TITLE: Kinetic Beds for Patients at Risk of Complications due to Immobility: A Review of the Clinical Effectiveness and Cost-Effectiveness

DATE: 2 December 2015

CONTEXT AND POLICY ISSUES

Some estimates suggest that up to 60% of patients who spend longer than five days in the intensive care unit (ICU) acquire a nosocomial infection. Ventilator associated pneumonia (VAP) and nosocomial pneumonia are two of the most important causes of preventable morbidity and mortality in critically ill patients. Prolonged immobilization due to critical illness and mechanical ventilation can result in serious complications such as nosocomial and ventilator associated pneumonia, pressure ulcers, and atelectasis. Without position changes, there is reduced ventilation, perfusion, and ineffective clearance of lung secretions, thus manual position changes and percussive therapy is often used in order to improve pulmonary outcomes as well as to relieve pressure on patients’ skin.

Kinetic bed therapy (also known as oscillation therapy, continuous lateral rotational therapy, profiling therapy, and alternating pressure therapy) is an alternative to standard beds with manual position changes. Kinetic beds generally allow for a continuous lateral rotation of at least 40 degrees to each side, changes in recumbent positioning, and can also allow for percussive therapy. In experimental studies, patients generally receive at least 12 and up to 24 hours of kinetic bed movement per day.

Manual position changes and percussion are time consuming (some nursing standards suggest position changes every two to four hours), and have the potential to result in injuries to healthcare workers. If kinetic beds are effective in preventing or treating complications due to immobility, they have the potential to improve patient outcomes while reducing burden on healthcare workers. The purpose of the review is to examine the clinical and cost-effectiveness of kinetic bed therapy the prevention and treatment of immobility-related complications.

RESEARCH QUESTIONS

1. What is the clinical effectiveness of the use of kinetic beds for patients at risk of immobility-related complications?
2. What is the cost-effectiveness of the use of kinetic beds for patients at risk of immobility-related complications?

**KEY FINDINGS**

Kinetic beds are generally well tolerated and may be effective in preventing ventilator associated pneumonia in adults and in improving oxygenation outcomes in ventilated children, but do not seem to have an effect on the treatment or prevention of pressure ulcers or on hospital or ICU mortality. Due to conflicting evidence, it is unclear whether there is an effect of kinetic beds on length of stay, duration of mechanical ventilation, development of atelectasis, or infectious outcomes.

**METHODS**

**Literature Search Methods**

A limited literature search was conducted on key resources including PubMed, CINAHL, The Cochrane Library, University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and major international health technology agencies, as well as a focused Internet search. No methodological filters were applied to limit the retrieval by study type. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2005 and November 4, 2015.

Rapid Response reports are organized so that the evidence for each research question is presented separately.

**Selection Criteria and Methods**

One reviewer screened citations and selected studies. In the first level of screening, titles and abstracts were reviewed and potentially relevant articles were retrieved and assessed for inclusion. The final selection of full-text articles was based on the inclusion criteria presented in Table 1.

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<th>Table 1: Selection Criteria</th>
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<td><strong>Population</strong></td>
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Table 1: Selection Criteria

| Study Designs | Heath technology assessments, systematic reviews with meta-analysis, randomized controlled trials, non-randomized studies, and economic evaluations. |

Exclusion Criteria

Articles were excluded if they did not meet the selection criteria outlined in Table 1, were duplicate publications, were systematic reviews for which an update was available, was available only as an abstract, or were published prior to 2005.

Critical Appraisal of Individual Studies

The included systematic reviews were critically appraised using the AMSTAR\(^9\) checklist and both the randomized controlled trials (RCTs) and non-randomized studies (NRS) were appraised using the Downs and Black checklist.\(^{10}\) Summary scores were not calculated for the included studies; rather, a review of the strengths and limitations of each included study were described.

SUMMARY OF EVIDENCE

Quantity of Research Available

A total of 342 citations were identified in the literature search. Following screening of titles and abstracts, 320 citations were excluded and 22 potentially relevant reports from the electronic search were retrieved for full-text review. Two potentially relevant publications were retrieved from the grey literature search. Of these potentially relevant articles, 18 publications were excluded for various reasons, while six publications met the inclusion criteria and were included in this report. The PRISMA flowchart\(^{11}\) of the study selection is included in Appendix 1.

Two studies specifically examining positioning within kinetic beds did not meet the inclusion criteria but are of potential interest and are provided in Appendix 5.

Summary of Study Characteristics

Study Design

Of the six included studies two were systematic reviews,\(^3,4\) two studies were randomized controlled trials\(^5,7\) (one of which was a cross-over randomized trial),\(^5\) and two studies were non-randomized (both retrospective cohort studies).\(^{12,13}\)

Country of Origin

The two systematic reviews were performed by international authors; the McNnes et al.\(^4\) authors were from Australia and the United Kingdom and the Delaney et al.\(^3\) authors were from Australia and Canada. The multi-centre RCT was conducted in Australia,\(^7\) and the remaining studies were conducted in the United States.\(^5,12,13\)
Patient Population

Adults

The McInnes et al. \(^4\) systematic review included studies that examined any patient group at risk for pressure ulcers. The three studies relevant to this report included 221 patients, however detailed patient characteristics were not provided. The Delaney et al. \(^3\) systematic review included 15 randomized studies that examined critically ill adults who were mechanically ventilated (N = 1169). The study sizes ranged from 11 to 255; no further patient characteristics were provided.

