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ORIGINAL RESEARCH

Analysis of the Positive Effects of Optimizing the Sequence of Attracting and Suctioning Below the Glottis on the Incidence of Ventilator-Associated Pneumonia

Honghong Yang, MM; Ling Wang, MM; Chaochao Liu, MM; Yanqing Bai, MM; Rong Zhang, MM

ABSTRACT

Objective • This study aimed to investigate the impact of optimizing the subglottic suction and aspiration sequence on ventilator-associated pneumonia (VAP) incidence.

Methods • A total of 108 patients undergoing transcatheter orotracheal intubation with subglottic secretion drainage (SSD) and mechanical ventilation were selected from the Department of Critical Care Medicine in our hospital between September 2021 and March 2023. The patients were randomly assigned to either the observation group or the control group (54 cases each) using a random number method. In the control group, patients underwent manual airway suction followed by subglottic suction with -100 mmHg pressure. In the observation group, subglottic suction with -100 mmHg pressure was performed first, followed by manual airway suction. The comparative analysis included blood gas parameters, sputum suction effectiveness, VAP occurrence, 28-day morbidity and mortality rates, tracheal secretion culture results, and the workload of nurses.

Results • The observation group exhibited significantly shorter tape replacement time, sputum suction time, and number of suctions, along with a longer suction interval compared to the control group ($P < 0.05$). Post-suctioning, the observation group demonstrated improved blood gas function and a lower incidence of VAP ($P < .05$). No significant difference in adverse reaction incidence was observed between the two groups ($P > .05$); however, the Kolcaba score was higher in the observation group ($P < .05$).

Conclusions • Pre-endotracheal intubation oral and nasal sputum suctioning proves effective in reducing the risk of VAP, lessening the workload of nurses, and enhancing the comfort of sputum suctioning. (*Altern Ther Health Med.* [E-pub ahead of print.])

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INTRODUCTION

Ventilator-associated pneumonia (VAP) is a lung infection that occurs either 48 hours after initiating mechanical ventilation or within 48 hours after discontinuing mechanical ventilation.[1,2] When patients undergo invasive ventilation through oral endotracheal intubation or tracheotomy, it leads to the accumulation of a significant amount of secretions in the oral cavity and below the vocal cords.[2] Current research indicates that the aspiration of retained material on the tracheal tube cuff is one of the critical mechanisms contributing to the onset of VAP.[3]

Pathogens can enter the lower respiratory tract through the gap between the artificial airway cuff and the tracheal wall, leading to infection.[4] One of the primary methods to mitigate aspiration and efficiently remove retained material on the cuff is subglottic suctioning, which has proven to be an effective measure in reducing the incidence of VAP.[5-7] Currently, studies on subglottic suctioning from China and worldwide primarily focus on the selection of suction pressure and the direction of suctioning.[8] Studies examining the impact of suctioning on the occurrence of VAP predominantly concentrate on suctioning methods and depth.[9]

However, there are no relevant studies from China or other countries regarding the effects of different sequences of subglottic suctioning and suctioning on the occurrence of VAP in mechanically ventilated patients with subglottic secretion drainage (SSD) tubes. Therefore, this study aims to fill the research gap and investigate the impact of optimizing the sequence of subglottic suctioning on the incidence of VAP. This study holds potential importance in contributing valuable insights to the field of respiratory care and critical

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care medicine. By exploring the effects of different subglottic suctioning sequences, the study aims to provide evidence-based recommendations that may enhance preventive measures against ventilator-associated pneumonia, ultimately contributing to improved patient outcomes and the overall quality of care in mechanically ventilated patients.

MATERIALS AND METHODS

Study Design

A total of 108 mechanically ventilated patients with SSD endotracheal tubes admitted to the Intensive Care Unit of the Fourth Affiliated Hospital of Nanjing Medical University from September 2021 to March 2023 were carefully selected for participation in this study. This study received approval from the hospital's ethics committee (20210622-K006). Informed consent was obtained from the patients' families, who signed the consent forms. The study was conducted in strict compliance with the Declaration of Helsinki.

