Cochrane
Library

Cochrane Database of Systematic Reviews

Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation (Review)

Wang L, Li X, Yang Z, Tang X, Yuan Q, Deng L, Sun X

Wang L, Li X, Yang Z, Tang X, Yuan Q, Deng L, Sun X.

Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation.

Cochrane Database of Systematic Reviews 2016, Issue 1. Art. No.: CD009946.

DOI: [10.1002/14651858.CD009946.pub2](https://doi.org/10.1002/14651858.CD009946.pub2).

www.cochranelibrary.com

Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation (Review)

Copyright © 2016 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

WILEY

TABLE OF CONTENTS

HEADER	1
ABSTRACT	1
PLAIN LANGUAGE SUMMARY	2
SUMMARY OF FINDINGS	4
BACKGROUND	8
OBJECTIVES	8
METHODS	8
Figure 1.	10
RESULTS	12
Figure 2.	12
Figure 3.	13
Figure 4.	16
DISCUSSION	16
AUTHORS' CONCLUSIONS	18
ACKNOWLEDGEMENTS	18
REFERENCES	19
CHARACTERISTICS OF STUDIES	23
DATA AND ANALYSES	37
Analysis 1.1. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 1 Clinically suspected pneumonia.	39
Analysis 1.2. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 2 Microbiologically confirmed VAP.	39
Analysis 1.3. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 3 ICU mortality. ...	39
Analysis 1.4. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 4 Hospital mortality.	40
Analysis 1.5. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 5 Length of ICU stay (days).	40
Analysis 1.6. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 6 Length of hospital stay (days).	40
Analysis 1.7. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 7 Duration of ventilation (days).	41
Analysis 1.8. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 8 Use of antibiotics.	41
Analysis 1.9. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 9 Pressure ulcers. ..	41
Analysis 1.10. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 10 Subgroup analysis 1: clinically suspected pneumonia.	42
Analysis 1.11. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 11 Subgroup analysis 2: clinically suspected pneumonia.	42
Analysis 1.12. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 12 Subgroup analysis 3: clinically suspected pneumonia.	43
Analysis 1.13. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 13 Sensitivity analysis: length of ICU stay (days).	44
Analysis 1.14. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 14 Sensitivity analysis: length of hospital stay (days).	44
Analysis 1.15. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 15 Sensitivity analysis: duration of ventilation (days).	44
Analysis 2.1. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 1 Clinically suspected VAP.	45
Analysis 2.2. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 2 Microbiologically confirmed VAP.	45
Analysis 2.3. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 3 ICU mortality.	46
Analysis 2.4. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 4 Hospital mortality.	46
Analysis 2.5. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 5 Length of ICU stay (days).	46
Analysis 2.6. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 6 Use of antibiotics.	46
APPENDICES	47
CONTRIBUTIONS OF AUTHORS	49

DECLARATIONS OF INTEREST	49
SOURCES OF SUPPORT	49
DIFFERENCES BETWEEN PROTOCOL AND REVIEW	50
INDEX TERMS	50

[Intervention Review]

Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation

Li Wang¹, Xiao Li², Zongxia Yang², Xueli Tang², Qiang Yuan², Lijing Deng³, Xin Sun⁴

¹Chinese Cochrane Centre, West China Hospital, Sichuan University, Chengdu, China. ²Chinese Evidence-Based Medicine Centre, West China Hospital, Sichuan University, Chengdu, China. ³Intensive Care Unit, West China Hospital, Sichuan University, Chengdu, China.

⁴Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Canada

Contact address: Li Wang, Chinese Cochrane Centre, West China Hospital, Sichuan University, No. 37, Guo Xue Xiang, Chengdu, Sichuan, 610041, China. cochrane@163.com, wangli_74@hotmail.com.

Editorial group: Cochrane Acute Respiratory Infections Group.

Publication status and date: New, published in Issue 1, 2016.

Citation: Wang L, Li X, Yang Z, Tang X, Yuan Q, Deng L, Sun X. Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation. *Cochrane Database of Systematic Reviews* 2016, Issue 1. Art. No.: CD009946. DOI: [10.1002/14651858.CD009946.pub2](https://doi.org/10.1002/14651858.CD009946.pub2).

Copyright © 2016 The Cochrane Collaboration. Published by John Wiley & Sons, Ltd.

ABSTRACT

Background

Ventilator-associated pneumonia (VAP) is associated with increased mortality, prolonged length of hospital stay and increased healthcare costs in critically ill patients. Guidelines recommend a semi-recumbent position (30° to 45°) for preventing VAP among patients requiring mechanical ventilation. However, due to methodological limitations in existing systematic reviews, uncertainty remains regarding the benefits and harms of the semi-recumbent position for preventing VAP.

Objectives

To assess the effectiveness and safety of semi-recumbent positioning versus supine positioning to prevent ventilator-associated pneumonia (VAP) in adults requiring mechanical ventilation.

Search methods

We searched CENTRAL (2015, Issue 10), which includes the Cochrane Acute Respiratory Infections Group's Specialised Register, MEDLINE (1946 to October 2015), EMBASE (2010 to October 2015), CINAHL (1981 to October 2015) and the Chinese Biomedical Literature Database (CBM) (1978 to October 2015).

Selection criteria

We included randomised controlled trials (RCTs) comparing semi-recumbent versus supine positioning (0° to 10°), or RCTs comparing alternative degrees of positioning in mechanically ventilated patients. Our outcomes included clinically suspected VAP, microbiologically confirmed VAP, intensive care unit (ICU) mortality, hospital mortality, length of ICU stay, length of hospital stay, duration of ventilation, antibiotic use and any adverse events.

Data collection and analysis

Two review authors independently and in duplicate screened titles, abstracts and full texts, assessed risk of bias and extracted data using standardised forms. We calculated the mean difference (MD) and 95% confidence interval (95% CI) for continuous data and the risk ratio (RR) and 95% CI for binary data. We performed meta-analysis using the random-effects model. We used the grading of recommendations, assessment, development and evaluation (GRADE) approach to grade the quality of evidence.

Main results

We included 10 trials involving 878 participants, among which 28 participants in two trials did not provide complete data due to loss to follow-up. We judged all trials to be at high risk of bias.

Semi-recumbent position (30° to 60°) versus supine position (0° to 10°)

A semi-recumbent position (30° to 60°) significantly reduced the risk of clinically suspected VAP compared to a 0° to 10° supine position (eight trials, 759 participants, 14.3% versus 40.2%, RR 0.36; 95% CI 0.25 to 0.50; risk difference (RD) 25.7%; 95% CI 20.1% to 30.1%; GRADE: moderate quality evidence).

There was no significant difference between the two positions in the following outcomes: microbiologically confirmed VAP (three trials, 419 participants, 12.6% versus 31.6%, RR 0.44; 95% CI 0.11 to 1.77; GRADE: very low quality evidence), ICU mortality (two trials, 307 participants, 29.8% versus 34.3%, RR 0.87; 95% CI 0.59 to 1.27; GRADE: low quality evidence), hospital mortality (three trials, 346 participants, 23.8% versus 27.6%, RR 0.84; 95% CI 0.59 to 1.20; GRADE: low quality evidence), length of ICU stay (three trials, 346 participants, MD -1.64 days; 95% CI -4.41 to 1.14 days; GRADE moderate quality evidence), length of hospital stay (two trials, 260 participants, MD -9.47 days; 95% CI -34.21 to 15.27 days; GRADE: very low quality evidence), duration of ventilation (four trials, 458 participants, MD -3.35 days; 95% CI -7.80 to 1.09 days), antibiotic use (three trials, 284 participants, 84.8% versus 84.2%, RR 1.00; 95% CI 0.97 to 1.03) and pressure ulcers (one trial, 221 participants, 28% versus 30%, RR 0.91; 95% CI 0.60 to 1.38; GRADE: low quality evidence). No other adverse events were reported.

Semi-recumbent position (45°) versus 25° to 30°

We found no statistically significant differences in the following prespecified outcomes: clinically suspected VAP (two trials, 91 participants, RR 0.74; 95% CI 0.35 to 1.56; GRADE: very low quality evidence), microbiologically confirmed VAP (one trial, 30 participants, RR 0.61; 95% CI 0.20 to 1.84; GRADE: very low quality evidence), ICU mortality (one trial, 30 participants, RR 0.57; 95% CI 0.15 to 2.13; GRADE: very low quality evidence), hospital mortality (two trials, 91 participants, RR 1.00; 95% CI 0.38 to 2.65; GRADE: very low quality evidence), length of ICU stay (one trial, 30 participants, MD 1.6 days; 95% CI -0.88 to 4.08 days; GRADE: very low quality evidence) and antibiotic use (two trials, 91 participants, RR 1.11; 95% CI 0.84 to 1.47). No adverse events were reported.

Authors' conclusions

A semi-recumbent position ($\geq 30^\circ$) may reduce clinically suspected VAP compared to a 0° to 10° supine position. However, the evidence is seriously limited with a high risk of bias. No adequate evidence is available to draw any definitive conclusion on other outcomes and the comparison of alternative semi-recumbent positions. Adverse events, particularly venous thromboembolism, were under-reported.

PLAIN LANGUAGE SUMMARY

Head bed elevation versus flat bed for preventing ventilator-associated pneumonia (VAP) in adults requiring mechanical ventilation

Background

Adults who are critically ill often need a machine to help maintain their breathing. One side effect of these machines is an increased risk of pneumonia. This is known as ventilator-associated pneumonia (VAP). It is a leading cause of death in critically ill patients and can also increase the length of hospital stay and healthcare costs. The angle at which ventilated patients lie might play an important role in preventing the infection of their lungs.

Review questions

Head bed elevation by tilting the angle of the hospital bed might prevent the source of infection from getting into the lung. We assessed the benefit and harm of semi-recumbent positioning for the prevention of VAP in critically ill adult patients requiring mechanical ventilation. We also investigated the best angle of head bed elevation in a semi-recumbent position.

Study characteristics

We identified 10 studies involving 878 participants. Twenty-eight participants were lost to follow-up. The evidence is current up to 27 October 2015. All participants were recruited from intensive care units (ICUs) and received mechanical ventilation for more than 48 hours.

Key results and quality of the evidence

Moderate quality evidence from eight studies involving 759 participants demonstrated that a semi-recumbent (30° to 60°) position reduced clinically suspected VAP by 25.7% when compared to a 0° to 10° supine position. Based on this result, we would expect that out of 1000 critically ill adult patients who are nursed in the semi-recumbent position (30° to 60°) for more than 48 hours, 145 patients would experience clinically suspected VAP compared to 402 patients nursed in the 0° to 10° supine position. There was no significant difference between the two positions in reducing microbiologically confirmed VAP (very low quality evidence), mortality (low quality evidence), length of ICU stay (moderate quality evidence), hospital stay (very low quality evidence), duration of ventilation or use of antibiotics. The main limitations of

the evidence were the small numbers of participants contributing data to the analyses and that for some studies researchers would have known which treatment group participants were from (a risk of bias).

Only two studies with 91 participants compared different degrees of bed head angle (45° versus 25° to 30° semi-recumbent position). Very low quality evidence showed no statistically significant differences in the effects of VAP (clinically suspected and microbiologically confirmed), mortality (ICU and hospital), length of ICU stay or use of antibiotics. Only one study reported the adverse event of pressure ulcers and did not find a difference between the 45° semi-recumbent and 10° supine positions. No other adverse events, such as thromboembolism, or side effects on heart rate or blood pressure were reported.

The balance of the benefit and harm of semi-recumbent positioning still remains uncertain due to the limited numbers of studies and the low quality of the existing evidence. More high quality evidence is required on the effects of the semi-recumbent versus supine position and the optimal body positions.

SUMMARY OF FINDINGS

Summary of findings for the main comparison. Semi-recumbent position (30° to 60°) versus supine position (0° to 10°) for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation

Patient or population: adults requiring mechanical ventilation
Settings: intensive care unit (ICU)
Intervention: semi-recumbent position (30° to 60°)
Comparison: supine position (0° to 10°)

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)
	Assumed risk	Corresponding risk			
	0° to 10° supine position	Semi-recumbent position			
Clinically suspected VAP Follow-up: > 48 hours	402 per 1000	145 per 1000 (100 to 201)	RR 0.36 (0.25 to 0.50)	759 (8 studies)	⊕⊕⊕⊖ moderate due to risk of bias ¹
Microbiologically confirmed VAP Follow-up: > 48 hours	316 per 1000	139 per 1000 (35 to 559)	RR 0.44 (0.11 to 1.77)	419 (3 studies)	⊕⊖⊖⊖ very low due to inconsistency ² , imprecision ³ and reporting bias ⁴
ICU mortality Follow-up: > 48 hours	276 per 1000	240 per 1000 (163 to 350)	RR 0.87 (0.59 to 1.27)	307 (2 studies)	⊕⊕⊖⊖ low due to imprecision ³ and reporting bias ⁴
Hospital mortality Follow-up: > 48 hours	343 per 1000	288 per 1000 (202 to 411)	RR 0.84 (0.59 to 1.20)	346 (3 studies)	⊕⊕⊖⊖ low due to imprecision ³ and reporting bias ⁴
Length of ICU stay Follow-up: > 48 hours	—	The mean length of ICU stay in the intervention groups was 1.64 days lower (4.41 days lower to 1.14 days higher)	MD -1.64 days (-4.41 to 1.14 days)	346 (3 studies)	⊕⊕⊕⊖ moderate due to imprecision ³

Length of hospital stay Follow-up: > 48 hours	—	The mean length of hospital stay in the intervention groups was 9.47 days lower (34.21 days lower to 15.27 days higher)	MD -9.47 days (-34.21 to 15.27 days)	260 (2 studies)	⊕⊕⊕⊕ very low due to inconsistency ⁵ , imprecision ³ and reporting bias ⁴
Pressure ulcers Follow-up: > 48 hours	303 per 1000	276 per 1000 (182 to 418)	RR 0.91 (0.60 to 1.38)	221 (1 study)	⊕⊕⊕⊕ low due to imprecision ³ and reporting bias ⁴

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **ICU:** intensive care unit; **MD:** mean difference; **RR:** risk ratio; **VAP:** ventilator-associated pneumonia

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

¹Six out of eight studies did not report the methods of random sequence generation and allocation concealment. None of them were able to blind the patients and caregivers. Seven of eight did not blind outcome assessors. One of the studies was stopped early for benefit.