Two of the included primary studies examined mechanically ventilated adult patients in the ICU.\(^7\),\(^12\) The RCT comprised 150 adult patients (n = 75 in each group) for whom the most common causes of admission were CPR and cardiogenic shock.\(^7\) The mean age of patients was similar in the intervention (59, standard deviation [SD] 16) and control (60, SD 15) groups, as were female sex (35% versus 32%), and lung injury score (1.2, SD 0.7 vs. 1.3, SD 0.7). The non-randomized cohort study examined the records of patients admitted for medical, cardiac, cardiothoracic, surgical/trauma, neurologic reasons, or burns.\(^12\) Records for 3,399 patients in the control group and 3,065 patients in the intervention group were examined; no further patient characteristics were reported.

One included non-randomized cohort study examined trauma patients who had surgery for thoracolumbar spine injuries (TLSI).\(^13\) The 108 patients in the intervention (n = 61) and control (n = 47) groups were similar with respect to mean age (intervention: 37.7 years SD 16.1 versus control: 36.7 years SD 15.9), or injury severity score (intervention: 21.7 SD 10.9 versus control: 18.7 SD 11.5), but there were more patients with neurological deficits in the intervention group (n = 42) than in the control (n = 11) group (P < 0.01). The patients received the study treatments in the pre-surgical period only (mean number of days 4.6, SD 1.4 in the intervention group and 3.9, SD 3.6 in the control group).

Children

The cross-over randomized study included 50 pediatric patients requiring positive pressure mechanical ventilation and invasive blood pressure monitoring.\(^5\) 52% of the participants were female and had a mean age of 32 months (range 8 to 96).

Interventions and Comparators

Neither of the included systematic reviews included the specifications of the kinetic\(^3,\(^4\) or profiling\(^4\) beds that were examined in the included studies. The specifications of the control beds were also not included – the authors included “usual care” as the comparator and for the purpose of this report, they are assumed to be standard hospital beds.

The adult patients in the Staudinger trial\(^7\) were randomized either to a Triadyne Proventa bed programmed to have rotation time >18 hours per day with (n = 35) or without (n = 40) percussion or were rotated according to nursing standard (positioned in supine semi-recumbent position between 30° and 45° and were turned manually to left and right semi lateral positions every 2 to 4 hours) in a standard bed (n = 75). The pediatric patients in the crossover RCT\(^5\) received kinetic therapy in the PediDyne Bed for 18 hours with an 80° arc, with automatic chest
physiotherapy as available on the bed and manual turning and percussion (right lateral, left lateral, and supine positions) on a conventional bed in random order.

The Chandy\textsuperscript{12} retrospective study specified that the kinetic bed used was the TotalCare SpO2RT Pulmonary Therapy System but the comparator beds were not specified. There were no details other than “kinetic bed” and “standard bed” reported in the Chipman non-randomized study.\textsuperscript{13}

Outcomes

The McInnes systematic review\textsuperscript{4} and the Staudinger RCT reported on the incidence of new\textsuperscript{4,7} and the healing of existing\textsuperscript{4} pressure ulcers, as well as length of hospital stay associated with the use of kinetic beds. The remaining included studies primarily examined infectious disease and pulmonary outcomes:

- ventilator associated or nosocomial pneumonia (2 studies)\textsuperscript{3,7}
- mortality (2 studies)\textsuperscript{3,7}
- development of atelectasis (2 studies)\textsuperscript{7,12}
- duration of mechanical ventilation (4 studies)\textsuperscript{3,7,12,13}
- length of stay in hospital or in the ICU (4 studies)\textsuperscript{3,7,12,13}
- changes in oxygenation (1 study)\textsuperscript{5}
- infectious outcomes (2 studies)\textsuperscript{7,13}
- tolerance (2 studies)\textsuperscript{5,7}

Year of Publication

The majority of the included studies were published more than 5 years ago\textsuperscript{3,5,12,13}. While the McInnes systematic review\textsuperscript{4} was updated in 2015 none of the included trials pertaining to kinetic bed therapy were published more recently than 2001.

Additional detail regarding the included studies is presented in Appendix 2 (Table A1 for systematic reviews, Table A2 for RCT and NRS).

Summary of Critical Appraisal

The quality of the systematic reviews was generally high. The McInnes review\textsuperscript{4} followed the Cochrane methods (i.e. comprehensive search strategy, duplicate selection, validity assessment, lists of included and excluded studies) and the main limitations were related to the level of detail related to the interventions and comparators in the included studies; neither the kinetic nor the standard care beds were well described in the systematic review. Additionally the text description of the studies was not always consistent with the details presented in the tables; these discrepancies did not affect the data on kinetic beds, but were rather for data presented for other interventions. The Delaney review\textsuperscript{3} had a comprehensive search strategy, duplicate selection, duplicate validity assessment, and duplicate data extraction, however there was no list of excluded studies presented (or included in online appendices) and limited information regarding the comparator beds was presented. The lack of detail regarding both the interventions and comparators may limit the ability to generalize the data to a local environment, as it is unclear what may be contributing to patient outcomes. There seemed to be no other major reasons to believe that there were any systematic biases present.
Limited reporting of details regarding comparator beds was also a limitation in the majority of the included primary studies.\textsuperscript{7,12,13} It is therefore difficult to determine the differences between the interventions and more difficult to generalize to a local environment.

Lack of blinding (or lack of reporting on blinding) was also an issue in many of the studies.\textsuperscript{5,12,13} The Staudinger RCT reported that the radiologists assessing outcomes were blinded, but that patients were not. The Shultz RCT did not report the binding of outcome assessors or patients, but the patients were in the kinetic bed during both automated and manual therapies, thus it is possible that blinding of the assessors occurred.\textsuperscript{5}

The Shultz RCT\textsuperscript{5} was a cross-over study; the authors appropriately discussed the impact of the order of interventions and analyzed the effect using ANOVA.

