4/40</td>
<td>7.06</td>
<td>0.56 (0.16, 1.91)</td>
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<tr>
<td>Summer et al[40]</td>
<td>10/41</td>
<td>8.06</td>
<td>0.91 (0.34, 2.45)</td>
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<tr>
<td>Traver et al[51]</td>
<td>12/44</td>
<td>11.58</td>
<td>0.79 (0.33, 1.86)</td>
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</tr>
<tr>
<td>deBoisblanc et al[47]</td>
<td>27/69</td>
<td>9.62</td>
<td>1.70 (0.78, 3.71)</td>
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<tr>
<td>Total (95% CI)</td>
<td>143/494</td>
<td>100.00</td>
<td>1.02 (0.77, 1.34)</td>
<td></td>
</tr>
</tbody>
</table>

Test for heterogeneity: $\chi^2 = 10.24$, df = 11 (P = .51), $\hat{\eta}^2 = 0$
Test for overall effect: $Z = 0.13$ (P = .90)

### Figure 4: Meta-analysis of pneumonia (with subgroups of prophylaxis and treatment for respiratory dysfunction): rotation versus control

<table>
<thead>
<tr>
<th>Study or subcategory</th>
<th>Proportion of patients with pneumonia</th>
<th>Odds ratio (fixed)</th>
<th>Weight, %</th>
<th>Odds ratio (fixed)</th>
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<tr>
<td>Pneumonia and prophylaxis</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demarest et al[50]</td>
<td>1/16</td>
<td>3.45</td>
<td>0.17 (0.02, 1.72)</td>
<td></td>
</tr>
<tr>
<td>Fink et al[53]</td>
<td>7/51</td>
<td>14.55</td>
<td>0.24 (0.09, 0.65)</td>
<td></td>
</tr>
<tr>
<td>Gentilello et al[57]</td>
<td>5/27</td>
<td>7.58</td>
<td>0.44 (0.13, 1.42)</td>
<td></td>
</tr>
<tr>
<td>Kelley et al[56]</td>
<td>5/18</td>
<td>6.77</td>
<td>0.36 (0.10, 1.30)</td>
<td></td>
</tr>
<tr>
<td>Kirschenbaum et al[56]</td>
<td>3/17</td>
<td>6.52</td>
<td>0.21 (0.05, 0.98)</td>
<td></td>
</tr>
<tr>
<td>Summer et al[57]</td>
<td>4/41</td>
<td>5.38</td>
<td>0.54 (0.15, 2.01)</td>
<td></td>
</tr>
<tr>
<td>Traver et al[51]</td>
<td>8/44</td>
<td>10.24</td>
<td>0.55 (0.21, 1.42)</td>
<td></td>
</tr>
<tr>
<td>Whiteman et al[56]</td>
<td>10/33</td>
<td>8.04</td>
<td>0.68 (0.25, 1.86)</td>
<td></td>
</tr>
<tr>
<td>deBoisblanc et al[56]</td>
<td>6/69</td>
<td>9.95</td>
<td>0.35 (0.12, 1.01)</td>
<td></td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>49/316</td>
<td>72.49</td>
<td>0.40 (0.27, 0.58)</td>
<td></td>
</tr>
</tbody>
</table>

Test for heterogeneity: $\chi^2 = 4.03$, df = 8 (P = .85), $\hat{\eta}^2 = 0$
Test for overall effect: $Z = 4.68$ (P < .001)

<table>
<thead>
<tr>
<th>Pneumonia treatment</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahrens et al[61]</td>
<td>14/97</td>
<td>27.51</td>
<td>0.34 (0.18, 0.67)</td>
<td></td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td>14/97</td>
<td>27.51</td>
<td>0.34 (0.18, 0.67)</td>
<td></td>
</tr>
</tbody>
</table>

Test for heterogeneity: not applicable
Test for overall effect: $Z = 3.12$ (P = .002)

Total (95% CI) 63/413 153/470 100.00 0.38 (0.27, 0.53)

Test for heterogeneity: $\chi^2 = 4.16$, df = 9 (P = .90), $\hat{\eta}^2 = 0$
Test for overall effect: $Z = 5.63$ (P < .001)
Although a number of randomized prospective controlled trials have been conducted, most of them had significant shortcomings.