²Heterogeneity test P value = 0.006, I² statistic = 87%.

³95% confidence interval includes no effect and fails to exclude important benefit or important harm.

⁴Only a few studies reported this outcome and there was asymmetry in the funnel plot.

⁵Heterogeneity test P value < 0.00001, I² statistic = 98%.

Summary of findings 2. Semi-recumbent positioning: 45° versus 25° to 30° for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation

Patient or population: adults requiring mechanical ventilation

Settings: intensive care unit (ICU)

Intervention: semi-recumbent position: 45°

Comparison: supine position: 25° to 30°

Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)
	Assumed risk	Corresponding risk

	25° to 30° supine position	Semi-recumbent position: 45°			
Clinically suspected VAP Follow-up: > 48 hours	261 per 1000	193 per 1000 (91 to 407)	RR 0.74 (0.35 to 1.56)	91 (2 studies)	⊕⊕⊕⊕ very low due to risk of bias ¹ , imprecision ² and reporting bias ³
Microbiologically confirmed VAP Follow-up: > 48 hours	385 per 1000	235 per 1000 (77 to 708)	RR 0.61 (0.20 to 1.84)	30 (1 study)	⊕⊕⊕⊕ very low due to risk of bias ⁴ , imprecision ² and reporting bias ³
ICU mortality Follow-up: > 48 hours	308 per 1000	202 per 1000 (62 to 486)	OR 0.57 (0.15 to 2.13)	30 (1 study)	⊕⊕⊕⊕ very low due to risk of bias ⁴ , imprecision ² and reporting bias ³
Hospital mortality Follow-up: > 48 hours	130 per 1000	130 per 1000 (50 to 346)	OR 1.00 (0.38 to 2.65)	91 (2 studies)	⊕⊕⊕⊕ very low due to risk of bias ¹ , imprecision ² and reporting bias ³
Length of ICU stay Follow-up: > 48 hours	—	The mean length of ICU stay in the intervention groups was 1.6 days higher (0.88 lower to 4.08 higher)	MD 1.6 days (-0.88 to 4.08 days)	61 (1 study)	⊕⊕⊕⊕ very low due to risk of bias ⁵ , imprecision ² and reporting bias ³

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: confidence interval; **ICU:** intensive care unit; **MD:** mean difference; **OR:** odds ratio; **RR:** risk ratio; **VAP:** ventilator-associated pneumonia

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

- ¹Loss to follow-up was over 40% in one study. The method of allocation concealment was unclear in the other study. Neither of them blinded the patients, caregivers or outcome assessors.
- ²95% confidence interval includes no effect fails to exclude important benefit or important harm.
- ³Only a few studies reported this outcome.
- ⁴Loss to follow-up was over 40% and there was no blinding of the patients, caregivers or outcome assessors.
- ⁵Unpublished data with no information about methodological issues.

BACKGROUND

Description of the condition

Ventilator-associated pneumonia (VAP) is a nosocomial pneumonia that can occur in patients receiving mechanical ventilation for a prolonged period (Kollef 2005), usually 48 to 72 hours after endotracheal intubation (Pieracci 2007). Early-onset VAP occurs 48 to 96 hours after intubation and late-onset VAP is seen 96 hours after intubation (Augustyn 2007).

VAP is a leading cause of death in patients on mechanical ventilation and is also associated with increased length of hospital stay and healthcare costs (Safdar 2005; Van Nieuwenhoven 2006; Warren 2003). The incidence of VAP ranges between 9% and 27% in Europe and the USA (Craven 2000; Klompas 2007; Rea-Neto 2008), and rises to 41% in low-income countries (Rosenthal 2006). Data from the United States National Nosocomial Infection Surveillance (NNIS) system showed that 31% of nosocomial infections were pneumonia (Richards 1999), of which 95% were associated with the use of mechanical ventilation (Mirza 2012). VAP is attributable to 20% to 50% of deaths in patients on mechanical ventilation; the mortality rate reaches up to 70% in patients with multi-resistant infections (Rea-Neto 2008). The mortality rate of patients with VAP is twice as high as those without (Safdar 2005). Therefore, preventing the development of VAP is critical in patients using mechanical ventilation.

Description of the intervention

A number of strategies are available to reduce the incidence and serious complications of VAP (Caruso 2009; Dennis 2001; Subirana 2007; Van Nieuwenhoven 2004). Physical strategies include the orotracheal route of intubation, airway humidification, use of a closed endotracheal suctioning system and continuous aspiration of subglottic secretions. Positional strategies include semi-recumbent and prone positioning. Other strategies include pharmacological interventions (e.g. antibiotics) and system-level approaches such as strict infection control and microbiologic surveillance (El-Khatib 2010; Mohamad 2010; Muscedere 2008).

Several guidelines from the American Thoracic Society, the Infectious Diseases Society of America, the Centers for Disease Control and Prevention (CDC), and others have recommended semi-recumbent positioning (i.e. elevation of the head-of-bed to 30° to 45°) for the prevention of VAP in mechanically ventilated patients (ATS-IDSA 2005; CDC 1997; Dodek 2004; El-Khatib 2010; Muscedere 2008). A randomised cross-over trial using radioactively labelled gastric contents revealed that ventilated patients in a semi-recumbent position can reduce reflux of contaminated gastric contents and aspiration (Torres 1992). It also suggested that aspiration of contaminated oropharyngeal secretions and gastric contents poses a major risk factor for VAP. Another randomised trial showed a threefold reduction in the incidence of VAP in mechanically ventilated patients using a semi-recumbent versus a supine position (Drakulovic 1999).

How the intervention might work

Contamination of oropharyngeal secretions and gastric contents with subsequent aspiration to the lower airways are pathogenic factors for VAP (Orozco-Levi 1995). Supine positioning, gastric tubes and stomach contents lead to the reflux of gastric contents, aspiration and, as a result, cause VAP. Semi-recumbent

positioning may help avoid these problems and reduce VAP (Keeley 2007). Using radioactively labelled enteral feeding, the risk of gastroesophageal reflux and aspiration was lower among patients in a semi-recumbent position than those in a completely supine position (Orozco-Levi 1995; Torres 1992).

Why it is important to do this review

While strategies for preventing VAP focus on the prevention of gastric colonisation and aspiration of infected gastric secretions (Collard 2003), semi-recumbent positioning has the advantage of convenience and almost no cost to implement (Keeley 2007). A multi-centre observational study revealed that the majority of mechanically ventilated patients are positioned with their head-of-bed angle at less than 30° (Reeve 1999). A head-of-bed positioning of less than 30° was likely to be associated with an increased risk of VAP and mortality during the first 24 hours of mechanical ventilation (Fernández-Crehuet 1997; Kollef 1993). However, these findings were inconsistent.

Some systematic reviews have indicated that 45° semi-recumbent positioning significantly reduced the risk of clinically diagnosed VAP compared to the supine position (Alexiou 2009; Leng 2012b; Liu 2011a; Mao 2013); others did not report similar findings (Niel-Weise 2011). All of the systematic reviews have some methodological limitations. A few studies even suggested that the increased elevation of the head might increase the risk of sacral pressure ulcers (Lippoldt 2014), haemodynamic instability (Gocze 2013), and venous thromboembolism (Simini 2000). Taking the overall body of evidence into consideration, the relative effects – benefits and harms – of alternative body positioning on the prevention of VAP remain inconclusive.

OBJECTIVES

To assess the effectiveness and safety of semi-recumbent positioning versus supine positioning to prevent ventilator-associated pneumonia (VAP) in adults requiring mechanical ventilation.

METHODS

Criteria for considering studies for this review

Types of studies

We included randomised controlled trials (RCTs). We excluded trials with cluster-randomisation or with a cross-over design because of the concern about 'herd effect' in cluster-randomised trials and 'carry-over' effect in cross-over trials. We also excluded quasi-RCTs due to the potential problems with imbalanced prognosis and the failure to conceal the treatment allocation. We did not exclude any studies on the basis of language of publication.

Types of participants

We included adult patients (18 years or older) undergoing endotracheal intubation and mechanical ventilation. We excluded studies among which more than 15% of patients were ineligible for semi-recumbent positioning, e.g. abdominal surgery, obesity (body mass index (BMI) greater than 30 kg/m²) (WHO 2000).

Types of interventions

We included studies comparing semi-recumbent positioning versus supine positioning in mechanically ventilated patients. We used the authors' definition regarding the semi-recumbent position. The supine position is defined as the body positioning with 0° to 10° head-of-bed elevation. We also included studies comparing different degrees of body positioning.

Types of outcome measures

Primary outcomes

1. Clinically suspected VAP, defined as a new, persistent or progressive radiographic infiltrate with at least two of the following criteria: fever (temperature > 38 °C or < 35 °C); leucocytosis or leucopenia (leucocytes > 10 × 10⁹/L or < 3 × 10⁹/L); and a positive culture of tracheal secretion (CDC 1997).
2. Microbiologically confirmed VAP, diagnosed according to the following: 10³ cfu/mL in protected specimen brush cultures; 10⁴ cfu/mL in bronchoalveolar lavage (El-Ebiary 1993); and 10⁵ cfu/mL in tracheobronchial aspirate (Meduri 1992).
3. Composite of clinically suspected and clinically confirmed VAP.
4. Intensive care unit (ICU) mortality.
5. Hospital mortality.

Secondary outcomes

1. Length of ICU stay.
2. Length of hospital stay.
3. Duration of ventilation.
4. Use of antibiotics.
5. Any adverse events reported by study authors, such as device-related adverse events (sore throat, laryngitis, discoloured tongue, dysphagia and laryngospasm), aspiration, venous thromboembolism, pressure ulcers and haemodynamic instability (e.g. hypotension, hypertension, abnormal heart rate, etc).

Search methods for identification of studies

Electronic searches

We searched the Cochrane Central Register of Controlled Trials (CENTRAL 2015, Issue 10) (accessed 27 October 2015), which

includes the Cochrane Acute Respiratory Infections Group's Specialised Register, MEDLINE (1946 to October 2015), EMBASE (2010 to October 2015), CINAHL (1981 to October 2015) and the Chinese Biomedical Literature Database (CBM) (1978 to October 2015).

We used the search strategy in Appendix 1 to search CENTRAL and MEDLINE (Ovid). We combined the MEDLINE search strategy with the Cochrane Highly Sensitive Search Strategy for identifying randomised trials in MEDLINE: sensitivity- and precision-maximising version (2008 revision); Ovid format (Lefebvre 2011). We adapted the search strategy for MEDLINE to search EMBASE (Appendix 2), CINAHL (Appendix 3) and CBM (Appendix 4) from the inception to 27 October 2015.

We did not apply any restrictions on language, date or publication type. We also included abstracts and unpublished data.

Searching other resources

We retrieved the reference lists of included studies, reviews and conference proceedings to identify all eligible studies. We also searched for unpublished studies and clinical trials on the following sites.

1. World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) (www.apps.who.int/trialsearch/).
2. ClinicalTrials.gov (www.clinicaltrials.gov/).

Data collection and analysis

Selection of studies

Two review authors (XL, XT) independently and in duplicate screened titles and abstracts for initial eligibility, as well as full texts for final eligibility. A third review author (LW) was consulted to resolve disagreements. We identified and excluded duplicates and collated multiple reports of the same study so that each study rather than each report is the unit of interest in the review. We recorded the selection process in sufficient detail to complete a PRISMA flow diagram (Figure 1) (Moher 2009), and 'Characteristics of excluded studies' table. We did not impose any language restrictions.

Figure 1. Figure 1. Flow diagram.

Data extraction and management

Two review authors (XL, ZY) independently and in duplicate extracted the following data and, where needed, a third review author (LW) adjudicated to resolve disagreements.

1. General study information: title, authors, contact address, publication source, publication year.
2. Study characteristics: design, study setting, inclusion and exclusion criteria, total sample size, sample size per group, number of comparisons.
3. Patient characteristics: age, sex, smoking, disease condition (e.g. trauma or emergency surgery, chronic obstructive pulmonary disease (COPD), acute respiratory distress syndrome), clinical pulmonary infection score (CPIS), APACHE II score, enteral feeding, use of sucralfate or H2 antagonists for stress ulcer prophylaxis, use of antibiotics, baseline comparability.
4. Intervention characteristics: positional types, head-of-bed angles, correctness of the position.
5. Outcomes measures: clinically suspected VAP, microbiologically confirmed VAP, hospital mortality, ICU mortality, duration of ventilation, length of ICU stay, length of hospital stay, use of antibiotics and adverse events.