The two non-randomized studies\textsuperscript{12,13} were retrospective case-control studies that used registry data in order to compare kinetic beds to control beds. Neither the patients nor the outcome assessors were blinded in either study. The Chandy study\textsuperscript{12} examined the records of patients before and after kinetic beds were introduced, and based on what the authors reported, there were no significant changes with respect to the patient population served by the hospital in that period of time. If there were changes with respect to infection control practices or other changes during the 2 years between the collection of the data on the control beds versus the kinetic beds, they were not reported. The patients, outcomes, and measurements of variability, however, were not well reported, and while the methods stated that t-tests and tests of $\chi^2$ were performed, they were not reported. The staff, places, and facilities were likely representative of those who would normally undergo TLSI surgery in the Chipman study and potential confounders were reported.\textsuperscript{13} There was, however, no clarity with respect to whether or not the control beds and kinetic beds were present in the hospital at the same time or whether there was a difference in the time period or care environment.

A full summary of critical appraisal for the included studies is included in Appendix 3 (Table A3 for SRs, Table A4 for RCTs, and Table A5 for NRS).

**Summary of Findings**

**What is the clinical effectiveness of kinetic beds for patients at risk of complications due to immobility?**

**Pressure Ulcers**

Results from the McInnes meta-analysis\textsuperscript{4} (based on two RCTs) suggest that kinetic beds are likely not effective in reducing the risk of pressure ulcers than standard mattresses (risk ratio [RR] 1.23, 95% confidence interval [CI] 0.57 to 2.63). The authors of the single RCT on profiling beds observed no new pressure ulcers in either the intervention or control group; regarding the healing of grade 1 pressure ulcers, all ulcers (4/4) healed in the profiling bed group and 20% (2/10) in the standard bed group.\textsuperscript{4}

The Staudinger RCT reported no statistically significant difference in the number of patients who developed new pressure ulcers in the kinetic (29%) versus standard bed (37%) groups.\textsuperscript{7}
**Ventilator Associated or Nosocomial Pneumonia**

Based on ten studies, there was a statistically significant reduction in the odds of developing nosocomial pneumonia in patients treated with kinetic bed therapy (odds ratio [OR] 0.38; 95% CI 0.28 to 0.53, \( P < 0.001 \)) in the Delaney meta-analysis.\(^3\) The results were sensitive to variations in allocation concealment and the rotation arc of the bed.\(^3\)

The prevalence of ventilator associated pneumonia was lower in patients in the kinetic bed group (8/75; 11%) than in the control group (8/75 versus 17/75; \( P = 0.058 \)) in the Staudinger RCT.\(^7\)

**Mortality**

The results of the meta-analysis of the 11 studies reporting on mortality in the Delaney systematic review found no statistically significant reduction in mortality associated with kinetic beds (OR 0.96; 95% CI 0.72 to 1.26, \( P = 0.75 \)); the specific comparator was not reported.\(^3\)

Neither the number of ICU (71% intervention versus 76% control; \( P = \text{NS} \)) nor hospital survivors (63% intervention versus 76% control; \( P = \text{NS} \)) were statistically significantly different between patients in kinetic versus conventional beds in the Staudinger RCT.\(^7\)

**Development of Atelectasis**

The number of days with atelectasis was lower in the kinetic bed group than in the control group in the Staudinger RCT\(^7\) (2 SD 2 intervention versus 4 SD 4 control; \( P < 0.001 \)), the number of patients with atelectasis was not reported. The number of patients who underwent bronchoscopy for atelectasis was higher in the kinetic bed group (83 patients) than the control group (71 patients) in the Chandy NRS,\(^{12}\) however \( P \) values were not reported, nor were the number of days with atelectasis.

**Duration of Mechanical Ventilation**

There was no statistically significant effect of kinetic beds on mechanical ventilation in the Delaney systematic review\(^3\) (pooled standardized mean difference [SMD] = -0.14 days; 95%CI - 0.29 to 0.02; \( P = 0.08 \)) and no significant difference between the number of ventilator-patient days for patients treated in a kinetic or a conventional bed (22,626 days intervention vs. 24,037 control; \( P = \text{NS} \)).\(^{12}\)

The number of days that patients were mechanically ventilated was statistically significantly lower in patients who were treated in kinetic versus control beds in the Staudinger RCT\(^7\) (8 ± 5 intervention versus 14 ± 23 control; \( P = 0.02 \)). Patients in the kinetic beds had a higher number of ventilator-free days than those in the control beds (mean 15 days ± 1 intervention versus 11 days ± 10 control; \( P = 0.04 \)).\(^7\)

In the Chipman NRS,\(^{13}\) the number of days on a ventilator was statistically significantly higher in patients receiving treatment in a kinetic bed versus a standard bed (3.1 ± 7.6 days intervention versus 0.7 ± 2.8 control; \( P = 0.04 \)).
**Length of Hospital or ICU stay**

Authors of the Delaney systematic review found no statistically significant effect of kinetic beds on length of hospital stay (pooled SMD = 0.05 days, 95%CI -0.18 to 0.27, \( P = 0.69 \); based on five studies) or ICU stay (pooled SMD = -0.064 days, 95%CI -0.21 to 0.086, \( P = 0.40 \); based on eight studies).

The Staudinger RCT\(^7\) found kinetic beds to be associated with a statistically significantly shorter hospital stay than control beds (25 days ± 22 intervention versus 39 ± 45 control; \( P = 0.01 \)). The Chandy NRS\(^{12}\) found that there was a shorter length of hospital stay for patients in kinetic beds (7.7 days intervention versus 8.2 days control; \( P = \text{NS} \)) but the length of ICU stay was slightly longer for patients who were treated in a kinetic bed (5.66 days for intervention vs. 5.28 days control; \( P \text{ values not reported} \)).

