Risk factors for ventilator-associated pneumonia in ICU mechanically ventilated patients: a meta-analysis

Qin Guan[1], Xiaoling Zhu[2], Lu Zhou[1], Zhipeng Xue[1], Binrun Zhang[2]*

1.College of Nursing, Dali University, Dali 671000, China.
2.Medical Department of the First Affiliated Hospital of Dali University, Dali 671000, China.

Abstract: Objective: This study aims to determine the risk factors for the development of ventilator-associated pneumonia (VAP) in ICU mechanically ventilated patients through meta-analysis. Method: Conduct a comprehensive search of multiple domestic and international databases, collect literature on the risk factors of VAP in ICU patients from November 2023, and conduct meta-analysis using RevMan5.4 software. Result: 31 high-quality studies were included, and it was found that age, COPD history, position, APACHE II score, antibiotic combination, repeated tracheal intubation, tracheostomy, indwelling gastric tube, mechanical ventilation time, and ICU hospitalization time were significantly associated with an increased risk of VAP; However, consciousness disorders and hypoalbuminemia do not show a significant correlation with the risk of VAP. Conclusion: Specific patient characteristics and clinical procedures are associated with increased risk of VAP, and clinical attention should be paid to these risk factors in order to intervene early to prevent VAP and improve patient prognosis.

Keywords: Mechanical Ventilation; Ventilator Associated Pneumonia; Risk Factors

1. Background

Mechanical ventilation is a method used in the ICU to treat critically ill patients, which includes both invasive and non-invasive methods aimed at meeting the respiratory needs of patients[1]. However, this treatment can lead to ventilator-associated pneumonia (VAP). VAP is the key cause of high morbidity and mortality in ICU patients. Its incidence rate and mortality have significant international differences. Incidental complications seriously threaten patients' lives [2]. This study discussed the risk factors for VAP in ICU mechanically ventilated patients both domestically and internationally through meta-analysis, aiming to provide data support for nursing practice and clinical decision-making to reduce the incidence of VAP.

2. Materials and Methods

Using meta-analysis method, relevant cohort studies and case-control studies on risk factors for VAP in ICU mechanical ventilation patients were collected by searching domestic and foreign databases. Extract and integrate research data, analyze and merge the data using RevMan 5.4 software.

3. Retrieval strategy

Conduct comprehensive searches on multiple domestic and international databases, including CNKI, Wanfang, VIP, Sinomed, Pubmed, Web of Science, EMbase, and Cochrane. The search period covers the period from database establishment to November 2023.

4. Discharge standards

Literature inclusion and exclusion criteria: ① The research method is cohort study or case-control study; ② The research subjects were ICU mechanically ventilated patients who did not develop pneumonia before admission; ③ The research focuses on the risk factors for VAP in ICU mechanically ventilated patients. Exclusion criteria: ① Non Chinese and English literature; ② Repeated publication; ③ Incomplete data and inability to obtain full text.

5. Literature screening and data extraction

To ensure the reliability and accuracy of the study, a double-blind independent screening method was adopted in this study. If there is any disagreement, it shall be judged by a third party. Extract literature information based on the required content.

6. Literature quality evaluation

To ensure the quality of the literature in the study, a double-blind independent evaluation method was adopted. Specifically, the New-castle Ottawa Scale (NOS) scale [3] was used to evaluate the risk of bias in the literature.

7. Statistical methods

A meta-analysis was conducted on risk factors using RevMan 5.4 software. Evaluate the homogeneity and heterogeneity of the study. If the number of studies included in the same outcome measure reaches 10 or more, a funnel plot is used to evaluate whether there is publication bias.

8. Literature screening results

By searching domestic and foreign databases, a total of 3102 articles were retrieved. Among them, there are 1231 articles in Chinese and 1871 articles in English, with 31 articles included, 21 in Chinese, and 10 in English. 25 case-control studies and 6 cohort studies are all high-quality studies.