Assessment of risk of bias in included studies

Two review authors (XL, ZY) independently and in duplicate assessed the risk of bias and a third review author (LW) was consulted to resolve discrepancies. We assessed the risk of bias of included trials using the criteria from the *Cochrane Handbook for Systematic Reviews of Interventions* including random sequence generation, allocation concealment, blinding of participants and caregivers, blinding of outcome assessors, incomplete outcome data and selective outcome reporting (Higgins 2011). We judged each of these domains as high, low or unclear risk of bias.

Measures of treatment effect

We used the mean difference (MD) and 95% confidence intervals (95% CI) to calculate continuous data (e.g. duration of ventilation, length of ICU stay, length of hospital stay) and risk ratio (RR) and 95% CI for binary data (e.g. clinically suspected VAP, microbiologically confirmed VAP, mortality).

Unit of analysis issues

We used data from parallel-group trials in which the unit of randomisation was the individual patient. We collected and analysed a single measurement for each outcome.

Dealing with missing data

One study reported the median and range of length of ICU and hospital stay and duration of ventilation (van Nieuwenhoven 2006). We assumed that the distribution of data was normal and imputed the standard deviation using the largest standard deviation from included studies when they reported the same outcome (Higgins 2011). We conducted a post hoc sensitivity analysis to explore the impact of data imputation.

Assessment of heterogeneity

We used the Chi² test and the I² statistic to assess heterogeneity among trials in each meta-analysis (Higgins 2003). We considered

an I² statistic between 0% to 30% as trivial or low heterogeneity; 31% to 50% as moderate heterogeneity; 51% to 75% as substantial heterogeneity; and 76% to 100% as considerable heterogeneity.

Assessment of reporting biases

We used both visual inspection of funnel plots and Egger's test to explore publication bias for the primary outcomes (Egger 1997).

Data synthesis

We performed meta-analysis using the random-effects model, which is more conservative than the fixed-effect model as it considers within-studies and between-studies differences in calculating the standard error used in the analysis (Higgins 2011). We used Review Manager software for data analysis (RevMan 2014).

GRADE and 'Summary of findings' table

We created a 'Summary of findings' table using clinically important outcomes: clinically suspected VAP, microbiologically confirmed VAP, ICU mortality, hospital mortality, length of ICU stay, length of hospital stay and pressure ulcers. We used the GRADE approach to categorise confidence in effect estimates for clinically important outcomes as high, moderate, low or very low (Guyatt 2011). We used the five GRADE considerations (study limitations, consistency of effect, imprecision, indirectness and publication bias) to assess the quality of the body of evidence as it relates to the studies that contribute data to the meta-analyses for the prespecified outcomes (Atkins 2004). We used the methods and recommendations described in Section 8.5 and Chapter 12 of the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011), using GRADEproGDT software (GRADEproGDT 2015). We justified all decisions to downgrade or upgrade the quality of studies using footnotes, and we made comments to aid the reader's understanding of the review where necessary.

Subgroup analysis and investigation of heterogeneity

We performed pre-defined subgroup analyses with the hypothesis of the direction of subgroup effects. We evaluated the difference in effects between subgroups using interaction tests in the subgroup analyses.

1. Duration of mechanical ventilation (< 96 hours versus ≥ 96 hours) - larger effect in < 96 hours subgroup.
2. Head-of-bed angle of semi-recumbent position (< 30° versus ≥ 30°) - larger effect in ≥ 30° semi-recumbent position.
3. Allocation concealment (yes versus no) - larger effect in studies with inadequate allocation concealment.
4. Blinding of outcome assessors (yes versus no) - larger effect in studies without blinding of outcome assessors.

Sensitivity analysis

We conducted sensitivity analyses using alternative effect measures (risk ratio (RR) versus odds ratio (OR)) and statistical models (random-effects model using Mantel-Haenszel method versus inverse variance method). Also, we conducted a post hoc sensitivity analysis to explore the impact of imputed data for missing standard deviations.

RESULTS

Description of studies

Results of the search

Figure 1 illustrates the flow diagram of study selection. We identified 420 deduplicated records from the search of the electronic databases. Twenty-six studies were potentially eligible, among which we included 10 (Cai 2006; Drakulovic 1999; Hang 2012; Hu 2012; Keeley 2007; Leng 2012; van Nieuwenhoven 2006; Wu 2009; Xue 2012; Yu 2012). We excluded 16 studies (Characteristics of excluded studies).

We identified one additional RCT with an unpublished full text (Leng 2012), after searching the reference lists of a published systematic review. We did not find any other unpublished trials from the WHO International Clinical Trials Registry Platform and ClinicalTrials.gov.

Included studies

Among the 10 included RCTs with 878 patients, three were published in English (Drakulovic 1999; Keeley 2007; van Nieuwenhoven 2006), and seven in Chinese (Cai 2006; Hang 2012; Hu 2012; Leng 2012; Wu 2009; Xue 2012; Yu 2012). All the participants were recruited from ICUs. Seven studies reported that enteral feeding was used among 80% to 100% of patients in five studies (Hang 2012; Hu 2012; Leng 2012; van Nieuwenhoven 2006;

Wu 2009), about 60% in one study (Drakulovic 1999), and 40% in Keeley 2007.

Most of the included studies were small, with a median sample size of 76, ranging from 39 to 221. Seven studies compared a semi-recumbent position (30° to 60°) versus a 0° supine position (Cai 2006; Drakulovic 1999; Hang 2012; Hu 2012; Wu 2009; Xue 2012; Yu 2012), among which three studies nursed patients in a semi-recumbent position at 30° to 45° (Hang 2012; Hu 2012; Xue 2012); one at 45° (Drakulovic 1999), one at 30° (Yu 2012), one at > 30° (Cai 2006), and one at 30° to 60° (Wu 2009). van Nieuwenhoven 2006 compared a 45° semi-recumbent position versus a 10° supine position; Keeley 2007 compared a 45° semi-recumbent position versus a 25° supine position; and Leng 2012 compared a 45° semi-recumbent position versus a 30° supine position in critically ill ventilated patients. Eight out of 10 studies did not report the implementation and monitoring of the semi-recumbent position (Cai 2006; Hang 2012; Hu 2012; Keeley 2007; Leng 2012; Wu 2009; Xue 2012; Yu 2012).

Excluded studies

We excluded 16 studies after the full-text screening for the following reasons: not a comparison of interest (n = 6), non-RCT study design (n = 5), quasi-RCT study design (n = 2), cross-over trial design (n = 1), not the target population (n = 1) and conference abstract (n = 1).

Risk of bias in included studies

Figure 2 and Figure 3 illustrate the risk of bias in the included studies.

Figure 2. 'Risk of bias' graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

Figure 3. 'Risk of bias' summary: review authors' judgements about each risk of bias item for each included study.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Cai 2006	?	?	?	?	+	?	?
Drakulovic 1999	+	+	?	?	-	+	-
Hang 2012	?	?	?	?	+	+	?
Hu 2012	?	?	?	?	+	+	?
Keeley 2007	+	+	?	?	-	?	?
Leng 2012	?	?	?	?	?	?	?
van Nieuwenhoven 2006	+	+	?	+	-	+	?
Wu 2009	?	?	?	?	+	+	?
Xue 2012	?	?	?	?	+	?	?
Yu 2012	?	?	?	?	+	?	?

Allocation

Three trials in English clearly reported the methods of randomisation sequence generation and concealed the allocation (Drakulovic 1999; Keeley 2007; van Nieuwenhoven 2006), while seven Chinese trials only reported that the patients were randomly allocated into two groups with no information on how the randomisation sequence was generated and whether allocation concealment was applied or not (Cai 2006; Hang 2012; Hu 2012; Leng 2012; Wu 2009; Xue 2012; Yu 2012).

Blinding

All trials failed to apply blinding to participants and caregivers, or to report the information about blinding, except for one study in which the outcome assessors were blinded for the diagnosis of VAP (van Nieuwenhoven 2006).

Incomplete outcome data

Three trials had differential withdrawal rates between groups, ranging from 3.3% to 44.4% (Drakulovic 1999; Keeley 2007; van Nieuwenhoven 2006), although intention-to-treat (ITT) analysis was applied to one study (van Nieuwenhoven 2006). Meanwhile, Keeley 2007 reported that over 40% of patients were lost to follow-up. Seven Chinese trials had no loss to follow-up (Cai 2006; Hang 2012; Hu 2012; Leng 2012; Wu 2009; Xue 2012; Yu 2012).

Selective reporting

We did not find protocols for any of the included studies. However, five trials reported all the outcomes that were stated in the methods section, including the most important outcomes, e.g. VAP (either clinically suspected or microbiologically confirmed VAP) and mortality (Drakulovic 1999; Hang 2012; Hu 2012; van Nieuwenhoven 2006; Wu 2009). The risk of reporting bias was unclear because protocols were not available or, in five trials, the description of expected outcomes in the methods section was unclear (Cai 2006; Keeley 2007; Leng 2012; Xue 2012; Yu 2012).

Other potential sources of bias

Drakulovic 1999 stopped the trial early due to significant benefit in the interim analysis when only 49.5% of anticipated patients were recruited. There was insufficient information to assess whether other potential risks of bias existed.

Effects of interventions

See: **Summary of findings for the main comparison** Semi-recumbent position (30° to 60°) versus supine position (0° to 10°) for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation; **Summary of findings 2** Semi-recumbent positioning: 45° versus 25° to 30° for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation

Semi-recumbent position (30° to 60°) versus supine position (0° to 10°)

Eight studies involving 764 patients compared a semi-recumbent position (30° to 60°) with a 0° supine position (Cai 2006; Drakulovic 1999; Hang 2012; Hu 2012; Wu 2009; Xue 2012; Yu 2012). One study had missing outcome data for four patients (Drakulovic 1999), thus we analysed 759 patients.

Primary outcomes

1. Clinically suspected ventilator-associated pneumonia (VAP)

When compared to a supine position (0° to 10°), a semi-recumbent position (30° to 60°) significantly reduced the risk of clinically suspected VAP (eight trials, 759 participants, 14.3% versus 40.2%, risk ratio (RR) 0.36; 95% CI 0.25 to 0.50; P value = 0.20, I² statistic = 29% (Analysis 1.1); risk difference (RD) 25.7%; 95% CI 20.1% to 30.1%; GRADE: moderate confidence in the estimate, [Summary of findings for the main comparison](#)).

2. Microbiologically confirmed VAP

Three studies reported microbiologically confirmed VAP (Drakulovic 1999; van Nieuwenhoven 2006; Wu 2009). There is a trend indicating that the semi-recumbent position (30° to 60°) might reduce microbiologically confirmed VAP. However, it did not reach significance (three trials, 419 participants, 12.6% versus 31.6%, RR 0.44; 95% CI 0.11 to 1.77; P value = 0.0006, I² statistic = 87%; GRADE: very low confidence in the estimate, [Summary of findings for the main comparison](#)) (Analysis 1.2). We detected significant heterogeneity (I² statistic = 87%). We did not conduct a subgroup analysis to explore the heterogeneity due to the small number of studies.

3. Composite of clinically suspected and clinically confirmed VAP

None of the included studies reported this outcome.

4. Intensive care unit (ICU) mortality

We found no significant difference in ICU mortality (Drakulovic 1999; van Nieuwenhoven 2006) (two trials, 307 participants, 29.8% versus 34.3%, RR 0.87; 95% CI 0.59 to 1.27; P value = 0.43, I² statistic = 0%; GRADE: low confidence in the estimate, [Summary of findings for the main comparison](#)) (Analysis 1.3).

5. Hospital mortality

There was no significant difference in hospital mortality (Drakulovic 1999; Hang 2012; van Nieuwenhoven 2006) (three trials, 346 participants, 23.8% versus 27.6%, RR 0.84; 95% CI 0.59 to 1.20; P value = 0.32, I² statistic = 12%; GRADE: low confidence in the estimate, [Summary of findings for the main comparison](#)) (Analysis 1.4).

Secondary outcomes

1. Length of ICU stay

Three studies reported length of ICU stay (Drakulovic 1999; Hang 2012; van Nieuwenhoven 2006). A semi-recumbent position (30° to 60°) might reduce the length of ICU stay. However, the result did not reach statistical significance (three trials, 346 participants, mean difference (MD) -1.64 days; 95% CI -4.41 to 1.14 days; P value = 0.21, I² statistic = 35%; GRADE: moderate confidence in the estimate, [Summary of findings for the main comparison](#)) (Analysis 1.5).

2. Length of hospital stay

Two studies reported length of hospital stay (Hang 2012; van Nieuwenhoven 2006). A semi-recumbent position (30° to 60°) might reduce the length of hospital stay by about 9.5 days. However, the reduction did not reach significance (two trials, 260 participants, MD -9.47 days; 95% CI -34.21 to 15.27 days; P value < 0.00001, I² statistic = 98%; GRADE: very low confidence in the estimate,

Summary of findings for the main comparison) (Analysis 1.6). An I^2 statistic of 98% represents high inconsistency between the two studies. We did not perform subgroup analyses due to the limited number of studies. However, we checked the data from the original studies: van Nieuwenhoven 2006 reported no difference in length of hospital stay between the semi-recumbent position (the average backrest elevation ranging from 23° to 29°) and the supine position (from 10° to 15°), while Hang 2012 reported a significant reduction in length of hospital stay when comparing a semi-recumbent position of 30° to 45° to a supine position of 0°.