Group Characteristics

Patients were randomly divided into an observation group and a control group based on the order of admission. The randomization process, employing a random number method, resulted in 54 patients in each group. In the observation group, there were 39 males and 15 females, with an average age of (66.2±11.3) years. Diagnoses included 27 cases of ARDS, 15 cases after major surgery, 8 cases of cerebrovascular accidents, and 4 cases of other conditions. The control group consisted of 36 males and 18 females, with an average age of (65.7±10.8) years. Diagnoses included 24 cases of ARDS, 17 cases after major surgery, 10 cases of cerebrovascular accidents, and 3 cases of other conditions.

Inclusion and Exclusion Criteria

The inclusion criteria for participant selection in this study were as follows: (1) mechanical ventilation time >48h and <7 days; (2) patients with SSD endotracheal tubes; (3) age >18 years; (4) have provided signed informed consent. The exclusion criteria encompass individuals with (1) a history of lung infection, aspiration, or pulmonary edema prior to tracheal intubation; (2) Patients exhibiting ineffective subglottic suctioning; and (3) those with a predicted mechanical ventilation time of less than 48 hours are also excluded from the study. Adherence to these inclusion and exclusion criteria was crucial to ensuring the accuracy and reliability of the study outcomes.

Preventive Measures and Suctioning Protocols

Training and Education. All participants involved in the study underwent comprehensive training on various relevant topics. This training encompassed several prevention measures designed to prevent VAP. Participants were educated on the importance of pre-suctioning assessments, monitoring and maintaining cuff pressures within the normal range, subglottic irrigation, intermittent subglottic suctioning, and the closed suctioning process. Additionally, instruction covered crucial aspects such as sputum sample collection and the accurate recording of observation indicators.

Suctioning Indications. Indications for suctioning were clearly defined and included criteria such as a decrease in SpO_2 greater than 3%, audible rales or coarse crackles during chest auscultation, visible changes in the V-P curve waveform, a significant reduction in tidal volume with pressure control mode, the presence of secretions in the airway with audible rales, coarse or wet breath sounds, decreased breath sounds, increased respiratory rate, or difficulty in sputum clearance.

Adherence to Guidelines. Both the observation and control groups thoroughly followed bundle prevention measures for VAP as stipulated in the guidelines. It involved strict adherence to indications for tracheal intubation, minimizing sedation with a focus on early extubation, maintaining an elevated head of the bed (30°-45°), and utilizing endotracheal tubes equipped with subglottic suctioning capabilities. Additionally, the teams ensured the proper maintenance of the ventilator circuit, positioning the condensate collection bottle at the lowest point, keeping it upright, and cleaning it in a timely manner. This strict adherence to guidelines aimed to optimize preventive measures against VAP.

Diagnostic Criteria for Ventilator-Associated Pneumonia (VAP)

Temporal Association with Mechanical Ventilation. Patients meeting the diagnostic criteria for VAP exhibited pulmonary infection within the initial 48 hours following the initiation of mechanical ventilation.

Clinical Indicators. Clinical manifestations include a body temperature exceeding 37.5°C, the presence of moist rales in the lungs, and the identification of purulent secretions in the respiratory tract. Additionally, peripheral blood leukocyte counts surpassing 10×10^9/L served as an important clinical indicator.

Radiological Findings. Radiological assessments through chest X-rays revealed the emergence of new infiltrative shadows, further supporting the diagnosis of VAP.

Microbiological Criteria. The confirmation of VAP involved the cultivation of pathogenic bacteria from bronchial secretions, emphasizing the microbiological aspect of the diagnostic process.

Sputum Culture Comparison. A distinctive feature involved the cultivation of pathogenic bacteria from sputum, with a comparative analysis of results obtained before and after mechanical ventilation. It was particularly relevant for individuals with pre-existing pulmonary infections.

Observation Indicators

Workload Assessment of Nursing Staff. A careful assessment of the workloads assumed by the nursing staff in both groups. Parameters such as the time required for changing adhesive tape, suctioning time, suctioning intervals, and the number of suctions were carefully observed and documented.

