Original Article

The effects of the 45° semi-recumbent position on the clinical outcomes of mechanically ventilated patients: a systematic review and meta-analysis study

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Background: A meta-analysis was conducted to investigate the effects of the 45° semi-recumbent position on the clinical outcomes of mechanically ventilated patients.

Methods: The PubMed, Embase, and Cochrane medical databases were searched using the keywords "45°", "head-of-bed elevation", and "semi-recumbent". All relevant randomized controlled trials (RCTs) published between 2005 and 2021 were obtained. The Cochrane system for randomized intervention was adopted and the RevMan 5.3.5 software was used to construct forest plots and funnel plots to assess the risk of bias for the included studies.

Results: A total of 128 literatures were initially screened for this meta-analysis, and 7 studies were finally included, with a total of 740 patients. Meta-analysis revealed that the incidence of ventilator-associated pneumonia (VAP) was significantly lower in patients in the 45° semi-recumbent position compared to patients in the 30° semi-recumbent position [odds ratio (OR) =0.48; 95% confidence interval (CI): 0.28 to 0.84; Z=2.59; P=0.009]. Furthermore, the incidence of gastric reflux was significantly lower in patients in the 45° semi-recumbent position compared to patients in the 30° semi-recumbent position (OR =0.50; 95% CI: 0.27 to 0.96; Z=2.09; P=0.04). Meta-analysis demonstrated that the incidence of pressure sores was significantly higher in patients in the 45° semi-recumbent position compared to patients in the 30° semi-recumbent position (OR =1.88; 95% CI: 1.05 to 3.36; Z=2.11; P=0.03).

Discussion: The 45° semi-recumbent position can reduce the incidence of VAP and gastric reflux in patients undergoing mechanical ventilation (MV), but it may also increase the risk of pressure sores. Thus, consideration should be made based on a comprehensive understanding of the patient's condition and physical state.

Keywords: 45°; semi-recumbent position; mechanical ventilation (MV); outcome; meta-analysis

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Introduction

Invasive mechanical ventilation (MV) has become a common adjuvant treatment modality in the intensive care unit (ICU). However, this technique requires tracheotomy or direct access to the trachea, which can increase the incidence of ventilator-associated pneumonia (VAP) (1). The occurrence of VAP prolongs the ventilation time required and greatly increases the risk of mortality (2), which can be as high as 13.0–25.2% (3). In the 1990s, it was demonstrated that body position is closely related to the occurrence of VAP, and bed

head elevation at a certain angle can significantly reduce the incidence of VAP. A multi-centered observational study showed that the majority of mechanically ventilated patients are positioned with their head-of-bed angle at less than 30° (4). However, study (5) revealed that with the position less than 30 it was very likely to increase the risk of VAP and mortality during the primary treatment of ventilation. Another randomized controlled trial (RCT) research (6) revealed that ventilated patients with a semi-recumbent position can reduce reflux of contaminated gastric contents and aspiration. A meta-analysis study by Wang *et al.* (7) was conducted to compare semi-recumbent position (45°) with 25° to 30° position in the outcomes of VAP, mortality, length of ICU stay, the results show not significant between the two, but there is only two trials included in the study and the GRADE showed very low quality evidence. In this study, more trials were included in the meta-analysis to provide more strong evidence for the 45° semi-recumbent position of mechanically ventilated patients.

We present the following article in accordance with the PRISMA reporting checklist (available at https://dx.doi.org/10.21037/apm-21-2359).

Methods

Database and search strategy

This study refers to PRISMA 2020 standard. The medical databases PubMed, Embase, and the Cochrane library were searched using the following keywords alone or in combination: "45°", "head-of-bed elevation", "semi-recumbent", "backrest", "head elevation", "ICU", "ventilation", and "ventilator". The filter was set by using the filtering function of the database. Reports of RCTs with full text articles published between 2005 and 2021 were included.