3. Duration of ventilation

Four trials reported duration of ventilation (Drakulovic 1999; Hang 2012; van Nieuwenhoven 2006; Wu 2009). The pooled analysis did not find a significant difference between the two groups (four trials, 458 participants, MD -3.35 days; 95% CI -7.80 to 1.09 days; P value < 0.00001, I^2 statistic = 93%) (Analysis 1.7). We did not conduct a subgroup analysis to explore heterogeneity due to inadequate information about subgroup factors.

4. Use of antibiotics

Four studies reported use of antibiotics, but only three reported the number of patients using antibiotics (Drakulovic 1999; Hu 2012; Wu 2009). We found no significant difference between the two positions (three trials, 284 participants, 84.8% versus 84.2%, RR 1.00; 95% CI 0.97 to 1.03) (Analysis 1.8). van Nieuwenhoven 2006 reported that both the mean number of antibiotic courses and the number of days on antibiotics were equal in the two groups.

5. Any adverse events

Only one study reported pressure ulcers (van Nieuwenhoven 2006). There was no significant difference in pressure ulcers between the two groups (221 participants, 28% versus 30%, RR 0.91; 95% CI 0.60 to 1.38; GRADE: low confidence in the estimate Summary of findings for the main comparison) and most of them (71% versus 70%) were at stage 1 or 2 (Analysis 1.9). No other adverse events were reported, e.g. device-related adverse events, aspiration, venous thromboembolism and haemodynamic instability.

Semi-recumbent position 45° versus 25° to 30°

Only two studies compared a semi-recumbent position of 45° versus 25° (Keeley 2007) or 30° (Leng 2012), involving 115 patients at randomisation. However, 24 patients (44.4%) were lost to follow-up in one trial (Keeley 2007). Thus, only 91 patients were analysed when comparing a semi-recumbent position of 45° versus 25°.

Primary outcomes

1. Clinically suspected VAP

There was no significant difference in clinically suspected VAP (two trials, 91 participants, 22.2% versus 26.1%, RR 0.74; 95% CI 0.35 to 1.56; GRADE: very low confidence in estimates, Summary of findings 2) (Analysis 2.1).

2. Microbiologically confirmed VAP

Only one study reported no significant difference in microbiologically confirmed VAP between a semi-recumbent position of 45° versus 25° (Keeley 2007) (one trial, 30 participants, 23.5% versus 38.5%, RR 0.61; 95% CI 0.20 to 1.84; GRADE: very low confidence in estimates, Summary of findings 2) (Analysis 2.2).

3. Composite of clinically suspected and clinically confirmed VAP

Neither of the two studies reported this outcome.

4. ICU mortality

One study reported no significant difference in ICU mortality (Keeley 2007) (one trial, 30 participants, 17.6% versus 30.8%, RR 0.57; 95% CI 0.15 to 2.13; GRADE: very low confidence in estimates, Summary of findings 2) (Analysis 2.3).

5. Hospital mortality

Two studies reported no significant difference in hospital mortality (Keeley 2007; Leng 2012) (two trials, 91 participants, 15.6% versus 13.0%, RR 1.00; 95% CI 0.38 to 2.65; GRADE: very low confidence in estimates, Summary of findings 2) (Analysis 2.4).

Secondary outcomes

1. Length of ICU stay

Only one study reported no significant difference in length of ICU stay (Leng 2012) (one trial, 30 participants, MD 1.6 days; 95% CI -0.88 to 4.08 days; GRADE: very low confidence in estimates, Summary of findings 2) (Analysis 2.5).

2. Length of hospital stay

No study reported the outcome of length of hospital stay.

3. Duration of ventilation

One trial reported mean hours of ventilation among two subgroups of patients with or without VAP (Keeley 2007). Among patients without VAP, mean ventilated hours were 61.5 and 63.1 in the 45° and 25° semi-recumbent positions respectively, while among patients with VAP this was 160 and 172.5 hours in the two groups respectively. No standard deviations for the ventilated hours were available to test the difference between the 45° and 25° semi-recumbent positions, although it seems to be non-significant.

4. Use of antibiotics

Two studies did not find a significant difference in the use of antibiotics (Keeley 2007; Leng 2012) (two trials, 91 participants, 71.1% versus 60.9%, RR 1.11; 95% CI 0.84 to 1.47) (Analysis 2.6).

5. Any adverse events

No adverse events data were reported.

Subgroup analyses and sensitivity analyses

Pre-defined subgroup analysis only found a significant interaction between blinding of outcome assessors and body positioning for clinically suspected VAP. We found a significant reduction of clinically suspected VAP only in studies with no blinding of outcome assessors (interaction P value = 0.005), although only one study reported blinding of outcome assessors and the average degrees of the semi-recumbent position only ranged from 23.1° to 29.3° (van Nieuwenhoven 2006). There was insufficient information for subgroup analyses of the different degrees of semi-recumbent positioning versus supine positioning. There was no significant interaction between allocation concealment and body positioning (interaction P value = 0.49). Only one study reported VAP according to different durations of mechanical ventilation (Drakulovic 1999).

(< 96 hours versus ≥ 96 hours) and found no difference between the two subgroups (interaction P value = 0.97).

Sensitivity analyses showed that the effects of a semi-recumbent position (30° to 60°) versus a supine position (0° to 10°) were robust when using alternative effect measures (risk ratio (RR) versus odds ratio (OR)) and statistical models (random-effects model using the Mantel-Haenszel method versus the inverse variance method). After excluding one study with imputation for missing standard deviations ([van Nieuwenhoven 2006](#)), the effect of a semi-recumbent position (30° to 60°) on the duration of ventilation did not change. However, the reduction of length of hospital

stay reached statistical significance after removing the study with imputation for missing standard deviations ([van Nieuwenhoven 2006](#)), although only one study was left to analyse this ([Hang 2012](#)).

Publication bias

We did not detect publication bias in the outcome clinically suspected VAP when comparing a semi-recumbent position (30° to 60°) with a 0° to 10° supine position; there was a relatively symmetrical funnel plot ([Figure 4](#)) and Egger's test P value = 0.293. However, publication bias may exist for the other outcomes, given that very few studies (from one to three) reported them.

Figure 4. Funnel plot of comparison: 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, outcome: 1.1 Clinically-suspected pneumonia.

DISCUSSION

Summary of main results

This systematic review shows that a semi-recumbent position (30° to 60°) significantly reduces the incidence of clinically suspected ventilator-associated pneumonia (VAP) (64% relative risk reduction, corresponding to 25.7% reduction in absolute risk) and we have moderate confidence in the estimate. When expressed as the number needed to treat to benefit (NNTB), every four patients nursed in a semi-recumbent position resulted in one patient free from clinically suspected VAP compared to the 0° to 10° supine position (NNTB = 4). However, the reduction of microbiologically confirmed VAP, hospital mortality, intensive care unit (ICU) mortality, length of ICU stay, length of hospital stay, use

of antibiotics and duration of ventilation did not reach statistical significance.

It remains uncertain which degrees of semi-recumbent position are optimal, given the very limited evidence amongst two trials of 91 patients that compared a semi-recumbent position at 45° versus 25° or 30°. There is no significant difference between alternative degrees of semi-recumbent positioning (GRADE: very low confidence in the estimate) in clinically suspected VAP, microbiologically confirmed VAP, ICU mortality, hospital mortality, length of ICU stay and use of antibiotics.

Adverse events were rarely reported. Only one study reported pressure ulcers, with no significant difference between a 45° semi-recumbent position (average degrees ranged from 23.1° to 29.3°) and a 10° supine position.

Overall completeness and applicability of evidence

This systematic review included 10 trials. Eight trials with 759 patients compared semi-recumbent positioning (30° to 60°) with supine positioning (0° to 10°) and two trials with 91 patients compared different degrees of semi-recumbent positioning (i.e. 45° versus 25° to 30°). The number of studies that investigated the effectiveness of semi-recumbent positioning for the prevention of VAP and the sample sizes were relatively small. All the participants were ICU patients requiring mechanical ventilation. Not all relevant outcome measures were reported, particularly adverse events. None of the included studies addressed venous thromboembolism, hypotension, hypertension, abnormal heart rate or device-related adverse events (sore throat, laryngitis, discoloured tongue, dysphagia and laryngospasm, aspiration, etc).

We applied comprehensive search strategies to several electronic databases and trial registers. There were no language or publication restrictions. However, most of the studies (seven out of 10 trials) were conducted in China, which may limit the applicability of evidence to broader healthcare systems.

Quality of the evidence

There were a number of limitations in the trials comparing a semi-recumbent position with a supine position or different degrees of semi-recumbent positions. None of the Chinese trials described randomisation details. It was not possible to blind patients and caregivers. Nevertheless, blinding of outcome assessors, particularly for the clinically suspected VAP outcome, was only applied in one trial ([van Nieuwenhoven 2006](#)). The loss to follow-up was high (44.4% in one trial, [Keeley 2007](#)). One trial was stopped early when about 50% of participants had been enrolled and the interim analysis found a significant reduction in clinically suspected pneumonia in the semi-recumbent position (P value = 0.003) ([Drakulovic 1999](#)). The results of the review need to be interpreted cautiously due to the risk of bias.

In addition, imprecision and reporting bias existed in most of the clinically important outcomes (e.g. microbiologically confirmed VAP, hospital mortality, ICU mortality, etc.), which are the major reasons why we downgraded the confidence in the estimates of effects.

The GRADE evidence profile demonstrated low to very low confidence in most of the estimates of effects ([Summary of findings for the main comparison](#); [Summary of findings 2](#)).

Potential biases in the review process

Despite the pre-specification of subgroup analyses, the lack of data and the small number of trials have limited the exploration of heterogeneity, particularly in outcomes other than clinically suspected VAP.

Our systematic review aimed to explore the effect of semi-recumbent versus supine positioning and the optimal head-of-bed angle of semi-recumbent positioning. However, nine out of 10 included studies did not report the adherence to the planned semi-recumbent position (e.g. 30° to 45°). Only three studies monitored and corrected the body positioning ([Drakulovic 1999](#); [van Nieuwenhoven 2006](#); [Wu 2009](#)). Only one trial consistently monitored the average angle of head-of-bed elevation in the semi-recumbent position group, which ranged from 23.1° to 29.2°

(much less than the target 45° semi-recumbent position) ([van Nieuwenhoven 2006](#)). The fact that usual practice failed to adhere to the recommended 30° to 45° semi-recumbent position is very common. Some studies have shown that patients receiving mechanical ventilation in the ICU were routinely nursed between the angles of 20° and 30° ([Cook 2002](#); [Grap 2005a](#); [Grap 2005b](#); [Liu 2003](#); [Wolken 2012](#)), and the adherence to a 30° to 45° semi-recumbent position only occurred in 15% to 58% of cases ([Cook 2000](#); [Liu 2011](#); [Yao 2013](#)). Therefore, the under-reporting of compliance with the designed head-of-bed angles for semi-recumbent positioning may affect the findings.

No gold standard is available for the diagnosis of VAP. Most of the included studies used, or slightly adjusted, the criteria for nosocomial infections defined by the Centers for Disease Control and Prevention for the diagnosis of clinically suspected VAP ([CDC 1997](#)). Additionally, no definition of VAP was reported in two trials ([Hu 2012](#); [Leng 2012](#)). If there is no clear and consistent definition of VAP, it will be difficult to differentiate between the diagnosis of VAP and nosocomial pneumonia – as is probably evident from the baseline risk of clinically suspected VAP across trials, which ranged from 18.3% to 85.7% (median 45.6%). The various definitions of VAP may have affected the findings.

We did not investigate the interaction between enteral feedings and body positioning, although some studies have suggested that enteral feeding was one of the most important risk factors for VAP ([Chen 2009](#); [Drakulovic 1999](#)).

We did not perform any sensitivity analysis to detect the impact of loss to follow-up in two studies (proportions of loss to follow-up were 3.3% and 44.4% respectively) ([Drakulovic 1999](#); [Keeley 2007](#)).

Agreements and disagreements with other studies or reviews

Our results are consistent with four systematic reviews that found a significant reduction in clinically suspected VAP and a trend toward a reduction of all-cause mortality ([Alexiou 2009](#); [Leng 2012b](#); [Liu 2011a](#); [Mao 2013](#)). However, clinically suspected VAP did not reach significance in one systematic review ([Niel-Weise 2011](#)), due to the underestimated events in one included trial ([Keeley 2007](#)), and the small number of included studies. Also, our review reported clinically important outcomes, e.g. microbiologically confirmed VAP, ICU mortality and length of ICU or hospital stay. We used GRADE, a transparent system for rating confidence in effect estimates (quality of evidence) to facilitate the interpretation of the findings of the study. In addition, our systematic review offers comparisons of effects between different degrees of head-of-bed elevation, despite limited evidence.