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Evaluation of Suctioning Effectiveness. In assessing the effectiveness of suctioning, three key parameters were analyzed: the duration of mechanical ventilation, patient comfort during suctioning, and the length of hospital stay. To measure changes in patient comfort, the study employed the Kolcaba Comfort Scale, a well-established tool comprising 28 items, each rated on a 4-point scale. The total score, ranging from 0 to 112, served as an indicator of patient comfort during suctioning care, with higher scores denoting a greater level of comfort. This complete evaluation aimed to provide a nuanced understanding of the impact of suctioning interventions on both the physiological and psychological aspects of patient care.

Physiological Measurements. For physiological assessment, pre- and post-suctioning measurements were conducted to analyze arterial oxygen saturation (SaO_2) and partial pressure of carbon dioxide ($PaCO_2$). This evaluation aimed to determine any variations in these vital respiratory parameters before and after suctioning interventions. The data collected in this process provided valuable insights into the impact of suctioning on the respiratory status of the patients.

Incidence Data Collection. To assess the impact of the intervention, data collection extended to various indicators, including skin injuries, mucosal injuries, and incidents of VAP in both patient groups. This detailed analysis captured and compared the occurrence of adverse events related to skin and mucosal integrity and instances of VAP. The collected data provided insights into the safety aspects of the intervention, guiding the evaluation of potential complications and adverse outcomes associated with suctioning practices.

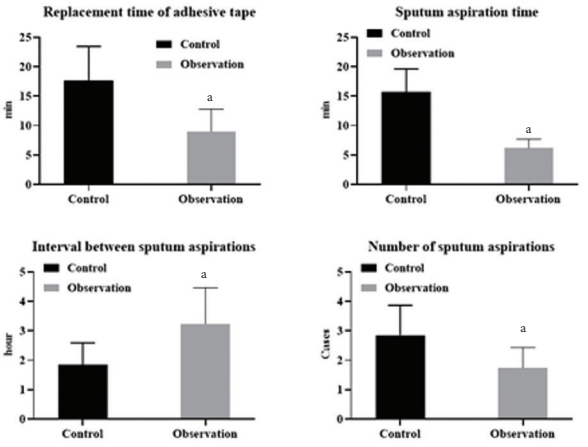
VAP Incidence Rate and Mortality Rate. The study calculated both the incidence rate and mortality rate within 28 days. It involved determining the ratio of deaths among patients who received mechanical ventilation for the specified duration. By quantifying the incidence rate and mortality rate, the study aimed to provide a quantitative understanding of the impact of suctioning interventions on both the occurrence and severity of VAP, offering insights into patient outcomes within the defined timeframe.

Microbiological Analysis. For microbiological analysis, secretion samples were systematically collected from the cuffs of ventilation bags in both groups at 48 hours and 72 hours. These samples were subsequently submitted for bacterial culture to assess the microbial composition. The study compared the culture results between the two groups, providing valuable insights into the microbiological impact of suctioning interventions on the ventilation system.

Statistical Analysis

Statistical analysis was performed using SPSS 20.0 software. The Chi-square test (χ^2) was used to compare categorical data. For continuous data, mean ± standard deviation ($\bar{x} \pm s$) was used. A paired t test was used to compare before and after suctioning. A significance level of $P < .05$ was considered statistically significant.

Figure 1. Comparison of Workloads between Two Groups of Nurses (n=108)



[a]$P < .05$, denotes a significant difference compared to the control group.

Note: The figure illustrates the comparison of workloads between the observation and control groups, each consisting of 108 cases.

RESULTS

Baseline Characteristics Comparison

In the comparison of baseline characteristics, specifically age, gender, and disease information, between the two groups, no statistically significant differences were observed ($P > .05$). This outcome ensures a high level of comparability between the groups, establishing a robust foundation for subsequent analyses and interpretations.