The usual control for the randomized studies cited in this review was manual turning of patients every 2 hours. This control may not be reflective of actual practice. In the study by Schallom et al., although 23 turns were possible for each patient, the mean actual number of turns was 9.6. In a study in which 74 ICU patients were observed every 15 minutes for a mean of 7.7 hours, Krishnagopalan et al. found that only 2 patients (2.7%) had a change in body position every 2 hours, and 28% of all patients were supine throughout all observation periods.

Little convincing evidence is available about which rotation parameters are the most effective. The effectiveness of rotational therapy may not depend entirely on the angle of rotation, but also on the frequency of rotation, the pause time, and the use of adjuncts such as vibration, percussion, or pulsation. The duration of rotation also may be important, as well as the underlying disease, the size and weight of the patient, and the use of physiotherapy or other respiratory interventions.

Little evidence is available on the most effective rotation parameters.

Berkemeier et al. presented an abstract of a study performed in 19 patients with ARDS who were randomized to 1 of 4 groups. One group was not rotated and the other groups were rotated for 24 hours to a maximum of 20°, 40°, or 60°. In patients rotated to 60°, cardiac output had increased and intrapulmonary shunt had decreased at 24 hours after baseline (baseline measurements were obtained before rotation). In patients rotated to 40° or 60°, PaO₂ was increased at 24 hours after baseline. However, because no figures were given for FIO₂, this information could not be meaningfully interpreted. No articles could be found in which these findings were reported completely. A large multicenter trial comparing different degrees of rotation is currently being performed and may provide answers to this question.

Some patients who are awake find it difficult to tolerate continuous rotation, particularly at the higher degrees of rotation. Personal experience suggests that tolerance may be improved by administering a scopolamine patch, providing both antiemetic and sedative effects. In general, acute lateral rotation therapy may be best suited to unconscious or sedated patients. It is possible that selected patients, perhaps those with a high body mass index, will benefit more than others. These patients may be more likely to have respiratory compromise and complications and may be less likely to receive regular manual turning. However, no data are currently available to support this hypothesis one way or another. Little evidence is available to guide clinicians in determining which diseases or complications are most responsive to rotational therapy.

Rotational therapy is just one technique among a raft of other interventions designed to prevent and treat respiratory complications in critically ill patients. Very few of the prospective randomized studies provided information about other treatments the patients were receiving or about steps taken to standardize therapy other than the rotational bed therapy. Unless overall management is standardized, the contribution of rotational therapy will remain difficult to assess.

Finally, the beds considered in this review have other uses apart from the prevention and treatment of respiratory complications, such as maintenance of skin integrity and mobilization of secretions. These other uses must be considered when deciding whether to place a compromised patient on a therapeutic bed.

ACKNOWLEDGMENT
This article would never have been written without Maria Etchels, who provided the inspiration and motivation.

FINANCIAL DISCLOSURES
Barbara McLean has been a speaker for KCI, Inc.
1. What is the generic term commonly used for positioning of patients using programmable beds that turn longitudinally, either intermittently or continuously?
   a. Manual turning and positioning
   b. TrialDyne therapy
   c. Continuous lateral rotation
   d. Proning therapy

2. Which of the following is not a hypothesized advantage of rotational therapy?
   a. Increases risk of venous thrombosis
   b. Improves drainage of secretions within the lungs and lower airways
   c. Increases functional residual capacity
   d. Increases critical opening pressures in the dependent lung

3. Which of the following is not a complication of immobility?
   a. Pulmonary embolism
   b. Decreased pressure ulcers
   c. Constipation
   d. Postural hypotension

4. Which of the following is a respiratory complication experienced by patients in the intensive care unit (ICU)?
   a. Atelectasis
   b. Acute respiratory distress syndrome
   c. Ventilator-associated pneumonia
   d. Pneumocystis pneumonia

5. Which of the following statements describes current best practice for ventilatory strategies?
   a. Current best practice is focused on strategies to prevent deep venous thrombosis and thus pulmonary embolism.
   b. Current best practice focuses on ventilatory strategies to protect the lung.
   c. Current best practice is focused on ventilatory strategies to treat complications.
   d. Current best practice is focused on strategies to prevent deep venous thrombosis and thus pulmonary embolism.