There are some limitations among the five published systematic reviews. Although they all included the three English language trials, they pooled data from [Keeley 2007](#) with data from other studies, which means that they considered a 25° body position as a supine position and pooled the 25° position with the 0° to 10° position. Some systematic reviews only reported a few outcomes (e.g. VAP and mortality) and failed to differentiate clinically suspected VAP and microbiologically confirmed VAP ([Alexiou 2009](#); [Leng 2012b](#); [Liu 2011](#); [Mao 2013](#)). Also, the searching for the five systematic reviews was not conducted recently and so they failed to include some trials included in our systematic review ([Cai 2006](#); [Hang 2012](#); [Hu 2012](#); [Xue 2012](#); [Yu 2012](#)). In addition, two Chinese

meta-analyses, [Liu 2011](#) and [Leng 2012b](#), included one cross-over study ([Xiao 2006](#)).

AUTHORS' CONCLUSIONS

Implications for practice

In this review, we found that the semi-recumbent position (30° to 60°) may effectively reduce clinically suspected ventilator-associated pneumonia (VAP) compared to the 0° to 10° supine position. However, due to the very limited numbers of included studies, with high risk of bias, the findings for the comparison between the semi-recumbent position and the supine position for the outcomes microbiologically confirmed VAP, intensive care unit (ICU) or hospital mortality, length of ICU or hospital stay, and pressure ulcers were far less conclusive. Adverse events, particularly venous thromboembolism, were under-reported. Overall, the optimal angle for semi-recumbent positioning remains uncertain due to very limited evidence.

Given the fact that there is no associated nursing cost in applying the semi-recumbent position and the potential benefit of reducing clinically suspected VAP, caregivers should discuss the use of the semi-recumbent position ($\geq 30^\circ$) with patients if no contraindications are present (e.g. patients with recent thoracic, abdominal or spine surgery/injury).

Implications for research

Future research should focus on adequately powered, well-designed randomised controlled trials (RCTs) to assess whether

the semi-recumbent position is superior to the supine position regarding patient-important outcomes, and which degree of head-of-bed elevation is optimal to balance the benefits with the potential risks, e.g. thromboembolism, decubitus ulcers or haemodynamic instability. Also, precise definitions of the outcomes and details about the implementation and monitoring of semi-recumbent positioning should be considered in future studies.

ACKNOWLEDGEMENTS

We are thankful to Sarah Thorning for developing the search strategies, to Jessica Moodie and Justin Clark for updating the search and to Manal Kassab, Lee Morrow, Francisco Baigorri, Viviana Rodriguez and Allen Cheng for commenting on the protocol. We are grateful to Jessica Moodie for her language editing. Finally we thank the following people for commenting on the draft review: Julie Gildie, Eman Sobh, Lee Morrow, Anju Sinha, Viviana Rodriguez and Allen Cheng.

Also, we would like to thank the National Natural Science Foundation of China (Project No. 71073105) and China Medical Board of New York for providing funding support for undertaking this study and staff training. The funding organisations had no role in the design and conduct of this systematic review, or in the preparation of, or decision to submit, the protocol.

REFERENCES

References to studies included in this review

Cai 2006 {published data only}

Fen C. Effect of different body position on ventilation-related pneumonia [不同体位对呼吸机相关性肺炎的影响]. *Journal of Nursing* 2006;**12**(04A):606-7.

Drakulovic 1999 {published data only}

Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogue S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomized trial. *Lancet* 1999;**354**(9193):1851-8.

Hang 2012 {published data only}

Hang H, Gu R. Semirecumbent position for the prevention of ventilator-associated pneumonia [半坐卧位在预防呼吸机相关性肺炎中的应用]. *Hu Li Shi Jian Yu Yan Jiu [Nursing Practice and Research]* 2012;**9**(4):48-9.

Hu 2012 {published data only}

Hu H. Posture management for the prevention of ventilator-associated pneumonia [体位护理预防机械通气相关性肺炎的影响]. *Yi Xue Qian Yan [Medical Frontier]* 2012;**8**(24):240-1.

Keeley 2007 {published data only}

Keeley L. Reducing the risk of ventilator-acquired pneumonia through head of bed elevation. *Nursing in Critical Care* 2007;**12**(6):287-94.

Leng 2012 {published data only}

Leng Y, Yi M, Nie C. 30 degree is more appropriate for the critically ill patients receiving mechanical ventilation. Unpublished but part of results presented in a meta-analysis 2012.

van Nieuwenhoven 2006 {published data only}

van Nieuwenhoven CA, Vandenbroucke-Grauls C, van Tiel FH, Joore HC, van Schijndel RJ, van der Tweel I, et al. Feasibility and effects of the semirecumbent position to prevent ventilator-associated pneumonia: a randomized study. *Critical Care Medicine* 2006;**34**(2):396-402.

Wu 2009 {published data only}

Wu H, Wei M, Wang J. Effect of different body position on ventilator-associated pneumonia [两种体位对呼吸机相关性肺炎的影响]. *Chinese Journal of General Practice* 2009;**7**(2):148-9.

Xue 2012 {published data only}

Xue F, Lin M. The effects of different positions for the prevention of ventilator-associated pneumonia [不同体位在预防呼吸机相关性肺炎的效果评价]. *Journal of Qiqihar University of Medicine* 2012;**33**(16):2261-2.

Yu 2012 {published data only}

Yu C, Wang W. The body position management in ICU for reducing ventilator-associated pneumonia incidence [ICU体位护理对减少机械通气相关性肺炎发病率的效果评价]. *Chinese Journal of Practical Nursing* 2012;**28**(11):21-2.

References to studies excluded from this review

Barber 2009 {published data only}

Barber LC, Mazer MA. Head of bed angle effects tidal volume in mechanically ventilated patients in the intensive care unit. *Chest* 2009;**136**(4):16s. [DOI: [10.1378/chest.136.4_MeetingAbstracts.16S-g](https://doi.org/10.1378/chest.136.4_MeetingAbstracts.16S-g)]

He 2011 {published data only}

He S. The effect of body position nursing in reducing incidence of ventilation associated pneumonia [体位护理在减少呼吸机相关性肺炎发生的作用]. *China Modern Medicine* 2011;**18**(6):115-6.

Leng 2012b {published data only}

Leng YX, Song YH, Yao ZY, Zhu X. Effect of 45 degree angle semirecumbent position on ventilator-associated pneumonia in mechanical ventilated patients: a meta-analysis [45. 半卧位对机械通气患者呼吸机相关性肺炎影响的Meta分析]. *Zhongguo Wei Zhong Bing Ji Jiu Yi Xue [Chinese Critical Care Medicine]* 2012;**24**(10):587-91.

Li 2013 {published data only}

Li R, Huang K, Wu C, Wang Z. Effect of modified body position combined with chlorhexidine oral cleaning on prevention of ventilator-associated pneumonia [改良式体位结合氯己定口腔清洁在呼吸机相关性肺炎预防中的效果]. *Zhong Hua Yi Yuan Gan Ran Xue Za Zhi [Chinese Journal of Nosocomiology]* 2013;**23**(16):4011-2.

Liu 2011a {published data only}

Liu Z, Ren W, Pan H. Meta-analysis of the impact of semirecumbent position on ventilator-associated pneumonia [半卧位对呼吸机相关肺炎影响的Meta分析]. *Zhong Hua Ji Zhen Yi Xue Za Zhi [Chinese Journal of Emergency Medicine]* 2011;**20**(2):147-50.

Liu 2011b {published data only}

Liu X, Xu F, Zhao Y. Application status and analysis of semirecumbent position of patients receiving mechanical ventilation [机械通气病人半卧位的规范应用现状及分析]. *Zhong Guo Hu Li Yan Jiu [Chinese Nursing Research]* 2011;**25**(10C):2741-2.

Liu 2013 {published data only}

Liu L. Oral rinse combined with body position for the prevention of ventilator-acquired pneumonia among 38 patients [口腔冲洗联合体位护理预防呼吸机相关性肺炎38例]. *China Pharmaceuticals* 2013;**22**(15):88-9.

Liu 2014 {published data only}

Liu L, Liu F, Zhan H, Wang Y, Xu S. The preventive effects of the intervention of changing patients body position from ventilator-associated pneumonia [强化气道管理对呼吸机相关性肺炎发生率影响的研究]. *Chinese Journal of Coal Industry Medicine* 2014;**17**(1):122-5.

Lu 2013 {published data only}

Lu C. Study on nursing body position for patients receiving mechanical ventilation [气管插管的卧位护理探讨]. *Ji Lin Yi Xue [Ji Lin Medicine]* 2013;**34**(17):3483-4.

Mao 2013 {published data only}

Mao Y, Sun X. Meta-analysis on effectiveness of different positions to prevent ventilator-associated pneumonia [不同体位预防呼吸机相关性肺炎有效性的Meta分析]. *Hu Li Yan Jiu [Chinese Nursing Research]* 2013;**27**(5A):1270-4.

Mi 2013 {published data only}

Mi J. Clinical study of bedside angle instrument in the prevention of ventilator-associated pneumonia [床头角度仪预防呼吸机相关性肺炎的临床研究]. *Chong Qing Yi Ke Da Xue Xue Bao [Journal of Chongqing Medical University]* 2013;**38**(7):708-10.

Wang 2013a {published data only}

Wang J, Xu S. Intervention of body position for the prevention of ventilator-associated pneumonia [体位护理干预对呼吸机相关性肺炎预防作用的研究]. *Hebei Medical Journal* 2013;**35**(12):1909-10.

Wang 2013b {published data only}

Wang H. Application of home made monitoring bed mark table for patients with severe brain injury receiving artificial airway mechanical ventilation [自制监护床刻度表在重症颅脑损伤人工气道机械通气病人中的应用]. *Hu Li Yan Jiu [Nursing Research]* 2013;**27**(12):4061.

Wu 2014 {published data only}

Wu Q, Zhu Y, Xu B. Impact analysis of two body positions on ventilator-associated pneumonia among PICU patients [两种体位对PICU患者呼吸机相关性肺炎的影响对比分析]. *Dang Dai Yi Xue [Contemporary Medicine]* 2014;**20**(11):126-7.

Xiao 2006 {published data only}

Xiao P, Liao L, Cai F, Zhu M. Study of the effect of postural care on ventilator - associated pneumonia [体位护理对机械通气相关性肺炎影响的研究]. *Modern Nursing* 2006;**12**(13):1177-8.

Zhang 2006 {published data only}

Zhang B, Xin R, Zhong X. Effect of body position on ventilation associated pneumonia [体位对呼吸机相关性肺炎的影响]. *Modern Nursing* 2006;**12**(15):1402-3.

Additional references
Alexiou 2009

Alexiou VG, Ierodiakonou V, Dimopoulos G, Falagas ME. Impact of patient position on the incidence of ventilator-associated pneumonia: a meta-analysis of randomized controlled trials. *Journal of Critical Care* 2009;**24**(4):515-22.

Atkins 2004

Atkins D, Best D, Briss PA, Eccles M, Falck-Ytter Y, Flottorp S, et al. GRADE Working Group. Grading quality of evidence and strength of recommendations. *BMJ* 2004;**328**(7454):1490.

ATS-IDSA 2005

American Thoracic Society and Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. *American Journal of Respiratory and Critical Care Medicine* 2005;**171**(4):388-416.

Augustyn 2007

Augustyn B. Ventilator-associated pneumonia: risk factors and prevention. *Critical Care Nurse* 2007;**27**(4):32-9.

Caruso 2009

Caruso P, Silvia D, Ruiz Soraia AL, Demarzo Sergio E, Deheinzeln D. Saline instillation before tracheal suctioning decreases the incidence of ventilator-associated pneumonia. *Critical Care Medicine* 2009;**37**(1):32-8.

CDC 1997

Centers for Disease Control and Prevention. Guidelines for prevention of nosocomial pneumonia. *Morbidity and Mortality Weekly Report* 1997;**46**(1):1-79.

Chen 2009

Chen Y-C. Critical analysis of the factors associated with enteral feeding in preventing VAP: a systematic review. *Journal of the Chinese Medical Association* 2009;**72**(4):171-8.

Collard 2003

Collard HR, Saint S, Matthay MA. Prevention of ventilator-associated pneumonia: an evidence-based systematic review. *Annals of Internal Medicine* 2003;**138**(6):494-501.

Cook 2000

Cook D, Richard JD, Reeve B, Randall J, Wigg M, Brochard L, et al. Ventilator circuit and secretion management strategies: a Franco-Canadian survey. *Critical Care Medicine* 2000;**28**(10):3547-54.

Cook 2002

Cook DJ, Meade MO, Hand LE, McMullin JP. Toward understanding evidence uptake: semirecumbency for pneumonia prevention. *Critical Care Medicine* 2002;**30**(7):1472-7.

Craven 2000

Craven DE. Epidemiology of ventilator-associated pneumonia. *Chest* 2000;**117**(4):186-7.

Dennis 2001

Dennis C, Bergmans JJ, Marc J, Bonten M, Gaillard CA, Paling JC, et al. Prevention of ventilator-associated pneumonia by oral decontamination: a prospective, randomized, double-blind, placebo-controlled study. *American Journal of Respiratory and Critical Care Medicine* 2001;**164**(3):382-8.

Dodek 2004

Dodek P, Keenan S, Cook D, Heyland D, Jacka M, Hand L, et al. Evidence-based clinical practice guidelines for the prevention of ventilator-associated pneumonia. *Annals of Internal Medicine* 2004;**141**(4):305-13.