Comparison of Workloads Between Two Groups of Nurses

Notable differences were observed in evaluating the workloads of nurses in both groups. The observation group exhibited significantly shorter times for changing adhesive tape, suctioning and a lower number of suctions compared to the control group. Additionally, the suctioning interval was significantly longer in the observation group than in the control group. These differences reached statistical significance ($P < .05$), indicating a higher efficiency in suctioning fluids when employing subglottic suction followed by the artificial airway. See Figure 1.

Comparison of SaO_2 and $PaCO_2$ Before and After Suctioning Between Two Groups of Patients

Prior to suctioning, no statistical difference in SaO_2 and $PaCO_2$ was identified between the two groups of patients ($P > .05$), indicating comparable baseline physiological parameters. However, after suctioning, noteworthy differences emerged. In the observation group, SaO_2 was significantly higher compared to the control group, and $PaCO_2$ was significantly lower than the control group ($P < .05$). These results underscore the effectiveness of subglottic suction followed by an artificial airway in enhancing the patient's blood gas function. See Figure 2.

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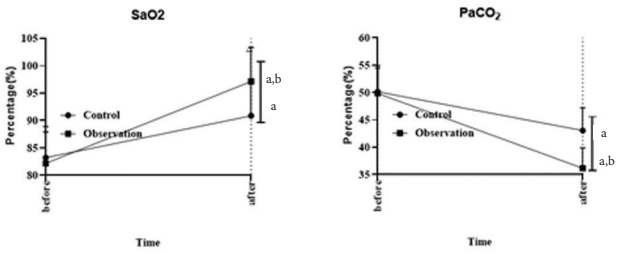
Figure 2. Comparison of SaO_2 and $PaCO_2$ before and after Suctioning (n=108)



[a]$P < .05$ compared with before suctioning
[b]$P < .05$ compared with the control group

Note: The figure depicts the comparison of arterial oxygen saturation (SaO_2) and partial pressure of carbon dioxide ($PaCO_2$) before and after suctioning in a sample size of 108 cases.

Table 1. Comparison of VAP Incidence Rate and 28-day Mortality Rate Between Two Groups

Group	n	VAP		28-Day Mortality Rate	
		Occurred	Not occurred	Died	Not died
Observation Group	54	5 (9.26%)	49 (90.74%)	8 (14.81%)	46 (85.19%)
Control Group	54	12 (22.22%)	42 (77.78%)	10 (18.52%)	44 (81.48%)
χ^2		4.537		0.942	
P value		.03		.836	

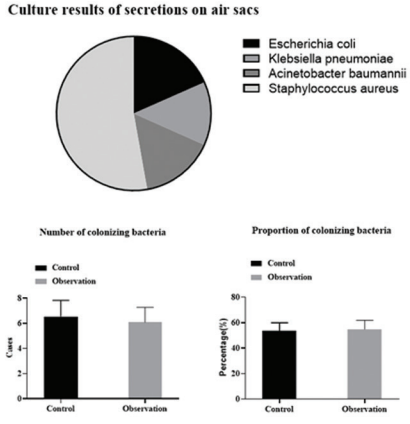
Notes: VAP - Ventilator-Associated Pneumonia; n - Number of cases; x^2-Chi-square test. The percentages in parentheses represent the proportion of cases in relation to the total within each category.

Table 2. Comparison of Incidence Rates of Skin Injuries and Mucosal Injuries between Two Groups of Patients

Group	n	Skin Damage	Mucosal Damage
Observation Group	54	8(14.81)	6(11.11)
Control Group	54	20(39.04)	8(14.81)
χ^2		5.26	1.533
P value		<.05	>.05

Notes: Chi-square (χ^2) values and corresponding *P* values are provided for the comparison of skin injuries and mucosal injury incidence rates between the observation and control groups. The percentages in parentheses represent the proportion of cases in relation to the total within each category.

Figure 3. Comparison of Culture Results of Secretions on Air Sacs (n=108)



Note: The figure presents a comparison of culture results from secretions on air sacs within a sample size of 108 cases.