Inclusion and exclusion criteria of the selected literature

Inclusion criteria

The following inclusion criteria were applied to the included literature: (I) all patients were aged 18 years and older and were treated in the ICU with MV to support respiration; (II) the intervention must include a group of patients given MV in the 45° bed head elevation angle, with adjustments not greater than 5°, and a control group treated at the 30° bed head elevation angle (other control groups might be included, such as a 0° group, but would not included in the final analysis); (III) the duration of bed head elevation must be identical for both the intervention group and the control group; (IV) the outcome indicators included VAP incidence rate, gastric reflux incidence rate, pressure sores incidence rate, ventilation indicators, ventilation time, mortality, length of hospital stay, and other indicators.

Exclusion criteria

The following articles were excluded: (I) non-randomized studies, studies or observational studies, investigations, case analysis, reviews, guidelines, systematic reviews, etc; (II) literatures with repeated study contents with others; and (III) literatures with missing data, or data that could not be transformed and/or used.

Literature quality evaluation

The Jadad scoring criteria were used to evaluate the quality of the included randomized controlled studies. The quality of the literatures were scored, and the evaluation process was independently completed by two researchers, If there was any disagreement during the process, a third researcher was resorted. A score of less than 3 presented a low-quality literature, and a score greater than 3 presented a high-quality literature.

Literature screening

Two researchers independently searched the database for the studies. The retrieval results were combined with replicative check, preliminary screening was performed by reading the title and the abstracts. Studies were further screened by reviewing the full-text articles applying the inclusion and exclusion criteria. Quality evaluations were performed on the remaining studies and those with scores of less than 3 were excluded.

Bias assessment

The Cochrane review handbook was used to assess the bias of the studies, including the following six aspects: (I) the random sequence generation; (II) the allocation concealment; (III) the blinding method; (VI) the outcome assessment; (V) the incomplete outcome data; and (IV) other bias. Any disagreement between the two researchers were resolved via discussion and consultation with a third investigator.