9. Meta analysis results

A publication bias analysis was conducted on risk factors for 10 or more articles on mechanical ventilation time, APACHE II score, antibiotic combination therapy, and age. The scatter plots of the first three risk factors show a basic symmetrical distribution, and the likelihood of publication bias is relatively small. The funnel plot of age risk factors shows an asymmetric distribution, which may lead to publication bias. A meta-analysis was conducted on 13 risk factors mentioned in more than 2 articles. The results of the meta-analysis are shown in Table 1:

Table 1 Meta analysis results of various risk factors

Risk factor	Quantity (piece)	Test for heterogeneity		Effect model	Merger effect			Is it statistically significant
		I2(%)	P value		Effect size	95%CI	P value	
Ventilation time	21	99%	< 0.001	Random	2.25	1.90-2.67	< 0.001	Yes
≥5days	5	50%	0.11	Random	7.09	5.62-8.94	< 0.001	Yes
≥7days	9	93%	< 0.001	Random	1.26	1.12-1.43	< 0.001	Yes
APACHEIIScore	13	98%	< 0.001	Random	3.20	2.27-4.51	< 0.001	Yes
15Score	9	98%	< 0.001	Random	3.73	1.95-7.16	< 0.001	Yes
Combination of antibiotics	11	0%	0.54	Fixation	4.61	3.92-5.42	< 0.001	Yes
Year	11	95%	< 0.001	Random	1.03	1.02-1.05	< 0.01	Yes
60years	6	96%	< 0.001	Random	1.57	1.28-1.94	< 0.001	Yes
COPD history	9	65%	0.006	Random	2.31	1.68-3.17	< 0.001	Yes
Repeated tracheal intubation	8	69%%	< 0.001	Random	5.82	4.21-8.05	< 0.001	Yes
Disturbance of consciousness	7	91%	0.001	Random	1.86	0.93-3.72	0.08	No
Indwelling gastric tube	6	36%	0.18	Fixation	3.70	2.65-5.19	< 0.001	Yes
Hypoproteinemia	5	97%	< 0.001	Random	1.92	0.77-4.75	0.16	No
Tracheotomy	5	30%	0.23	Fixation	1.41	1.21-1.63	< 0.001	Yes
ICU hospitalization time	4	90%	< 0.001	Random	2.67	1.11-6.43	0.03	Yes
position	4	28%	0.25	Fixation	3.88	2.82-5.34	< 0.001	Yes

9.1 Elderly individuals, history of COPD, and long-term supine position are risk factors for VAP

Research has shown through meta-analysis that elderly people over 60 years old are significantly at risk for VAP due to weakened lung function and immunity[4]. Airways should be kept clean, appropriate ventilation strategies should be adopted, and chronic diseases should be managed to reduce risk. COPD patients have a high risk of VAP and need to follow medical advice and receive timely treatment. Long term supine position increases the risk of VAP. It is recommended to change the position, such as prone and 45 ° semi prone positions, to promote lung ventilation and reduce VAP[5-6].

9.2 High APACHE II score and combination of multiple antibiotics are risk factors for VAP

Research analysis shows that a high APACHE II score is a risk factor for VAP[7], and personalized treatment is needed to reduce risk if the score is ≥ 15. The combination of antibiotics may increase drug-resistant bacteria and increase the risk of VAP. It is recommended to assess the risk and consider bacterial spectrum and drug sensitivity when selecting antibiotics to reduce infection[8].

9.3 Invasive airway operations can increase the risk of VAP occurrence

This study conducted a meta-analysis on the impact of invasive airway procedures and found that repeated tracheal intubation, tracheostomy, and indwelling gastric tubes all increased the risk of VAP. These operations may disrupt the respiratory defense structure, impair immune cell function, reduce self-defense ability, and allow bacteria to cause respiratory infections through multiple pathways [9]. It is recommended that medical staff adopt aseptic techniques, optimize operating methods, reduce operating frequency, and minimize the risk of VAP.