Egger 1997

Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;**315**(7109):629-34. [DOI: [10.1136/bmj.315.7109.629](https://doi.org/10.1136/bmj.315.7109.629)]

El-Ebiary 1993

El-Ebiary M, Torres A, González J, De la Bellacasa JP, García C, Jiménez de Anta MT, et al. Quantitative cultures of endotracheal aspirates for the diagnosis of ventilator-associated pneumonia. *American Journal of Respiratory and Critical Care Medicine* 1993;**148**(7):1552-7.

El-Khatib 2010

El-Khatib MF, Zeineldine S, Ayoub C, Husari A, Bou-Khalil PK. Critical care clinicians' knowledge of evidence-based guidelines for preventing ventilator-associated pneumonia. *American Journal of Critical Care* 2010;**19**(3):272-6.

Fernández-Crehuet 1997

Fernández-Crehuet R, Díaz-Monila C, De Irala J, Martínez-Concha D, Salcedo-Leal I, Masa-Calles J. Nosocomial infection in an intensive-care unit: identification of risk factors. *Infection Control and Hospital Epidemiology* 1997;**18**:825-30.

Gocze 2013

Gocze I, Streng F, Zeman F, Creutzenberg M, Graf BM, Schlitt HJ, et al. The effects of the semirecumbent position on hemodynamic status in patients on invasive mechanical ventilation: prospective randomized multivariable analysis. *Critical Care* 2013;**17**(2):R80.

GRADEproGDT 2015 [Computer program]

GRADEproGDT. GRADEpro Guideline Development Tool [www.guidelinedevelopment.org]. Hamilton: McMaster University (developed by Evidence Prime, Inc.), 2015.

Grap 2005a

Grap MJ, Munro CL, Hummel RS, 3rd, Elswick RK, Jr, McKinney JL, Sessler CN. Effect of backrest elevation on the development of ventilator-associated pneumonia. *American Journal of Critical Care* 2005;**14**(4):325-32.

Grap 2005b

Grap MJ, Munro CL. Quality improvement in backrest elevation: improving outcomes in critical care. *AACN Clinical Issues* 2005;**16**(2):133-9.

Guyatt 2011

Guyatt G, Oxman AD, Akl E, Kunz R, Vist G, Brozek J, et al. GRADE Guidelines: 1. Introduction to GRADE evidence profiles and summary of findings tables. *Journal of Clinical Epidemiology* 2011;**64**(4):383-943.

Higgins 2003

Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;**327**(7414):557-60.

Higgins 2011

Higgins JP, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0

[updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.

Klompas 2007

Klompas M. Does this patient have ventilator-associated pneumonia?. *JAMA* 2007;**297**(14):1583-93.

Kollef 2005

Kollef MH. What is ventilator-associated pneumonia and why is it important?. *Respiratory Care* 2005;**50**(6):714-21.

Kollef 1993

Kollef MH. Ventilator-associated pneumonia: a multivariate analysis. *JAMA* 1993;**270**(16):1965-70.

Lefebvre 2011

Lefebvre C, Manheimer E, Glanville J. Chapter 6: Searching for studies. In: Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.

Lippoldt 2014

Lippoldt J, Pernicka E, Staudinger T. Interface pressure at different degrees of backrest elevation with various types of pressure-redistribution surfaces. *American Journal of Critical Care* 2014;**23**(2):119-26.

Liu 2003

Liu W, Yuan H, Wang F, Yao M. Exploratory research on the body positioning among ICU patients [ICU病人体位的探索性研究]. *Zhong Guo Xing Wei Yi Xue Za Zhi [Chinese Journal of Behavioral Medical Science]* 2003;**12**(3):285-6.

Liu 2011

Liu Z, Ren W, Pan H. Meta-analysis of the impact of semirecumbent position on ventilator-associated pneumonia [半卧位对呼吸机相关肺炎影响的Meta分析]. *Zhong Hua Ji Zhen Yi Xue Za Zhi [Chinese Journal of Emergency Medicine]* 2011;**20**(2):147-50.

Meduri 1992

Meduri GU, Chastre J. The standardization of bronchoscopic techniques for ventilator-associated pneumonia. *Chest* 1992;**102**(Suppl 5):557-64.

Mirza 2012

Mirza A, Custodio HT. Hospital-acquired infections clinical presentation. www.reference.medscape.com (accessed 5 January 2012).

Mohamad 2010

Mohamad BK, El-Khatib F, Zeineldine S, Ayoub C, Husari A, Pierre K. Critical care clinicians' knowledge of evidence-based guidelines for preventing ventilator-associated pneumonia. *American Journal of Critical Care* 2010;**19**:272-6.

Moher 2009

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *BMJ* 2009;**339**:2535.

Muscedere 2008

Muscedere J, Dodek P, Keenan S, Fowler R, Cook D, Heyland D. Comprehensive evidence-based clinical practice guidelines for ventilator-associated pneumonia: prevention. *Journal of Critical Care* 2008;**23**(1):126-37.

Niel-Weise 2011

Niel-Weise BS, Gastmeier P, Kola A, Vonberg RP, Wille JC, van den Broek PJ. An evidence-based recommendation on bed head elevation for mechanically ventilated patients. *Critical Care* 2011;**15**(2):R111.

Orozco-Levi 1995

Orozco-Levi M, Torres A, Ferrer M, Piera C, El-Ebiary M, De la Bellacasa JP, et al. Semi-recumbent position protects from pulmonary aspiration but not completely from gastroesophageal reflux in mechanically ventilated patients. *American Journal of Respiratory and Critical Care Medicine* 1995;**152**(4):1387-90.

Pieracci 2007

Pieracci FM, Barie PS. Strategies in the prevention and management of ventilator-associated pneumonia. *The American Surgeon* 2007;**73**:421-32.

Rea-Neto 2008

Rea-Neto A, Youssef NC, Tuche F, Brunkhorst F, Ranieri VM, Reinhart K, et al. Diagnosis of ventilator-associated pneumonia: a systematic review of the literature. *Critical Care* 2008;**12**(2):R56.

Reeve 1999

Reeve BK, Cook DJ. Semirecumbency among mechanically ventilated ICU patients: a multicenter observational study. *Clinical Intensive Care* 1999;**10**:241-4.

RevMan 2014 [Computer program]

The Nordic Cochrane Centre, The Cochrane Collaboration. Review Manager (RevMan). Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014.

Richards 1999

Richards MJ, Edwards JR, Culver DH, Gaynes RP. Nosocomial infections in medical intensive care units in the United States. National Nosocomial Infections Surveillance System. *Critical Care Medicine* 1999;**27**(8):887-92.

Rosenthal 2006

Rosenthal VD, Maki DG, Salomao R, Moreno CA, Mehta Y, Higuera F, et al. Device-associated nosocomial infections in 55 intensive care units of 8 developing countries. *Annals of Internal Medicine* 2006;**145**(8):582-91.

Safdar 2005

Safdar N, Dezfulian C, Collard HR, Saint S. Clinical and economic consequences of ventilator-associated pneumonia: a systematic review. *Critical Care Medicine* 2005;**33**(10):2184-93.

Simini 2000

Simini B. Semirecumbent position in intensive care patients. *Lancet* 2000;**355**(9208):1012.

Subirana 2007

Subirana M, Solà I, Benito S. Closed tracheal suction systems versus open tracheal suction systems for mechanically ventilated adult patients. *Cochrane Database of Systematic Reviews* 2007, Issue 4. [DOI: [10.1002/14651858.CD004581.pub2](https://doi.org/10.1002/14651858.CD004581.pub2)]

Torres 1992

Torres A, Serra-Batlles J, Ros E, Piera C, Puig de la Bellacasa J, Cobos A, et al. Pulmonary aspiration of gastric contents in patients receiving mechanical ventilation: the effect of body position. *Annals of Internal Medicine* 1998;**116**(7):540-3.

Van Nieuwenhoven 2004

Van Nieuwenhoven CA, Buskens E. Oral decontamination is cost-saving in the prevention of ventilator-associated pneumonia in intensive care units. *Critical Care Medicine* 2004;**32**(1):126-30.

Van Nieuwenhoven 2006

Van Nieuwenhoven CA, Vandenbroucke-Grauls C, Van Tiel FH, Joore HC, Van Schijndel RJ, Van der Tweel I, et al. Feasibility and effects of the semirecumbent position to prevent ventilator-associated pneumonia: a randomized study. *Critical Care Medicine* 2006;**34**(2):396-402.

Warren 2003

Warren DK, Shukla SJ, Olsen MA, Kollef MH, Hollenbeak CS, Cox MJ, et al. Outcome and attributable cost of ventilator-associated pneumonia among intensive care unit patients in a suburban medical center. *Critical Care Medicine* 2003;**31**(15):1312-7.

WHO 2000

World Health Organization Consultation on Obesity. Obesity: Preventing and Managing the Global Epidemic. Geneva: World Health Organization, 2000.

Wolken 2012

Wolken RF, Woodruff RJ, Smith J, Albert RK, Douglas IS. Observational study of head of bed elevation adherence using a continuous monitoring system in a medical intensive care unit. *Respiratory Care* 2012;**57**(4):537-43.

Yao 2013

Yao Y, He L. Survey of compliance of semirecumbent position for ICU patients among nurses [ICU护士予重症患者实施半卧位的依从性调查与改进对策]. *Yi Xue Xin Xi [Medical Information]* 2013;**10**(26):110-2.

References to other published versions of this review

Li 2012

Li X, Yuan Q, Wang L, Sun X, Deng L. Semi-recumbent position versus supine position for the prevention of ventilator-associated pneumonia in adults requiring mechanical ventilation. *Cochrane Database of Systematic Reviews* 2012, Issue 7. [DOI: [10.1002/14651858.CD009946](https://doi.org/10.1002/14651858.CD009946)]

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Cai 2006

Methods	RCT
Participants	<p>Sample size: 54</p> <p>Patients recruited from May 2002 to August 2008</p> <p>Country: China</p> <p>Mean age: 54 (34 to 76)</p> <p>Male/female: 39/15</p> <p>Duration of mechanical ventilation: 2 to 31 days</p> <p>Enteral feeding: not reported</p> <p>Sucralfate or H2 antagonists for stress ulcer prophylaxis: not reported</p> <p>Reason for admission to ICU:</p> <ul style="list-style-type: none"> - Chronic obstructive pulmonary disease (COPD): 17 - Multiple organ failure (MOF): 4 - Organophosphorous poisoning: 23 - Cerebrovascular accident: 10 <p>Baseline characteristics: comparable</p>
Interventions	<p>Semi-recumbent position (> 30°) versus supine position (0°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning, and did not report whether they monitored and corrected the position during the study</p>
Outcomes	Incidence of clinically suspected pneumonia
Notes	Non-English language article

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias)	Unclear risk	Not reported

Cai 2006 (Continued)

All outcomes

Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Unclear risk	Insufficient information (no protocol available and not enough information from study reporting)
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Drakulovic 1999

Methods	RCT
Participants	<p>Sample size: 90</p> <p>Patients recruited from June 1997 to May 1998</p> <p>Country: Spain</p> <p>Mean age:</p> <ul style="list-style-type: none"> - Treatment group (45°): 63 ± 16 - Control group (0°): 67 ± 14 <p>Male/female:</p> <ul style="list-style-type: none"> - Treatment group (45°): 30/9 - Control group (0°): 35/12 <p>APACHE II score:</p> <ul style="list-style-type: none"> - Treatment group (45°): 21.3 ± 6.0 - Control group (0°): 23.8 ± 6.1 <p>Duration of follow-up: 72 hours</p> <p>Enteral feeding:</p> <ul style="list-style-type: none"> - Treatment group (45°): 22 (56%) - Control group (0°): 28 (60%) <p>Sucalfate:</p> <ul style="list-style-type: none"> - Treatment group (45°): 33 (85%) - Control group (0°): 35 (75%) <p>Ranitidine:</p> <ul style="list-style-type: none"> - Treatment group (45°): 16 (41%) - Control group (0°): 29 (62%) <p>Use of antibiotics:</p> <ul style="list-style-type: none"> - Treatment group (45°): 18 (46%)

Drakulovic 1999 (Continued)

- Control group (25°): 24 (51%)
- Cause of acute respiratory failure:
 - COPD: 13 versus 16
 - Other pulmonary diseases: 8 versus 12
 - Surgery: 7 versus 8
 - Drug overdose or neurological emergency: 5 versus 3
 - Other: 6 versus 10
- Baseline characteristics: comparable

Interventions	Semi-recumbent position (45°) versus supine position (0°) Correctness of the position was checked once a day, but the authors did not report the average angle of head bed elevation for semi-recumbent positioning
Outcomes	1. Clinically suspected pneumonia 2. Microbiologically confirmed pneumonia 3. ICU mortality 4. Hospital mortality 5. Use of antibiotics
Notes	—

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Patients were randomly allocated by a computer-generated list
Allocation concealment (selection bias)	Low risk	The allocation table was generated and disclosed by an independent person
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	3/90 (3.3%) withdrawn due to protocol violation (reintubation) (only in intervention group); 1 died before intervention was given in the intervention group
Selective reporting (reporting bias)	Low risk	The study protocol is not available but the published reports include all expected outcomes, including those that were prespecified in the methods section
Other bias	High risk	Stopped early for benefit