Comparison of VAP Incidence Rate and 28-day Mortality Rate Between Two Groups

The comparative analysis of the VAP incidence rate and 28-day mortality rate revealed noteworthy differences between the two groups. The results indicated a significantly lower incidence rate of VAP in the observation group compared to the control group, with a statistically significant difference ($P < .05$). However, there was no statistically significant difference in the 28-day mortality rate between the observation group and the control group ($P > .05$). These findings suggest that the implementation of subglottic suction followed by an artificial airway can effectively reduce the incidence of VAP. Refer to Table 1.

Comparison of Incidence Rates of Skin Injuries and Mucosal Injuries Between Two Groups of Patients

Notable differences were observed in the incidence rates of skin injuries and mucosal injuries between the two patient groups. The observation group exhibited a lower incidence rate of skin injuries compared to the control group, and this difference was statistically significant ($P < .05$). Conversely, while the incidence rate of mucosal injuries in the observation group was slightly lower than in the control group, this difference did not reach statistical significance ($P > .05$). These findings collectively suggest that the implementation of subglottic suction followed by an artificial airway contributes to a safer patient care environment, particularly in mitigating the occurrence of skin injuries. Refer to Table 2.

Comparison of Culture Results of Secretion Samples from Ventilation Bag Cuffs

The analysis of culture results from secretion samples collected from the cuffs of ventilation bags revealed the presence of common bacteria, including *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *Staphylococcus aureus*. Notably, *Escherichia coli*, *Klebsiella pneumoniae*, and *Acinetobacter baumannii* collectively accounted for 29.8%, while *Staphylococcus aureus* constituted 33.3% of the identified bacteria.

After nursing interventions, the quantities and proportions of colonization bacteria cultured from the secretion samples on the cuffs of ventilation bags were compared between the two patient groups at 48 hours and 72 hours of mechanical ventilation. The results demonstrated no statistically significant difference ($P > .05$), indicating that there was no evident difference in the impact of the two suctioning sequences on the colonization of pathogenic bacteria. See Figure 3.

Comparison of Suctioning Effectiveness Between Two Groups of Patients

Notable differences were observed in evaluating the effectiveness of suctioning interventions between the two patient groups. The results demonstrated that the observation group exhibited significantly shorter durations of mechanical ventilation and hospital stays compared to the control group.

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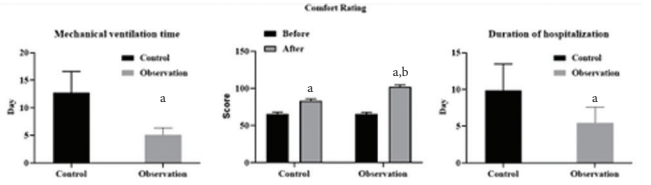
Furthermore, the scores on the Kolcaba Comfort Scale, a key indicator of patient comfort, were notably higher in the observation group than in the control group, with a statistically significant difference ($P < .05$). These outcomes collectively suggest that the implementation of subglottic suction followed by an artificial airway contributes to improved patient comfort, as evidenced by enhanced scores on the Kolcaba Comfort Scale. See Figure 4.

Figure 4. Comparison of Suctioning Effectiveness between Two Groups of Patients



[a]$P < .05$ compared with before suctioning
[b]$P < .05$ compared with the control group

DISCUSSION

Mechanical ventilation stands as a crucial intervention for rescuing critically ill patients, serving to enhance respiratory function and alleviate the burden on the heart and lungs. However, VAP emerges as a prevalent and severe complication associated with mechanical ventilation. Its onset poses challenges in the weaning process from the ventilator, escalating the complexity of treatment.[10] In severe cases, VAP can prove life-threatening, emphasizing the critical importance of preventative measures and effective management during mechanical ventilation. The successful implementation of strategies to minimize the occurrence of VAP is imperative to ensure overall well-being and favorable outcomes for patients undergoing mechanical ventilation.[10,11]

One study highlighted that the incidence of VAP in the intensive care unit is 22.22%, demonstrating a close correlation with factors such as the duration of ventilator use and patient positioning.[12] Existing research data further revealed that in elderly patients undergoing mechanical ventilation, the incidence of VAP rises significantly to 45.31%, accompanied by a substantial mortality rate of 36.21%.[13] Previous studies highlight the elevated risk of VAP in mechanically ventilated patients, influenced by multiple factors. Thus, mitigating the incidence of VAP has become paramount in the realms of both treatment and nursing care, emphasizing the critical need for proactive preventive measures and attentive patient management.