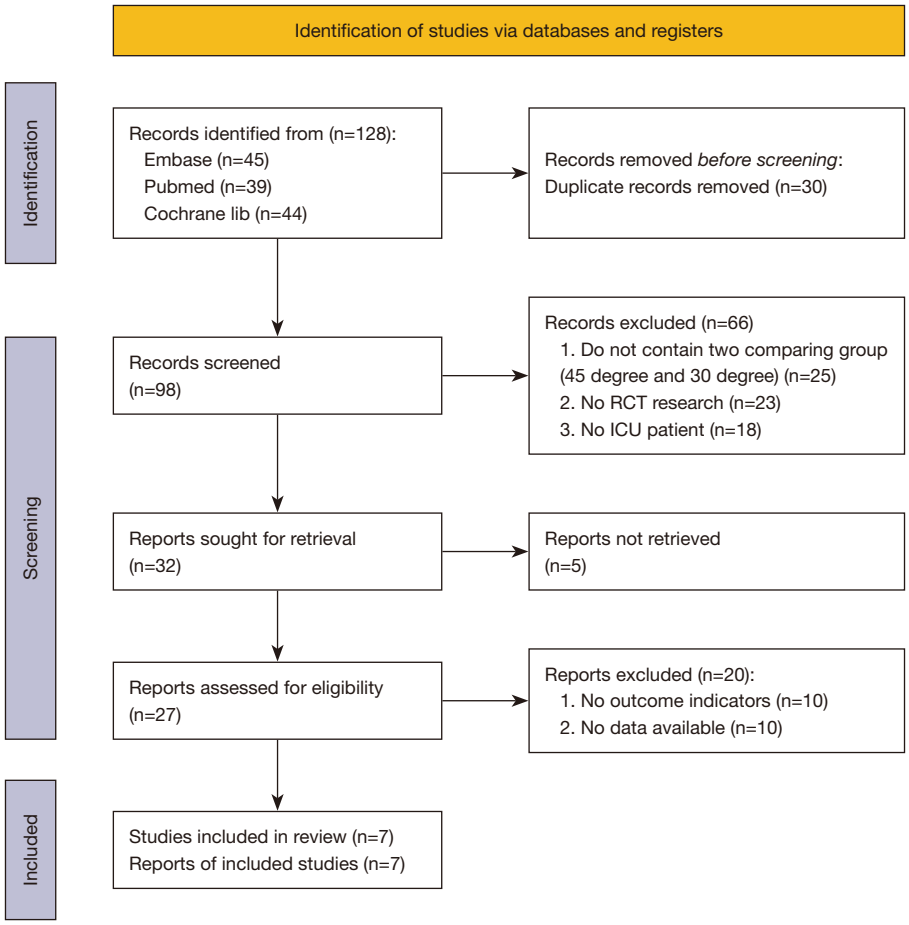

Figure 1 The select flow chart. RCT, randomized controlled trial; ICU, intensive care unit.

Data extraction

Studies that met the inclusion and exclusion criteria were summarized and the basic characteristics were collated, including authors, publication year and month, sample size, characteristics of the study subjects, intervention methods, outcome measures.

Statistical methods

All data were analyzed using the RevMan 5.3.5 software. The enumeration data such as VAP incidence rate, gastric reflux incidence rate, and pressure sores incidence rate, were reported using an odds ratio (OR) value and 95% confidence interval (CI). P value <0.05 was considered statistically significant. The heterogeneity of the studies was examined by I^2 analysis and Q check. Analyses with I^2>25% or P<0.1 suggested significant heterogeneity and the random-effects model would be used, otherwise, the fixed effects model was used. If heterogeneity was suggested among the studies, sensitivity analysis was performed using a case-by-case elimination method. Funnel plots were used to present publication bias.

Results

Literature screening results

Initially, 128 literatures were identified from the database searches. Following a review of the titles and the abstracts, non-randomized controlled studies, repeated studies, and studies with missing intervention methods and incomplete data were excluded. Finally, 7 literatures, with a total of 740 patients, were included in this meta-analysis, the selection process was shown in (*Figure 1*), and the characteristics of included literatures were shown in (*Table 1*).

Table 1 Basic characteristics of included literatures

Author	Year	Region	Study subjects	Total samples (T/C)	Age (years) (T/C)	Intervention mode (T/C)	Outcome measures	Jadad score
Ghezeljeh *et al.* (8)	2017	Iran	ICU mechanically ventilated patients	80 (40/40)	64.7/65.7	T: head of bed elevation angle 45° (lasting for 3 d); C: head of bed elevation angle 30° (lasting for 3 d)	VAP incidence rate, pressure sores incidence rate	4
Schallom *et al.* (9)	2015	NA	ICU mechanically ventilated patients	15 (8/7)	NA	T: head of bed elevation angle 45° (lasting for 2 d); C: head of bed elevation angle 30° (lasting for 2 d)	VAP incidence rate, gastric reflux incidence rate, pressure sores incidence rate	5
Güner *et al.* (10)	2021	NA	ICU mechanically ventilated patients	40 (20/20)	NA	T: head of bed elevation angle 45° (lasting for 5 d); C: head of bed elevation angle 30° (lasting for 5 d)	VAP incidence rate	4
Göcze *et al.* (11)	2013	Germany	Hemodynamically stable ICU MV	100 (50/50)	60.0/60.5	T: head of bed elevation angle 45° (lasting for 1 d); C: head of bed elevation angle 30° (lasting for 1 d)	MAP, $ScvO_2$, incidence of hypotension	4
van Nieuwenhoven *et al.* (12)	2006	The Netherlands	Mechanically ventilated patients	221 (112/109)	64.8/63.0	T: head of bed elevation angle 45° (lasting for 7 d); C: head of bed elevation angle 30° (lasting for 7 d)	VAP incidence rate, gastric reflux incidence rate, length of hospital stay, mortality	5
Li *et al.* (13)	2015	China	Mechanically ventilated patients	238 (119/119)	NA	T: head of bed elevation angle 45°; C: head of bed elevation angle 30°	VAP incidence rate, gastric reflux incidence rate, pressure sores incidence rate	5
Jiang *et al.* (14)	2016	China	Mechanically ventilated patients	46 (23/23)	68.0/70.6	T: head of bed elevation angle 45° (lasting for 7 d); C: head of bed elevation angle 30° (lasting for 7 d)	VAP incidence rate, pressure sores incidence rate, arterial oxygen index	5