Hang 2012

Methods	RCT
Participants	<p>Sample size: 39</p> <p>Patients recruited from January to December 2008</p> <p>Country: China</p> <p>Mean age: 49.23, range (21 to 75)</p> <p>Male/female: 26/13</p> <p>Enteral feeding:</p> <ul style="list-style-type: none"> - Treatment group (30 to 45°): 17 (85%) - Control group (0°): 16 (84.2%) <p>Sucralfate or H2 antagonists for stress ulcer prophylaxis:</p> <ul style="list-style-type: none"> - Treatment group (30 to 45°): 8 (40%) - Control group (0°): 6 (31.6%) <p>Duration of mechanical ventilation > 48 hours</p> <p>Reason for admission to ICU: severe brain injury, multiple trauma, organophosphorous poisoning, acute respiratory distress syndrome (ARDS) - no numbers of patients in each category reported</p>
Interventions	<p>Semi-recumbent position (30° to 45°) versus supine position (0°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	<ol style="list-style-type: none"> 1. Clinically suspected pneumonia 2. Duration of mechanical ventilation 3. Length of ICU stay 4. Length of hospital stay 5. Hospital mortality
Notes	Non-English language article

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias)	Unclear risk	Not reported

Hang 2012 (Continued)

All outcomes

Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	The study protocol is not available but the published reports include all expected outcomes, including those that were prespecified in the methods section
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Hu 2012

Methods	RCT
Participants	<p>Sample size: 86</p> <p>Patients recruited from March 2010 to March 2012</p> <p>Country: China</p> <p>Mean age: 46.6, range (34 to 78)</p> <p>Male/female: 46/40</p> <p>Duration of mechanical ventilation: 2 to 10 days</p> <p>Enteral feeding: 100%</p> <p>H2 antagonists for stress ulcer prophylaxis: 100%</p> <p>Use of antibiotic prophylaxis: 100%</p> <p>Reason for admission to ICU:</p> <ul style="list-style-type: none"> - Brain injury: 20 - Poisoning: 9 - Pancreatitis: 8 - Severe cholangitis: 4 - Haemorrhage of brain stem: 7 - Major surgery: 26 - Post-cardiopulmonary resuscitation: 11 <p>Baseline characteristics: comparable</p>
Interventions	<p>Semi-recumbent position (30° to 45°) versus supine position (0°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	Clinically suspected pneumonia, but no definition
Notes	Non-English language article

Hu 2012 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	The study protocol is not available but the published reports include all expected outcomes, including those that were prespecified in the methods section
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Keeley 2007

Methods	RCT
Participants	<p>Sample size: 54</p> <p>Patients recruited from April to August 2005</p> <p>Country: UK</p> <p>Mean age:</p> <ul style="list-style-type: none"> - Treatment group (45°): 64 - Control group (25°): 68 <p>Male/female :</p> <ul style="list-style-type: none"> - Treatment group (45°): 8/9 - Control group (25°): 5/8 <p>APACHE II score:</p> <ul style="list-style-type: none"> - Treatment group (45°): 20 - Control group (25°): 20 <p>Duration of mechanical ventilation:</p>

Keeley 2007 (Continued)

- Patients without VAP: 61.5 hours in treatment group, 63.1 hours in control group

- Patients with VAP: 160 hours in treatment group, 172.5 hours in control group

Enteral feeding:

- Treatment group (45°): 6 (35%)

- Control group (25°): 6 (46%)

Ranitidine:

- Treatment group (45°): 0

- Control group (0°): 9 (75%)

Use of antibiotics:

- Treatment group (45°): 13 (76%)

- Control group (25°): 10 (76%)

Baseline characteristics: comparable

Interventions	Semi-recumbent position (45°) versus semi-recumbent position (25°) Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study
Outcomes	1. Clinically suspected pneumonia 2. Microbiologically confirmed pneumonia 3. ICU mortality 4. Hospital mortality 5. Use of antibiotics
Notes	—

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Patients were randomised to treatment or control groups by taking a sealed, opaque envelope from a box of identical shuffled envelopes. The envelopes were prepared by an independent person at the start of the trial in batches of 50 and were in equal numbers for each group
Allocation concealment (selection bias)	Low risk	A sealed, opaque envelope from a box of identical shuffled envelopes
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	High risk	12/29 withdrawn from intervention group; 12/25 withdrawn from control group. The proportion of loss to follow-up was 44.4%

Keeley 2007 (Continued)

Selective reporting (re-reporting bias)	Unclear risk	Insufficient information (no protocol available and not enough information from study reporting)
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Leng 2012

Methods	RCT
Participants	<p>Sample size: 61</p> <p>Patients from surgical ICU</p> <p>Enteral feeding: 100%</p> <p>Use of antibiotics:</p> <ul style="list-style-type: none"> - Treatment group (45°): 19 (67.9%) - Control group (30°): 18 (54.5%)
Interventions	<p>Semi-recumbent position (45°) versus semi-recumbent position (30°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	<ol style="list-style-type: none"> 1. Clinically suspected pneumonia 2. Hospital mortality 3. Length of ICU stay 4. Use of antibiotics
Notes	Non-English language article. Full text was unpublished, but some data presented in one meta-analysis published by the same author

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Unpublished trial. No information about the methods
Allocation concealment (selection bias)	Unclear risk	Unpublished trial. No information about the methods
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Unpublished trial. No information about the methods
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Unpublished trial. No information about the methods
Incomplete outcome data (attrition bias)	Unclear risk	Unpublished trial. No information about the methods

Leng 2012 (Continued)

All outcomes

Selective reporting (reporting bias)	Unclear risk	Unpublished trial. No information about the methods
Other bias	Unclear risk	Unpublished trial. No information about the methods

van Nieuwenhoven 2006

Methods	RCT
Participants	<p>Sample size: 221</p> <p>Patients recruited from January 1999 to December 2000</p> <p>Country: the Netherlands</p> <p>Mean age:</p> <ul style="list-style-type: none"> - Treatment group (45°): 64.8 ± 13.8 - Control group (10°): 63.0 ± 16.0 <p>Male/female :</p> <ul style="list-style-type: none"> - Treatment group (45°): 67/45 - Control group (10°): 73/36 <p>APACHE II score:</p> <ul style="list-style-type: none"> - Treatment group (45°): 25.6 ± 7.7 - Control group (10°): 24.8 ± 7.6 <p>Duration of follow-up: 48 hours</p> <p>Enteral feeding:</p> <ul style="list-style-type: none"> - Treatment group (45°) = 82 (73.21%) - Control group (10°) = 87 (79.81%) <p>H2 antagonists and/or HKATPase inhibitors</p> <ul style="list-style-type: none"> - Treatment group (45°) = 65 (58%) - Control group (10°) = 64 (58.7%) <p>Sucralfate:</p> <ul style="list-style-type: none"> - Treatment group (45°) = 3 (2.7%) - Control group (10°) = 1 (0.9%) <p>Use of antibiotics:</p> <ul style="list-style-type: none"> - Course 2 (0 to 5) in semi-recumbent group, 2 (0 to 6) in supine group - Antibiotic days 4 (0 to 45) versus 4 (0 to 25) <p>Reason for admission to ICU:</p>

van Nieuwenhoven 2006 (Continued)

- Cardiovascular disease: 15 versus 13
- Acute respiratory failure: 60 versus 55
- Gastrointestinal disease: 9 versus 9
- Neurological disease: 9 versus 11
- Sepsis: 11 versus 8
- Trauma: 1 versus 8
- Metabolic disorders: 4 versus 2
- Other: 3 versus 2

Baseline characteristics: comparable

Interventions	<p>Semi-recumbent position (45°) versus supine position (10°). Backrest elevation was measured every 60 seconds by means of a transducer with pendulum</p> <p>A dedicated nurse controlled patient position 2 or 3 times daily and restored backrest elevation to the randomised position when possible. However, the average degrees of semi-recumbent position ranged only from 23.1° to 29.3° from day 1 to day 7</p>
Outcomes	<ol style="list-style-type: none"> 1. Clinically suspected pneumonia 2. Microbiologically confirmed pneumonia 3. ICU mortality 4. Hospital mortality 5. Length of ICU stay 6. Length of hospital stay 7. Duration of ventilation
Notes	—

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Patients were randomly assigned, on a one-to-one allocation basis per hospital, to the semi-recumbent position or standard care by means of closed, non-transparent, numbered envelopes
Allocation concealment (selection bias)	Low risk	Closed, nontransparent, numbered envelopes
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Low risk	3 investigators, blinded to randomisation codes, independently evaluated all relevant data related to the diagnosis of VAP
Incomplete outcome data (attrition bias) All outcomes	High risk	23/112 withdrawn from intervention group; 17/109 withdrawn from control group. 18.1% patients lost to follow-up

van Nieuwenhoven 2006 (Continued)

Selective reporting (reporting bias)	Low risk	The study protocol is not available but the published reports include all expected outcomes, including those that were prespecified in the methods section
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Wu 2009

Methods	RCT
Participants	<p>Sample size: 112</p> <p>Patients recruited from January 2004 to October 2006</p> <p>Country: China</p> <p>Mean age: 48.9 ± 20.9</p> <p>Male/female: 80/32</p> <p>Duration of mechanical ventilation: 10 ± 8 days (range 2 to 39 days)</p> <p>Enteral feeding: 100%</p> <p>Sucralfate or H2 antagonists for stress ulcer prophylaxis: not reported</p> <p>Use of antibiotic prophylaxis: 100%</p> <p>Reason for admission to ICU:</p> <ul style="list-style-type: none"> - Severe brain injury: 30 - Organophosphorous poisoning: 34 - COPD: 24 - MOF: 22 - Carbon monoxide poisoning: 2 <p>Baseline characteristics: comparable</p>
Interventions	<p>Semi-recumbent position (30° to 60°) versus supine position</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	<ol style="list-style-type: none"> 1. Incidence of clinically suspected pneumonia 2. Duration of ventilation
Notes	Non-English language article

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation

Wu 2009 (Continued)

Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Low risk	The study protocol is not available but the published reports include all expected outcomes, including those that were prespecified in the methods section
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Xue 2012

Methods	RCT
Participants	<p>Sample size: 96</p> <p>Patients recruited from January to December 2011</p> <p>Country: China</p> <p>Age range: 18 to 78</p> <p>Male/female: 68/28</p> <p>Duration of mechanical ventilation > 48 hours</p> <p>Enteral feeding: not reported</p> <p>Sucralfate or H2 antagonists for stress ulcer prophylaxis: not reported</p> <p>Reason for admission to ICU: severe brain injury, septic shock, major surgery, COPD with respiratory failure, poisoning, post-cardiopulmonary resuscitation - no numbers of patients in each category reported</p> <p>Baseline characteristics: comparable</p>
Interventions	<p>Semi-recumbent position (30° to 45°) versus supine position (0°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	Clinically suspected pneumonia
Notes	Non-English article

Risk of bias

Xue 2012 (Continued)

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Unclear risk	Insufficient information (no protocol available and not enough information from study reporting)
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

Yu 2012

Methods	RCT
Participants	<p>Sample size: 65</p> <p>Patients recruited from December 2008 to December 2011</p> <p>Country: China</p> <p>Mean age: 52.2 ± 12.5, range (15 to 71)</p> <p>Male/female: 41/24</p> <p>Duration of mechanical ventilation: 16.8 ± 9.36 days (range 2 to 65 days)</p> <p>Enteral feeding: not reported</p> <p>Sucralfate or H2 antagonists for stress ulcer prophylaxis: not reported</p> <p>Reason for admission to ICU: not reported</p> <p>- Carbon monoxide poisoning: 2</p> <p>Baseline characteristics: comparable</p>
Interventions	<p>Semi-recumbent position (30°) versus supine position (0°)</p> <p>Authors did not report the average angle of head bed elevation for semi-recumbent positioning and did not report whether they monitored and corrected the position during the study</p>
Outcomes	Clinically suspected pneumonia

Yu 2012 (Continued)

Notes Non-English language article

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Patients were randomly allocated, but there was no information about the methods of random sequence generation
Allocation concealment (selection bias)	Unclear risk	Not reported
Blinding of participants and personnel (performance bias) All outcomes	Unclear risk	Not reported
Blinding of outcome assessment (detection bias) All outcomes	Unclear risk	Not reported
Incomplete outcome data (attrition bias) All outcomes	Low risk	No loss to follow-up
Selective reporting (reporting bias)	Unclear risk	Insufficient information (no protocol available and not enough information from study reporting)
Other bias	Unclear risk	Insufficient information to assess whether an important risk of bias exists

COPD: chronic obstructive pulmonary disease

ICU: intensive care unit

MOF: multiple organ failure

RCT: randomised controlled trial

VAP: ventilator-associated pneumonia

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Barber 2009	Conference abstract
He 2011	Not a comparison of interest: patients in the control group received a comfortable position (include supine position, lateral position)
Leng 2012b	Not a RCT
Li 2013	Not a comparison of interest: semi-recumbent position + chlorhexidine oral rinse versus semi-recumbent position + saline
Liu 2011a	Not a RCT
Liu 2011b	Not a RCT

Study	Reason for exclusion
Liu 2013	Not a comparison of interest: semi-recumbent position + chlorhexidine gluconate oral rinse versus supine position + 0.9% saline solution
Liu 2014	Quasi-RCT: patients were assigned based on alternation
Lu 2013	Not a comparison of interest: patients in the treatment group received a comfortable position based on patients' conditions
Mao 2013	Not a RCT
Mi 2013	Not a comparison of interest: head-of-bed angle was measured by bedside angle instrument versus visual monitoring
Wang 2013a	Quasi-RCT: patients were assigned based on alternation
Wang 2013b	Not a comparison of interest: head-of-bed angle was measured by self made bed marker versus lift-based on nurses' experience
Wu 2014	Not the target population: paediatric patients from paediatric intensive care unit
Xiao 2006	Cross-over trial
Zhang 2006	Not a RCT