9.4 The longer the duration of mechanical ventilation and hospitalization, the higher the risk of VAP occurrence

This study conducted a meta-analysis on "mechanical ventilation time" and "ICU hospitalization time", which showed that prolonged time increased the risk of VAP occurrence, matching the findings of Wu et al. Prolonged ventilation and hospital stay make patients more susceptible to the long-term effects of respiratory equipment and environmental bacteria, and may lower immunity and increase the risk of VAP [10]. Research suggests reducing the occurrence of VAP through strict aseptic procedures, regular replacement of pipelines, shortened ventilation time, and early weaning.

9.5 There is no significant relationship between consciousness disorders, hypoalbuminemia, and the occurrence of VAP

Meta analysis found that consciousness disorders and hypoalbuminemia are not independent risk factors for VAP, although the literature is inconsistent[11]. Research suggests that consciousness disorders reduce patient protection, and hypoalbuminemia affects immunity and tissue repair, which are among the multiple factors of VAP. It is recommended to regularly replace pipelines and clean disinfection equipment, limit the use of sedatives and sleeping pills, and provide nutrition and protein supplementation for patients with hypoalbuminemia to strengthen immunity and repair.

10. Summary

This study used meta-analysis to investigate the risk factors of VAP in ICU mechanically ventilated patients. It was found that aging, history of COPD, long-term lying flat, high APACHE II score, use of multiple antibiotics, and invasive airway procedures were significantly correlated with the risk of VAP. In addition, mechanical ventilation and prolonged hospital stay increase the risk of VAP, while consciousness disorders and hypoalbuminemia are not significantly associated with the occurrence of VAP. It is recommended to conduct clinical interventions targeting risk factors to improve patient outcomes. The results are influenced by differences in literature and require more high-quality research to verify.

References

[1] Tobin M, Manthous C. Mechanical Ventilation. Am J Respir Crit Care Med. 2017 Jul 15;196(2):P3-P4.

[2] Kózka M, Sega A, Wojnar-Gruszka K, et al. Risk factors of pneumonia associated with mechanical ventilation[J]. International Journal of Environmental Research and Public Health, 2020, 17(2): 656.

[3] Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses[J]. European journal of epidemiology, 2010, 25: 603-605.

[4] Xu Y, Lai C, Xu G, et al. Risk factors of ventilator-associated pneumonia in elderly patients receiving mechanical ventilation[J]. Clinical Interventions in Aging, 2019: 1027-1038.

[5] Singh D, Agusti A, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease: the GOLD science committee report 2019[J]. European Respiratory Journal, 2019, 53(5).

[6] Pozuelo-Carrascosa D P, Cobo-Cuenca A I, Carmona-Torres J M, et al. Body position for preventing ventilator-associated pneumonia for critically ill patients: a systematic review and network meta-analysis[J]. Journal of Intensive Care, 2022, 10(1): 9.

[7] Sutiono A B, Arifin M Z, Adhipratama H, et al. The utilization of APACHE II score to predict the incidence of ventilator-associated pneumonia in patients with severe traumatic brain injury: A single-center study[J]. Interdisciplinary Neurosurgery, 2022, 28: 101457.

[8] Vincent J L, Bassetti M, François B, et al. Advances in antibiotic therapy in the critically ill[J]. Critical Care, 2016, 20(1): 1-13.

[9] Yıldırım F, Tahir E. Relationship between Tracheostomy and Ventilator-associated Pneumonia in Intensive Care[J]. Journal of Critical and Intensive Care, 2017, 8(1): 19.

[10] Wolkewitz M, Palomar-Martinez M, Alvarez-Lerma F, et al. Analyzing the impact of duration of ventilation, hospitalization, and ventilation episodes on the risk of pneumonia[J]. Infection Control & Hospital Epidemiology, 2019, 40(3): 301-306.

[11] Wu D, Wu C, Zhang S, et al. Risk factors of ventilator-associated pneumonia in critically III patients[J]. Frontiers in pharmacology, 2019, 10: 482.