The authors of the Chipman NRS\(^{13}\) observed a statistically significant increase in the length of hospital stay for patients undergoing kinetic bed therapy (16.6 days ± 11.3 intervention versus 11.6 days ± 5.6 control; \( P < 0.01 \)).

**Changes in Oxygenation, Respiratory Failure**

The Shultz crossover RCT measured oxygenation index (OI) and the arterial-alveolar oxygen tension difference \([P(A-a)O_2]\).\(^5\) They found that when compared with manual turning therapy and manual percussion, kinetic bed therapy (including automated percussion) was associated with improvements in both OI and \(P(A-a)O_2\). There was an order effect; the changes were not statistically significant when the standard therapy occurred first (OI \( P = 0.184 \); \( P(A-a)O_2 \) \( P = 0.355 \)) but were significant when the kinetic therapy occurred first (OI \( P = 0.015 \); \( P(A-a)O_2 \) \( P = 0.023 \)). Although the mechanism of this effect was not known, authors speculated that kinetic therapy was more efficient in terms of ventilation/perfusion ratio matching.

In the database review by Chipman et al., the number of patients with respiratory failure was higher in the kinetic bed group than in the control group (\( P = 0.02 \)).

**Infectious Outcomes**

In the Staudinger RCT, the number of patients receiving antibiotics during their ICU stay was lower in the kinetic bed group (88%) than in the control group (92%), but the difference was not statistically significant (\( P \text{ reported as NS} \)).\(^7\)

The authors of the Chipman NRS\(^{13}\) found that the number of patients with infectious complications was higher in the kinetic bed group (23%) than in the control group (6%), as were the number of patients with pneumonia (15% versus 6%); the differences were statistically significant for both outcomes (\( P = 0.03, P = 0.02 \) respectively).

**Tolerance of Kinetic Beds**

Premature termination of kinetic therapy due to intolerance during ventilator weaning was reported in 39% of patients in the Staudinger RCT, however, no statement was made regarding the patients in the control group.\(^7\)
In the Schultz crossover RCT (N = 50), 2 patients could not tolerate either therapy, 3 patients tolerated kinetic therapy more than standard therapy, and 3 patients had circulatory stability problems during kinetic therapy.

Additional detail regarding outcomes and author conclusions of the included systematic reviews, randomized controlled trials, and non-randomized studies is included in Appendix 4.

*What is the cost-effectiveness of kinetic beds for patients at risk of complications due to immobility?*

No studies relevant to the cost-effectiveness of kinetic beds for the prevention and treatment of immobility-related complications were identified.

**Limitations**

One of primary limitations of the body of literature was the lack of clear description of intervention and comparator beds. It was not always clear which kinetic bed was being used, what the features of the kinetic beds were, which features were being used, and what the beds were being compared to. This limits the generalizability of the review as well as the ability to determine the differences between the beds and thus what the added value of a kinetic bed may be.

Another potential limitation of the body of literature reviewed is the publication dates of the included studies. All of data regarding the effectiveness of the beds being studied was generated prior to 2010. If there has been a change in the technological specifications of kinetic beds or if the technology has improved, the data may not be generalizable to newer beds.

The Chipman NRS examined the pre-operative use of kinetic bed therapy (KT). Patients did not receive post-operative or long-term KT and unlike the participants in many of the other included studies, were therefore not receiving the therapy for an extended period of time. The treatment duration may not have been adequate to see an effect of KT and the intervention may not be comparable to others reviewed in this report. Furthermore, the clinicians at the institution were more likely to initiate kinetic therapy in patients with neurological impairment, thus the differences between those who received kinetic versus control treatment may not have been solely due to the differences in treatment type.

In all of the included studies, blinding was an issue. As it is difficult to blind patients and staff who treat patients within beds to which type of bed a patient was in, it is possible that some bias (in the direction of the intervention being more effective; if patients or staff believe the newer more technologically advanced bed to be superior, patients may feel better or staff may perceive the patient to be doing better simply by virtue of being or seeing them in the bed) was introduced. One study attempted to minimize bias by blinding the radiologists examining pulmonary outcomes and in one study, the patients were in kinetic bed during the control phase of the study and, though not reported, it was possible that patients and outcome assessors could have been blinded. Although patients could behave differently depending on the type of intervention they are receiving, the blinding of the outcome assessors has the potential to have a greater contribution to ensuring internal validity than patient blinding, as the outcomes were primarily measures such as presence or absence of infectious outcomes, and not dependent on patient report.
The patients in the Staurdinger RCT were sedated and thus the results may not be generalizable to a non-sedated population. Only one included trial examined pediatric patients. Thus it is unclear if the results of this study are relevant to the adult population or if the rest of the results reviewed in this report can be generalized to the pediatric population.

CONCLUSIONS AND IMPLICATIONS FOR DECISION OR POLICY MAKING

The clinical effectiveness of kinetic beds for the treatment and prevention of complications due to immobility is unclear. The conflicting results and the lack of detail regarding both kinetic and control beds make it difficult to come to definitive conclusions.

The evidence is consistent for outcomes of VAP, nosocomial pneumonia, mortality, and pressure ulcers in adult patients who are mechanically ventilated; kinetic beds seem to reduce the odds of acquiring nosocomial and ventilator associated pneumonia, but do not seem to have an effect on hospital mortality, ICU mortality or the prevention or treatment of pressure ulcers.

The potential effect of kinetic beds on the development of atelectasis, duration of mechanical ventilation, length of hospital or ICU stay, and infectious outcomes is mixed. It is unclear whether kinetic beds aid in prevention of those outcomes.