T, intervention group; C, control group; NA, not available; ICU, intensive care unit; MV, mechanical ventilation; VAP, ventilator-associated pneumonia; MAP, mean arterial pressure; $ScvO_2$, central venous oxygen saturation.

Quality evaluation of the included literature

Quality assessment and bias analysis were performed using the Cochrane System for Randomized Intervention Evaluation criteria (*Figures 2,3*). There were two publications in which the description of random sequence generation was unclear and there might result in selective bias. One literature had unclear concealment method and there might be selective bias. Three articles had unclear blinding method and there might be operational bias.

Figure 2 Summary of bias analysis of the seven included literatures.

Meta-analysis results

The incidence of VAP

There were six articles that included the incidence of VAP as an outcome indicator. Meta-analysis revealed that these literatures showed statistical homogeneity (I^2=0%; P=0.88). The fixed effects model demonstrated a significant difference between the 45° group and the 30° control group in terms of the incidence of VAP (OR =0.48; 95% CI: 0.28 to 0.84; Z=2.59; P=0.009; *Figure 4*).

The incidence of gastric reflux

The three studies that documented the incidence of gastric reflux in the outcome measures showed statistical homogeneity (I^2=0%; P=0.74). The fixed effects model revealed statistically significant differences between the 45° group and the 30° control group in terms of the incidence of gastric reflux (OR =0.50; 95% CI: 0.27 to 0.96; Z=2.09; P=0.04; *Figure 5*).

The incidence of pressure sores

The four studies that reported the incidence of pressure sores showed statistical homogeneity (I^2=0%; P=0.85). The fixed effects model showed a statistically significant difference between the 45° group and the 30° control group in terms of the incidence of pressure sores (OR =1.88; 95% CI: 1.05 to 3.36; Z=2.11; P=0.03; *Figure 6*).

Analysis of sensitivity and publication bias

Some literatures contained unclear descriptions regarding the random sequence generation and the blinding method,

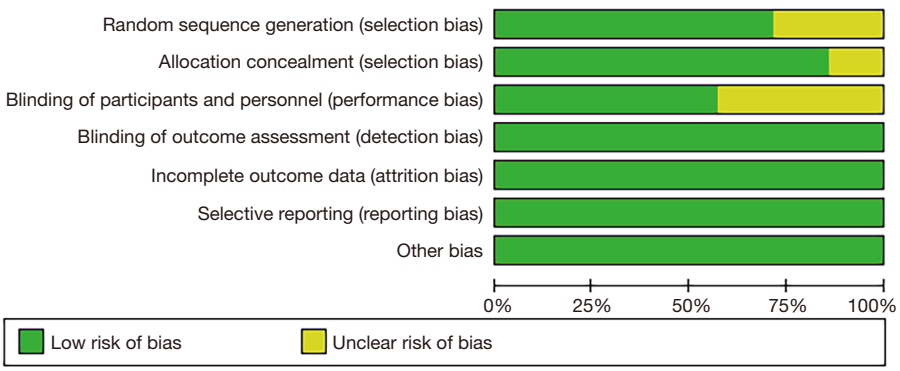

Figure 3 Bias risk assessment of the seven included literatures.