RCT: randomised controlled trial

DATA AND ANALYSES

Comparison 1. Semirecumbent position (30° to 60°) versus 0° to 10° supine position

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Clinically suspected pneumonia	8	759	Risk Ratio (M-H, Random, 95% CI)	0.36 [0.25, 0.50]
2 Microbiologically confirmed VAP	3	419	Risk Ratio (M-H, Random, 95% CI)	0.44 [0.11, 1.77]
3 ICU mortality	2	307	Risk Ratio (M-H, Random, 95% CI)	0.87 [0.59, 1.27]
4 Hospital mortality	3	346	Risk Ratio (M-H, Random, 95% CI)	0.84 [0.59, 1.20]
5 Length of ICU stay (days)	3	346	Mean Difference (IV, Random, 95% CI)	-1.64 [-4.41, 1.14]
6 Length of hospital stay (days)	2	260	Mean Difference (IV, Random, 95% CI)	-9.47 [-34.21, 15.27]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
7 Duration of ventilation (days)	4	458	Mean Difference (IV, Random, 95% CI)	-3.35 [-7.80, 1.09]
8 Use of antibiotics	3	284	Risk Ratio (M-H, Random, 95% CI)	1.00 [0.97, 1.03]
9 Pressure ulcers	1	221	Risk Ratio (M-H, Random, 95% CI)	0.91 [0.60, 1.38]
10 Subgroup analysis 1: clinically suspected pneumonia	8	759	Risk Ratio (M-H, Random, 95% CI)	0.36 [0.25, 0.50]
10.1 Allocation concealed	2	307	Risk Ratio (M-H, Random, 95% CI)	0.46 [0.14, 1.56]
10.2 Allocation not concealed	6	452	Risk Ratio (M-H, Random, 95% CI)	0.30 [0.21, 0.41]
11 Subgroup analysis 2: clinically suspected pneumonia	8	759	Risk Ratio (M-H, Random, 95% CI)	0.36 [0.25, 0.50]
11.1 Outcome assessor blinded	1	221	Risk Ratio (M-H, Random, 95% CI)	0.78 [0.43, 1.42]
11.2 Outcome assessor not blinded	7	538	Risk Ratio (M-H, Random, 95% CI)	0.29 [0.21, 0.40]
12 Subgroup analysis 3: clinically suspected pneumonia	1	172	Risk Ratio (M-H, Random, 95% CI)	0.22 [0.09, 0.55]
12.1 Duration of MV: 48 to 96 hours (early-onset)	1	86	Risk Ratio (M-H, Random, 95% CI)	0.23 [0.07, 0.72]
12.2 Duration of MV: >= 96 hours (late-onset)	1	86	Risk Ratio (M-H, Random, 95% CI)	0.22 [0.05, 0.93]
13 Sensitivity analysis: length of ICU stay (days)	2	125	Mean Difference (IV, Random, 95% CI)	-2.92 [-8.98, 3.15]
14 Sensitivity analysis: length of hospital stay (days)	1	39	Mean Difference (IV, Random, 95% CI)	-22.25 [-28.43, -16.07]
15 Sensitivity analysis: duration of ventilation (days)	3	237	Mean Difference (IV, Random, 95% CI)	-4.56 [-9.30, 0.18]

Analysis 1.1. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 1 Clinically suspected pneumonia.

Analysis 1.2. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 2 Microbiologically confirmed VAP.

Analysis 1.3. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 3 ICU mortality.

Analysis 1.4. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 4 Hospital mortality.

Analysis 1.5. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 5 Length of ICU stay (days).

Analysis 1.6. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 6 Length of hospital stay (days).

Analysis 1.7. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 7 Duration of ventilation (days).

Analysis 1.8. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 8 Use of antibiotics.

Analysis 1.9. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 9 Pressure ulcers.

Analysis 1.10. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 10 Subgroup analysis 1: clinically suspected pneumonia.

Analysis 1.11. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 11 Subgroup analysis 2: clinically suspected pneumonia.

Analysis 1.12. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 12 Subgroup analysis 3: clinically suspected pneumonia.

Analysis 1.13. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 13 Sensitivity analysis: length of ICU stay (days). **Analysis 1.14. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 14 Sensitivity analysis: length of hospital stay (days).** **Analysis 1.15. Comparison 1 Semirecumbent position (30° to 60°) versus 0° to 10° supine position, Outcome 15 Sensitivity analysis: duration of ventilation (days).** **Comparison 2. Semirecumbent positioning 45° versus 25° to 30°**

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Clinically suspected VAP	2	91	Risk Ratio (M-H, Random, 95% CI)	0.74 [0.35, 1.56]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2 Microbiologically confirmed VAP	1	30	Risk Ratio (M-H, Random, 95% CI)	0.61 [0.20, 1.84]
3 ICU mortality	1	30	Risk Ratio (M-H, Random, 95% CI)	0.57 [0.15, 2.13]
4 Hospital mortality	2	91	Risk Ratio (M-H, Random, 95% CI)	1.00 [0.38, 2.65]
5 Length of ICU stay (days)	1	61	Mean Difference (IV, Random, 95% CI)	1.60 [-0.88, 4.08]
6 Use of antibiotics	2	91	Risk Ratio (M-H, Random, 95% CI)	1.11 [0.84, 1.47]

Analysis 2.1. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 1 Clinically suspected VAP.

Analysis 2.2. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 2 Microbiologically confirmed VAP.

Analysis 2.3. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 3 ICU mortality.

Analysis 2.4. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 4 Hospital mortality.

Analysis 2.5. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 5 Length of ICU stay (days).

Analysis 2.6. Comparison 2 Semirecumbent positioning 45° versus 25° to 30°, Outcome 6 Use of antibiotics.

APPENDICES

Appendix 1. MEDLINE (Ovid) search strategy

1 Pneumonia, Ventilator-Associated/
2 vap.tw.
3 exp Pneumonia/
4 pneumon*.tw.
5 3 or 4
6 exp Respiration, Artificial/
7 exp Ventilators, Mechanical/
8 (ventilat* or respirat*).tw.
9 or/6-8
10 5 and 9
11 1 or 2 or 10
12 exp Posture/
13 posture*.tw.
14 Patient Positioning/
15 position*.tw.
16 Supine Position/
17 supine*.tw.
18 (semi-recumbent* or semi-recumbent*).tw.
19 (semi-reclin* or semireclin*).tw.
20 (semisupin* or semi-supin*).tw.
21 half-sitting.tw.
22 ((head* or bed or backrest) adj5 (elevat* or rais* or inclin* or angle)).tw.
23 or/12-22
24 11 and 23

Appendix 2. EMBASE (Elsevier) search strategy

#31 #22 AND #30
#30 #25 NOT #29
#29 #26 NOT #28
#28 #26 AND #27
#27 'human'/de
#26 'animal'/de OR 'animal experiment'/de OR 'nonhuman'/de
#25 #23 OR #24
#24 random*: ab,ti OR placebo*: ab,ti OR allocat*: ab,ti OR trial: ti OR (doubl* NEAR/1 blind*): ab,ti
#23 'randomized controlled trial'/exp OR 'single blind procedure'/exp OR 'double blind procedure'/exp
#22 #12 AND #21
#21 #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20
#20 ((head* OR bed OR backrest) NEAR/5 (elevat* OR rais* OR inclin* OR angle)): ab,ti
#19 'semi-recumbent': ab,ti OR semi-recumbent*: ab,ti OR semireclin*: ab,ti OR 'semi-recline': ab,ti OR 'semi-reclining': ab,ti OR 'semi-reclined': ab,ti OR 'semi-reclines': ab,ti OR semisupin*: ab,ti OR 'semi-supine': ab,ti OR 'half-sitting': ab,ti
#18 supine*: ab,ti
#17 'supine position'/de OR 'recumbency'/de

```
#16 'head position'/de
#15 posture*: ab,ti OR position*: ab,ti
#14 'patient positioning'/de
#13 'position'/de OR 'body position'/de OR 'body posture'/de
#12 #3 OR #11
#11 #6 AND #10
#10 #7 OR #8 OR #9
#9 ventilat*: ab,ti OR respirat*: ab,ti
#8 'artificial ventilation'/exp
#7 'ventilator'/de
#6 #4 OR #5
#5 pneumon*: ab,ti
#4 'pneumonia'/exp
#3 #1 OR #2
#2 vap: ab,ti
#1 'ventilator associated pneumonia'/de
```

Appendix 3. CINAHL (Ebsco) search strategy

```
S33 S22 and S32
S32 S23 or S24 or S25 or S26 or S27 or S28 or S29 or S30 or S31
S31 (MH "Quantitative Studies")
S30 TI placebo* OR AB placebo*
S29 (MH "Placebos")
S28 (MH "Random Assignment")
S27 TI random* OR AB random*
S26 TI ((singl* or doubl* or trebl* or tripl*) W1 (blind* or mask*)) OR AB ((singl* or doubl* or trebl* or tripl*) W1 (blind* or mask*))
S25 TI clinic* trial* OR AB clinic* trial*
S24 PT clinical trial
S23 (MH "Clinical Trials+")
S22 S12 and S21
S21 S13 or S14 or S15 or S16 or S17 or S18 or S19 or S20
S20 TI ((head* or bed or backrest) N1 (elevat* or rais* or inclin* or angle)) OR AB ((head* or bed or backrest) N1 (elevat* or rais* or inclin* or angle))
S19 TI (semi-recumbent* or semi-recumbent* or semireclin* or semi-reclin* or semisupin* or semi-supin* or half-sitting) OR AB (semi-recumbent* or semi-recumbent* or semireclin* or semi-reclin* or semisupin* or semi-supin* or half-sitting)
S18 TI supine* OR AB supine*
S17 (MH "Supine Position")
S16 TI (position* or posture*) OR AB (position* or posture*)
S15 (MH "Body Positions")
S14 (MH "Posture")
S13 (MH "Patient Positioning")
S12 S3 or S11
S11 S6 and S10
S10 S7 or S8 or S9
S9 TI (ventilat* or respirat*) OR AB (ventilat* or respirat*)
S8 (MH "Ventilator Patients")
S7 (MH "Respiration, Artificial+")
S6 S4 or S5
S5 TI pneumon* OR AB pneumon*
S4 (MH "Pneumonia+")
S3 S1 or S2
S2 TI vap OR AB vap
S1 (MH "Pneumonia, Ventilator-Associated")
```

Appendix 4. Chinese Biomedical Literature Database

```
13 #12 and #11
12 #8 or #7 or #6
11 #10 or #2 or #1
```

10 #9 and #3

9 #5 or #4

8 关键词: 平卧位

7 关键词: 半卧位

6 主题词: 体位/全部树/全部副主题词

5 关键词: 呼吸机

4 关键词: 机械通气

3 主题词: 肺炎/全部树/全部副主题词

2 关键词: VAP

1 主题词: 肺炎, 呼吸机相关性/全部树/全部副主题词

CONTRIBUTIONS OF AUTHORS

Drafting the full review	Li Wang, Xiao Li
Searching and update	Li Wang, Xiao Li, Xueli Tang
Studies screening and data extraction	Xiao Li, Zongxia Yang, Xueli Tang
Comments and suggestions on clinical contents	Lijing Deng, Qiang Yuan
Methodological comments and suggestions	Xin Sun, Li Wang
Revision and approval of the submission	Li Wang, Xiao Li, Zongxia Yang, Xueli Tang, Qiang Yuan, Lijing Deng, Xin Sun

DECLARATIONS OF INTEREST

Li Wang: none known.

Xiao Li: none known.

Zongxia Yang: none known.

Xueli Tang: none known.

Qiang Yuan: none known.

Lijing Deng: none known.

Xin Sun: Xin Sun currently receives research funding from public and non-public funding agencies and industry (i.e. Pfizer China). He did academic presentations paid by pharmaceutical companies, the topics of which were unrelated to any of the pharmaceutical products of the companies.

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- China Medical Board of New York (CMB), USA.

CMB provided funding for overseas systematic review training.

- National Natural Science Foundation of China (NSFC), China.

NSFC (Project No. 71073105) provides the funding for research and training, and has no role in the design and conduct of the systematic review, or in the preparation of and decision to submit the protocol.

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

We excluded quasi-RCTs due to the potential problems with imbalanced prognosis and the failure to conceal the treatment allocation. We conducted a post hoc sensitivity analysis by removing one study in which we imputed the missing standard deviations for length of ICU and hospital stay, and duration of ventilation. We added two additional outcomes in this review: ICU mortality and use of antibiotics. We changed the authorship based on the authors' contribution to the full review post protocol publication.

INDEX TERMS

Medical Subject Headings (MeSH)

*Respiration, Artificial [statistics & numerical data]; Anti-Bacterial Agents [therapeutic use]; Hospital Mortality; Intensive Care Units [statistics & numerical data]; Length of Stay; Patient Positioning [*methods]; Pneumonia, Ventilator-Associated [microbiology] [mortality] [*prevention & control]; Pressure Ulcer [epidemiology]; Randomized Controlled Trials as Topic; Supine Position

MeSH check words

Adult; Humans