Kinetic beds seem to be generally well tolerated by both pediatric and adult patients (though they may be more difficult to tolerate during weaning from mechanical ventilation) and may result in better oxygenation outcomes in mechanically ventilated children however it is unclear if this result generalizes to an adult population. As previously stated, it is unclear whether or not newer kinetic beds differ significantly from those studied in the included studies and thus it is unclear whether or not the conclusions are relevant to newer beds.

Additionally, there is some evidence that for mechanically ventilated patients, the oxygenation of different patients responds differently to the various positions of kinetic beds. That lengthy pauses in the lateral sleep position could impair the compliance of the respiratory system, and that automated prone positioning may improve the oxygenation of patients with acute respiratory distress syndrome.

The conclusions presented in this review are consistent with guidance from the Institute for Clinical Systems Improvement, who suggest that while kinetic bed therapy may be effective in reducing VAP and some other pulmonary outcomes, they do not make strong recommendations for the use of the beds, as they may not be available in all ICUs. It is unclear whether or not kinetic beds are effective for the prevention of other complications and the cost-effectiveness is unknown.

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REFERENCES


APPENDIX 1: Selection of Included Studies

342 citations identified from electronic literature search and screened

320 citations excluded

22 potentially relevant articles retrieved for scrutiny (full text, if available)

2 potentially relevant reports retrieved from other sources (grey literature, hand search)

24 potentially relevant reports

18 reports excluded:
- irrelevant population (2)
- irrelevant intervention (2)
- irrelevant comparator (2)
- irrelevant outcomes (1)
- irrelevant study design (8)
- Outdated Cochrane systematic review (2)
- published only as an abstract (1)

6 reports included in review
### APPENDIX 2: Characteristics of Included Publications

<table>
<thead>
<tr>
<th>First Author, Publication Year, Country</th>
<th>Types and numbers of primary studies included</th>
<th>Population Characteristics</th>
<th>Intervention</th>
<th>Comparator(s)</th>
<th>Clinical Outcomes, Length of Follow-Up</th>
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<tr>
<td>McInnes, 2015, International</td>
<td>RCTs, ‘quasi’-RCTs. 59 total included studies; Kinetic beds: 4 RCTs (2 of which were not able to be procured in full text) Profiling beds: 1 RCT</td>
<td>Any patient group at risk for pressure ulcers in any setting in which pressure ulcers are measured or monitored Total number of patients: 221</td>
<td>Kinetic bed Profiling bed</td>
<td>Conventional beds</td>
<td>Outcomes: new pressure ulcers, healing of pressure ulcers. Length of follow-up: variable (mostly unclear)</td>
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<tr>
<td>Delaney, 2006, Australia and Canada</td>
<td>15 RCTs</td>
<td>Critically ill adults receiving mechanical ventilation. 1,169 patients randomized (largest study sample n = 255)</td>
<td>Kinetic bed (at least 24 hours)</td>
<td>Control (assumed conventional bed details not reported)</td>
<td>Nosocomial pneumonia, mortality, duration of mechanical ventilation, ICU or hospital length of stay. Length of follow-up variable (from 3 days to “until discharge”)</td>
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RCT = randomized controlled trial
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<tr>
<th>First Author, Publication Year, Country, Study Name</th>
<th>Study Design</th>
<th>Patient Characteristics</th>
<th>Intervention(s)</th>
<th>Comparator(s)</th>
<th>Clinical Outcomes</th>
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<td><strong>Randomized Controlled Trials</strong></td>
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| Staudinger, 2010, Austria                          | RCT (multi-centre took place in ICU setting) | Inclusion: aged 19 to 89 years, ventilated\(^a\) for medical reasons for <48 hrs, free from pneumonia, no acute lung injury. N = 150 (75 in each group)  
   Most common causes of admission were CPR and cardiogenic shock.  
   Female Sex: 35% intervention; 32% control  
   Mean age: 59 (SD 16) intervention; 60 (SD 15) control  
   LIS: 1.2 (SD 0.7) intervention; 1.3 (SD 0.7) control. | Triadyne Proventa bed programmed to have rotation time >18 hours per day.\(^b\) Patients divided into: rotation with percussion\(^c\) (n = 35) and rotation without percussion (n = 40) prior to endotracheal suction. | Conventional bed, rotated according to nursing standard.\(^d\) (n = 75) | Primary: occurrence of VAP  
Secondary: hospital LOS, duration of mechanical ventilation, ventilator-free days during the first 28 days after intubation, ICU and hospital mortality, number and duration of atelectases, prevalence of ALI, prevalence of ARDS, changes in LIS during the study period, complications such as pressure sores or intolerance |
| Schultz, 2005, USA                                  | Crossover RCT | Children weighing 6.8 and 36.4 kg and requiring PPMV and invasive blood pressure monitoring considered for inclusion.  
50 patients enrolled (n = 24 to standardized first; n = 26) | Kinetic therapy with percussion in PediDyne Bed for 18 hours - 80° arc (40° to each side with 7 second pauses at right, left, and center), with | Manual turning and percussion (right lateral, left lateral, and supine positions; percussed by nurse or | Oxygenation index.  
Arterial-alveolar oxygen tension difference [P(A-a)O\(_2\)] |
<table>
<thead>
<tr>
<th>First Author, Publication Year, Country, Study Name</th>
<th>Study Design</th>
<th>Patient Characteristics</th>
<th>Intervention(s)</th>
<th>Comparator(s)</th>
<th>Clinical Outcomes</th>
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<td><strong>Non-Randomized Studies</strong></td>
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<tr>
<td>Chandy, 2007, USA</td>
<td>Retrospective chart review (Before and after study)</td>
<td>Mechanically ventilated patients in the ICU for medical, cardiac, cardiothoracic, surgical/trauma neurologic reasons, or burns. July 2000 to June 2001 for control beds (3,399 patients admitted); July 2002 to June 2003 for kinetic beds (3,065 patients admitted).</td>
<td>TotalCare SpO2RT Pulmonary Therapy System. 20 percussion and 20 CLRT modules; unclear if these were add-ons to the TotalCare beds or to other beds.</td>
<td>No details given. Assumed standard beds, however unclear if support surfaces or other add-ons were used.</td>
<td>Development ofatelectasis. Ventilator-patient days. Hospital length of stay.</td>
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<tr>
<td>Chipman, 2006, USA</td>
<td>Retrospective registry review</td>
<td>Trauma patients who had surgery for thoracolumbar spine injuries. N = 108 (n = 61 intervention; n = 47 control) Mean age: intervention: 37.7 SD 16.1; control: 36.7</td>
<td>Preoperative treatment on a kinetic bed. Details of bed unclear.</td>
<td>Preoperative treatment on a standard bed. Details of bed unclear</td>
<td>Infectious complications (included SSI, UTI, and pneumonia) Respiratory failure Pneumonia Ventilator duration</td>
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### Table A2: Characteristics of Included Randomized and Non-Randomized Studies