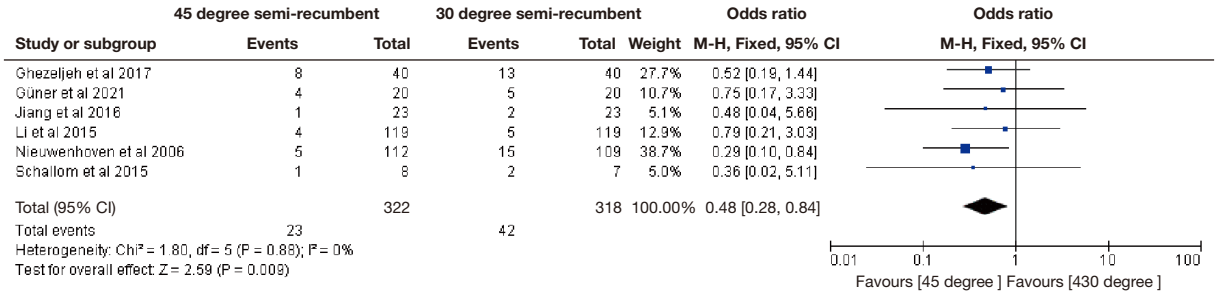

Figure 4 A comparison of the incidence of VAP between the 45° and 30° semi-recumbent positions. VAP, ventilator-associated pneumonia.

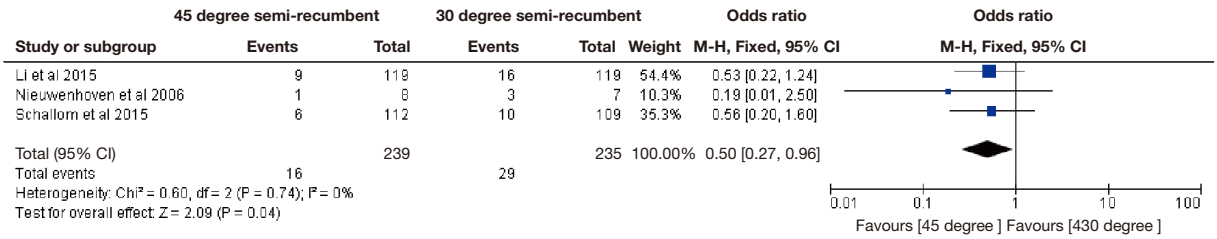

Figure 5 A comparison of the incidence of gastric reflux between the 45° and 30° semi-recumbent positions.

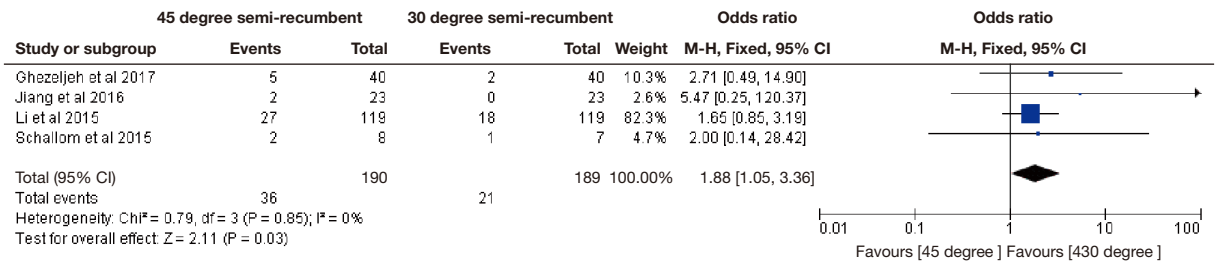

Figure 6 A comparison of the incidence of pressure sores between the 45° and 30° semi-recumbent positions.

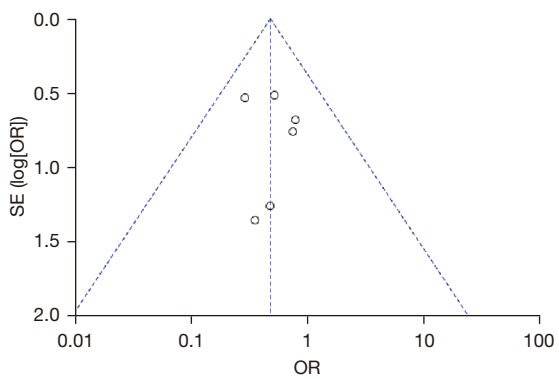

Figure 7 Funnel plot for the comparison of outcomes between the 45° and 30° semi-recumbent positions.

and this may have contributed to bias in the synthesis results. However, all synthesis results showed statistical homogeneity, and thus, sensitivity analysis were not conducted. The funnel plot in *Figure* 7 shows an uneven distribution in the two groups, suggesting that there may be publication bias.