6. Which of the following statements is true concerning rotational bed characteristics?
   a. These beds do not vary in the degree or frequency of rotation, method of rotation, or inclusion of other therapies.
   b. These beds vary in the degree or frequency of rotation, but do not vary in the method of rotation or the inclusion of other therapies.
   c. These beds vary in the degree or frequency of rotation, method of rotation, and inclusion of other therapies.
   d. These beds do not vary in the degree or frequency of rotation, but do vary in the method of rotation and the inclusion of other therapies.

7. Which of the following was not included as a patient type in the nonrandomized, uncontrolled, or retrospective studies?
   a. Critically ill patients
   b. Progressive care patients
   c. Patients with spinal cord injury
   d. Trauma patients

8. Why did Takiguchi and colleagues compare the Restuce bed with the Biodynamic bed?
   a. Both beds provided the same degree of rotation
   b. To assess the bed that was the most comfortable
   c. To compare the prevention of respiratory complications between the 2 beds
   d. To compare the prevention of complications versus the treatment of established complications

9. Which statement best describes the findings of a meta-analysis by Nelson and Choi?
   a. The analysis showed that the incidence of pneumonia, atelectasis, number of hours intubated, and ICU length of stay were not significantly reduced.
   b. The analysis showed that the incidence of pneumonia and atelectasis were significantly reduced, whereas the number of hours intubated and ICU length of stay were not significantly reduced.
   c. The analysis showed that the incidence of pneumonia, atelectasis, number of hours intubated, and ICU length of stay were significantly reduced.
   d. The analysis showed that the incidence of pneumonia, atelectasis, number of hours intubated, and ICU length of stay were increased as a result of rotational therapy.

10. Which of the following is not a complication of rotational therapy?
    a. Disconnection of intravascular catheters
    b. Decreased intracranial pressure
    c. Intolerance of patients to rotational therapy
    d. Arrhythmias

11. Which of the following would not be an appropriate patient for initiation of rotational therapy?
    a. A patient with a PaO2/FIO2 ratio less than 300 mm Hg
    b. A patient with positive end-expiratory pressure greater than 10 cm H2O
    c. A patient with a PaO2/FIO2 ratio greater than 300 mm Hg
    d. A patient with visible infiltrates on radiograph

12. Which statement best describes the reason manual turning as a control for rotational therapy may not be reflective of actual practice?
    a. Schallom and colleagues found that out of 12 possible turns for each patient, the actual number of turns was only 3.
    b. Schallom and colleagues found that out of 23 possible turns for each patient, the actual number of turns was only 9.6.
    c. In an observational study, Krishnagopalan and colleagues found that 78% of patients were manually turned every 2 hours.
    d. In an observational study, Krishnagopalan and colleagues found that 8% of patients were never manually turned.

13. Which statement best reflects why there is little convincing evidence about the rotational parameters that are most effective?
    a. The effectiveness of rotational therapy may not depend entirely on the angle of rotation, but also on the frequency of rotation, pause time, and use of adjuncts such as vibration, percussion, and palpation.
    b. The effectiveness of rotational therapy depends entirely on the angle of rotation, but may also depend on the frequency of rotation, pause time, and use of adjuncts such as vibration, percussion, and palpation.
    c. The effectiveness of rotational therapy depends entirely on the use of adjuncts such as vibration, percussion, and palpation.
    d. The effectiveness of rotational therapy depends entirely on the frequency of rotation and pause time.

Test Answers: Mark only one box for your answer to each question. You may photocopy this form.

<table>
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<tr>
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<tr>
<td>c</td>
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</table>

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Rotational Bed Therapy to Prevent and Treat Respiratory Complications: A Review and Meta-Analysis
David R. Goldhill, Michael Imhoff, Barbara McLean and Carl Waldmann

Am J Crit Care 2007;16 50-61
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