<table>
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<tr>
<th>First Author, Publication Year, Country, Study Name</th>
<th>Study Design</th>
<th>Patient Characteristics</th>
<th>Intervention(s)</th>
<th>Comparator(s)</th>
<th>Clinical Outcomes</th>
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<td>SD 15.9 ISS: intervention: 21.7 SD 10.9; control: 18.7 SD 11.5. Time to surgery (days): intervention: 4.6 SD 4.1; control: 3.9 SD 3.6. Neurologic impairment: intervention: 41; control: 11 (P &lt; 0.01)</td>
<td></td>
<td></td>
<td>Hospital LOS</td>
</tr>
</tbody>
</table>

ALI = acute lung injury; ARDS = acute respiratory distress syndrome; CLRT = continuous lateral rotation therapy; hrs = hours; ICU = intensive care unit; ISS = injury severity score; kg = kilogram; LIS = lung injury score; LOS = length of stay; PPMV = positive pressure mechanical ventilation; RCT = randomized controlled trial; SSI = surgical site infection; UTI = urinary tract infection; VAP = ventilator associated pneumonia

a. Orotracheal intubation
b. Rotation of the upper part of the body through a maximum angle of about 90° and the duration of a complete cycle of rotation was 7 minutes 20 seconds. Rotation was started through a 60° angle and then escalated to maximum angle over two to six hours.
c. Percussion involved 12 vibrations/second for 1 minute before suctioning
d. Positioned in supine semi-recumbent position between 30° and 45° and were turned manually to left and right semi lateral positions every 2 to 4 hours.
## APPENDIX 3: Critical Appraisal of Included Publications

### Table A3: Strengths and Limitations of Systematic Reviews and Meta-Analyses

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>McInnes</strong></td>
<td>Limited data available related to the interventions and outcomes of interest.</td>
</tr>
<tr>
<td>- Strong methods used (comprehensive literature search, two authors performing tasks, critical appraisal, list of excluded studies, etc.).</td>
<td>- Standard care mattresses were often poorly described.</td>
</tr>
<tr>
<td>- Conflict of interest statement included.</td>
<td>- Text description of the studies did not always match with the information in the tables.</td>
</tr>
<tr>
<td><strong>Delaney</strong></td>
<td>Excluded studies list not available.</td>
</tr>
<tr>
<td>- Comprehensive literature search</td>
<td>- Limited information on comparator beds presented.</td>
</tr>
<tr>
<td>- Two authors performed tasks</td>
<td></td>
</tr>
<tr>
<td>- Critical appraisal performed.</td>
<td></td>
</tr>
<tr>
<td>- Heterogeneity of studies examined and discussed prior to performing meta-analysis.</td>
<td></td>
</tr>
<tr>
<td>- Methodological quality of included studies considered when the conclusions were being made.</td>
<td></td>
</tr>
<tr>
<td>- Likelihood of publication bias addressed.</td>
<td></td>
</tr>
<tr>
<td>- Conflict of interest statement included.</td>
<td></td>
</tr>
<tr>
<td>- Sensitivity analyses performed.</td>
<td></td>
</tr>
</tbody>
</table>

### Table A4: Strengths and Limitations of Randomized Controlled Trials

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Staudinger</strong></td>
<td>Comparator bed not clearly described. Unclear if there was an additional mattress support or if it was a conventional mattress.</td>
</tr>
<tr>
<td>- Objectives, outcomes, patients, intervention, distribution of confounders, and main study findings clearly described.</td>
<td>- Unclear how large the source population was and whether those who participated were a representative sample.</td>
</tr>
<tr>
<td>- Actual probability values reported for the primary outcomes and for statistically significant outcomes, values that were not significant were reported as NS.</td>
<td></td>
</tr>
<tr>
<td>- Radiologists evaluating chest radiographs were blinded.</td>
<td></td>
</tr>
<tr>
<td>- ITT analysis was planned; however, there were no losses to follow-up.</td>
<td></td>
</tr>
<tr>
<td>- Primary outcome was 28 day instance of VAP, so all patients had the same length of follow-up for the primary outcome.</td>
<td></td>
</tr>
<tr>
<td>- The study took place in three centres – there is nothing to suggest that the study is not representative of medical intensive care units of university tertiary care hospitals.</td>
<td></td>
</tr>
<tr>
<td>- Randomization of patients occurred, power calculation provided.</td>
<td></td>
</tr>
</tbody>
</table>
### Table A4: Strengths and Limitations of Randomized Controlled Trials using Downs and Black\(^{10}\)