Discussion

Although the Center for Disease Control and Prevention recommends that mechanically ventilated patients remain in the 45° position to reduce the risk of VAP, there is still a lack of strong evidence supporting this position in the practical clinical setting (15). Our meta-analysis examined

a total of 740 patients across 7 qualified publications and found that the incidence of VAP in patients with a 45° angle supine position was significantly lower than that observed in patients with a 30° angle supine position, suggesting that the 45° angle semi-recumbent position was sufficient to reduce the incidence of VAP. Furthermore, the incidence of gastric reflux was significantly reduced in patients with a 45° semi-recumbent position compared to patients with a 30° supine position. Reflux of gastric contents and subsequent microaspiration of bacterial contaminate the oropharyngeal fluids and lead to the development of VAP, but a combination of nasogastric feeding tube and the supine position prevents gastroesophageal reflux and increases the volume of oropharyngeal fluids significantly (16). With the 45° recumbent position, the gastric contents refluxing rate are reduced, followed by a reduction of bacterial colonization in the oropharynx, thereby reducing the possibility of infections (17). However, the elevation angle of the bed head inevitably increases the pressure on the sacrococcygeal skin contact surface, which increases the risk of pressure sores (18). This meta-analysis revealed that there was a significant difference in the incidence of pressure sores between the 45° semi-recumbent position and the 30° position, suggesting that the 45° semi-recumbent position was more prone to inducing pressure sores, which meant that patients should change their position more often than the 30° position (most probably every 2 hours).

In addition, although raising the head of the bed to 45° is a simple method for the prevention of VAP, it is very difficult to maintain this position. In a survey on semi-sitting positions, only 26.4% of bedridden patients were able to maintain an elevation angle of more than 30° (19). Some studies have also suggested that the lack of sufficient comfort, fear of pressure ulcers, frequent change of position are all the factors effecting the adherence to 45° position (20). Therefore, the decision to adopt a bedside elevation of 45° should be determined based on the patient's condition and physical tolerance. Several guidelines from the American Thoracic Society, the Infectious Diseases Society of America, and others have recommended the semi-recumbent positioning with an elevation head-of-bed angle of 30° to 45°, which implying an angle slightly lower than 45° might be the best choice for the patients who could not endure the fully 45° recumbent position (21). Besides, nurses need knowledge and education about the 45° recumbent position, a precise adjustment and permanent monitoring of the slope of bed using electronic devices may help maintaining the elevation of head of bed (HOB) to 45 degrees due to the degree wasn't always that accurate (22).

In this study, RevMan software was used to analyze the publication bias of seven documents. Both sides of the funnel plot showed asymmetry, suggesting that there may be selective literature publication bias. In addition, analysis of the three indicators showed homogeneity among the studies, which may be due to the limited number of randomized trials in this meta-analysis preventing the detection of heterogeneity between literatures, and thus, resulting in bias in the results. As there is currently no fixed criteria for VAP diagnosis in clinical practice, there may be a bias in the statistics of VAP. The included literatures also had problems such as unclear random sequence generation method, unclear blinding method, and unclear hidden method, which may pose a risk of bias to the final results. Future work should include more RCTs to enable in-depth analysis of this topic.

Conclusions

The 45° semi-recumbent position is effective for reducing the incidence VAP, but it may also increase the risk of pressure sores. Future research should focus on methods to maintain the continuity of the 45° semi-recumbent position, and developing management regimens to reduce the incidence of pressure sores.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-2359

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apm-21-2359). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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