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Schultz\(^{2}\) | • Objectives, outcomes, interventions clearly described.  
• Patient characteristics described  
• Power calculation presented.  
• Potential effect of carryover therapy analyzed (using ANOVA) and discussed  
• Reasons for withdrawal/losses to follow up were reported. | • Confounders partially described.  
• Retention was low.  
• Unclear whether the patients who participated were representative of the sample or whether the sample was representative of the larger population.  
• Unclear whether or not blinding of those assessing outcomes was attempted. However, patients were placed in the kinetic bed even for manual turning treatment, thus it is possible that outcome assessors were blinded. |

ANOVA = analysis of variance; ITT = intention to treat; NS = not significant

### Table A5: Strengths and Limitations of Non-Randomized Controlled Trials using Downs and Black\(^{10}\)

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Chandy\(^{12}\) | • Objectives clearly stated.  
• Authors do not make definitive conclusions regarding the impact of kinetic beds, which is appropriate considering it is a retrospective chart review.  
• Outcome measurements are reliable and valid (measurement of atelectasis done by bronchoscopy; this is a valid and reliable method, though it does not necessarily catch all instances, there would not likely be a difference between groups with respect to whether they were identified via bronchoscopy). | • No description of the control beds and the description of the intervention beds is unclear.  
• Patients not clearly described.  
• Outcomes for the control group not clearly reported.  
• Methods stated that t tests and \(\chi^2\) tests were performed but it was unclear whether all of them were reported (no comparison between the control and intervention groups for the primary outcomes were reported.  
• Estimates of variability for the primary outcome not reported.  
• Unclear if the subjects were representative of the population as a whole.  
• No power calculation. |

| Chipman\(^{13}\) | • Objectives clearly stated.  
• Patient details reported.  
• Actual \(P\) values reported.  
• Staff, places, and facilities were likely representative of those who would normally undergo TLSI surgery.  
• Potential confounders reported (including neurologic defects – a higher number of patients with neurologic defects were treated in the KT bed). | • Intervention and comparator details were not clearly reported.  
• Unclear if there was a difference in time with respect to the two interventions. Unclear if there was an introduction of beds or if there was the option of a kinetic bed the entire study period.  
• Unclear if the subjects were representative of the population as a whole.  
• Outcome assessors were likely not blinded to the interventions. |

KT = kinetic; TLSI = thoracolumbar spine injuries
## Table A6: Summary of Findings of Included Studies

<table>
<thead>
<tr>
<th>Systematic Reviews</th>
<th>Author’s Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Study Findings</strong></td>
<td><strong>Author’s Conclusions</strong></td>
</tr>
<tr>
<td><strong>Systematic Reviews</strong></td>
<td></td>
</tr>
<tr>
<td>McInnes, 2015(^5)</td>
<td><em>The relative merits of “high-tech” pressure mattresses are unknown.</em></td>
</tr>
<tr>
<td>- Based on 2 RCTs, the effect size of kinetic beds vs. standard mattresses on pressure ulcer incidence: RR 1.23, 95% CI 0.57 to 2.63</td>
<td></td>
</tr>
<tr>
<td>- 1 included RCT compared profiling beds (n = 50) with standard beds with pressure relieving foam mattresses (n = 50). No patient developed a new pressure ulcer. Healing of grade 1 pressure ulcers: 4/4 in the profiling bed group; 2/10 in the standard bed group.</td>
<td></td>
</tr>
</tbody>
</table>

| Delaney, 2006\(^3\) | |
| - **Nosocomial pneumonia** (10 studies): | *Kinetic bed therapy was found to be associated with significantly decreased odds of developing nosocomial pneumonia in patients who are mechanically ventilated.* |
| - **Mortality** (11 studies): | |
| - **Duration of mechanical ventilation** (7 studies): | |
| - **Duration of ICU stay** (8 studies): | |

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\(^5\) McInnes, 2015

\(^3\) Delaney, 2006

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Kinetic Beds for Patients at Risk of Complications due to Immobility
<table>
<thead>
<tr>
<th>Main Study Findings</th>
<th>Author's Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of hospital stay (5 studies):</td>
<td></td>
</tr>
<tr>
<td>o No effect of kinetic beds on the duration of hospital stay (pooled SMD = 0.05 days, 95%CI -0.18 to 0.27, p = 0.69)</td>
<td></td>
</tr>
<tr>
<td><strong>Randomized Controlled Trials</strong></td>
<td></td>
</tr>
<tr>
<td>Staudinger, 2010</td>
<td>They observed a reduction in VAP, LOS, and ventilation time in patients who underwent continuous rotation.</td>
</tr>
<tr>
<td>VAP prevalence: 8/75 (11%) intervention vs. 17/75 (23%) control; P = 0.058</td>
<td>They recommended early continuous rotation for sedated patients who are undergoing mechanical ventilation and at high risk for VAP; they concluded it was a feasible and effective addition to VAP prophylaxis.</td>
</tr>
<tr>
<td>Days on mechanical ventilation: 8 (SD 5) intervention vs. 14 (SD 23) control; P = 0.02</td>
<td></td>
</tr>
<tr>
<td>Ventilator free days: 15 (SD 1) intervention vs. 11 (SD 10) control; P = 0.04</td>
<td></td>
</tr>
<tr>
<td>LOS (days): 25 (SD 22) intervention vs. 39 (SD 45) control; P = 0.01.</td>
<td></td>
</tr>
<tr>
<td>Days with atelectases: 2 (SD 2) intervention vs. 4 (SD 4) control; P &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>ICU survivors: 53 (71%) intervention vs. 57 (76%) control; P = NS</td>
<td></td>
</tr>
<tr>
<td>Hospital survivors: 47 (63%) intervention vs. 57 (76%) control; P = NS.</td>
<td></td>
</tr>
<tr>
<td>Antibiotics during ICU stay: 66 (88%) intervention vs. 69 (92%) control; P = NS.</td>
<td></td>
</tr>
<tr>
<td>New pressure ulcers (number of patients): 22 (29%) intervention vs. 28 (37%) control; P = NS</td>
<td></td>
</tr>
<tr>
<td>Premature discontinuation of kinetic rotation: 39%</td>
<td></td>
</tr>
<tr>
<td>Schultz, 2005</td>
<td>They observed a reduction in VAP, LOS, and ventilation time in patients who underwent continuous rotation.</td>
</tr>
<tr>
<td>Median (25th, 75th percentile) change in oxygenation index between baseline and first therapy: -18.2% (-51.9%, +0.4%) for kinetic first and -20.0% (-70.6%, +33.5%) for standard first (P = 0.62).</td>
<td>They recommended early continuous rotation for sedated patients who are undergoing mechanical ventilation and at high risk for VAP; they concluded it was a feasible and effective addition to VAP prophylaxis.</td>
</tr>
<tr>
<td>Median (25th, 75th percentile) change in P(A-a)O&lt;sub&gt;2&lt;/sub&gt; between baseline and first therapy: - 23.3% (-64.6%, +1.1%) for kinetic first and -9.2% (-70.9%, +36.9%) for standard first (P = 0.51).</td>
<td>When compared with standard manual turning therapy and percussion, kinetic therapy lead to statistically significant improvements in OI and P(A-a)O&lt;sub&gt;2&lt;/sub&gt;. These improvements seemed to persist after therapy was discontinued.</td>
</tr>
<tr>
<td>Significant effect of order on the changes observed in OI and P(A-a)O&lt;sub&gt;2&lt;/sub&gt;.</td>
<td>Automatic percussion and kinetic therapy was well tolerated. There was some observed need for extra suctioning – it is possible that the kinetic therapy mobilized secretions.</td>
</tr>
<tr>
<td>o When standard therapy occurred first, there were no significant changes in OI (P = 0.184) or P(A-a)O&lt;sub&gt;2&lt;/sub&gt; (P = 0.355) after standard therapy whereas there was a significant decrease in OI (P = 0.044) and a decreasing trend in P(A-a)O&lt;sub&gt;2&lt;/sub&gt; (P = 0.077) after kinetic therapy.</td>
<td></td>
</tr>
</tbody>
</table>
### Table A6: Summary of Findings of Included Studies

<table>
<thead>
<tr>
<th>Main Study Findings</th>
<th>Author’s Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>o When kinetic therapy occurred first, there were statistically significant</td>
<td></td>
</tr>
<tr>
<td>decreases from baseline in OI ((P = 0.015)) and (P(A-a)O_2 (P = 0.023)) after</td>
<td></td>
</tr>
<tr>
<td>kinetic therapy. Decreases following subsequent standard therapy were observed but</td>
<td></td>
</tr>
<tr>
<td>they were not statistically significant.</td>
<td></td>
</tr>
<tr>
<td>• Tolerance:</td>
<td></td>
</tr>
<tr>
<td>o 2 patients could not tolerate either therapy</td>
<td></td>
</tr>
<tr>
<td>o 3 patients tolerated kinetic therapy more than standard therapy</td>
<td></td>
</tr>
<tr>
<td>o 3 patients had circulatory stability problems during kinetic therapy</td>
<td></td>
</tr>
</tbody>
</table>

#### Non-Randomized Studies

**Chandy, 2007**

- ICU length of stay: 5.66 days for intervention vs. 5.28 days control \((P \text{ values not reported})\)
- Hospital length of stay: 7.7 days intervention vs. 8.2 days control \((P = \text{NS})\)
- Patients who underwent fibreoptic bronchoscopy for atelectasis: 83 patients (58% left side, 36% right side, 6% bilateral) for intervention vs. 71 patients (sides not reported) for control \((P \text{ values not reported})\)
- Ventilator-patient days: 22,626 intervention vs. 24,037 control \((P = \text{NS})\)

- Use of kinetic beds in the ICU does not assure the reduction of atelectasis in mechanically ventilated patients.
- In order to observe the benefits of kinetic beds protocols are likely needed.

**Chipman, 2006**

- Number of patients with infectious complications: 14 (23%) intervention vs. 3 (6%) control \((P = 0.03)\)
- Patients with respiratory failure: 17 (28%) intervention vs. 4 (9%) control \((P = 0.02)\)
- Patients with pneumonia: 9 (15%) vs. 3 (6%) \((P = 0.22)\)
- Ventilator duration (days): 3.1 (SD 7.6) intervention vs. 0.7 (SD 2.8) control \((P = 0.04)\)
- Hospital length of stay (days): 16.6 (SD 11.3) intervention vs. 11.6 (SD 5.6) control \((P < 0.01)\)

- Kinetic bed therapy was found to be associated with an increase in infectious complications, and ventilator days in patients with similar injury severity who underwent surgery for thoracolumbar spine injuries.
- Authors speculated that the increased infectious complications likely contributed to increased length of stay in the kinetic therapy group.

CI = confidence interval; ICU = intensive care unit; OR = odds ratio; \(P(A-a)O_2\) = arterial-alveolar oxygen tension difference RR = risk ratio; SD = standard deviation; SMD = standardized mean difference; VAP = ventilator-associated pneumonia; vs = versus
APPENDIX 5: Additional References of Potential Interest

Excluded – studies examined the type of positioning of patients in kinetic beds