Suctioning is a crucial preparatory step preceding mechanical ventilation, primarily aimed at clearing the patient's respiratory secretions and ensuring an unobstructed airway. However, inadequate suctioning practices can elevate the risk and severity of VAP, thereby highlighting its important role in clinical nursing.[14,15]

Currently, investigations into the impact of suctioning on the incidence of VAP, both within China and globally, are predominantly centered on exploring suctioning methods and depth. However, there is a notable oversight in the examination of the suctioning sequence. The conventional suctioning sequence entails initially clearing the secretions inside the tracheal tube, followed by employing a disposable suction catheter to suction or cleanse the nasal and oral secretions. After the suctioning of secretions inside the tracheal tube, there is a significant decrease in cuff pressure, facilitating the re-entry of nasal and oral secretions into the airway. Therefore, nurses are compelled to repeatedly suction the airway, leading to an extension in suctioning time and an escalation in patient discomfort.

In this study, we modified the suctioning sequence to initially clear nasal and oral secretions, followed by suctioning the tracheal tube. The results indicated that the experimental group exhibited reduced tape changing time, suctioning time, number of suctioning episodes, mechanical ventilation time, and hospital stay in comparison to the control group. Furthermore, the experimental group demonstrated longer suctioning intervals and enhanced comfort compared to the control group. These findings suggest that the adapted suctioning sequence offers notable advantages in clinical nursing, effectively alleviating the workload of nurses and enhancing overall patient comfort.

Suctioning procedures are inherently traumatic, and the traditional suctioning sequence involves multiple insertions and removals of the suction catheter into the trachea. This approach significantly prolongs suctioning time and contributes to a decline in patient comfort. Conversely, initiating the process with the cleaning and suctioning of nasal and oral secretions can effectively prevent the reentry of these secretions into the airway. This approach facilitates the subsequent suctioning of tracheal secretions, leading to a reduction in the number of suctioning episodes, elimination of the need for repeated suctioning, and a diminished risk of respiratory pathogen colonization from the nasal and oral cavity into the lungs.

Our study revealed that after suctioning, the experimental group exhibited higher SaO_2 levels and lower $PaCO_2$ levels in comparison to the control group. Several factors contribute to these findings: (1) Initiating the process with nasal and oral secretion suctioning and cleaning alleviates obstruction caused by secretions, thereby enhancing oxygen flow and reducing carbon dioxide concentration; (2) Thoroughly clearing nasal and oral secretions before suctioning tracheal secretions significantly improves suctioning effectiveness, ensuring airway patency; (3) Suctioning nasal and oral secretions as the initial step proves faster than repeated airway suctioning, facilitating the prompt removal of respiratory secretions and rapid restoration of oxygen flow.

This study illustrates that the experimental group exhibited significantly lower rates of both skin damage and VAP when compared to the control group. These findings suggest that the modified suctioning sequence proves effective in reducing the incidence of VAP and preventing skin damage. The occurrence of skin damage post-suctioning is primarily attributed to excess saliva, contributing to skin moisture. Moreover, frequent tape changes can mechanically irritate the local skin, leading to skin abrasions, bleeding, and even ulceration.[16,17]

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Initiating the suctioning process with nasal and oral secretion removal facilitates the timely elimination of oral secretions. This approach prevents excessive salivation and preserves the dryness of the local skin, thereby minimizing the risk of skin damage. Furthermore, the adapted suctioning method adeptly prevents the downward colonization of pathogens, mitigating the adverse effects of suctioning on the patient's respiratory function and effectively reducing the incidence of VAP. Previous research has indicated that proper suctioning not only enhances patients' recovery but also contributes to cost savings in treatment and elevates the overall quality of nursing care.[18]

The results of secretion cultures from the cuff indicated that Gram-negative bacteria were the predominant pathogens. Implementation of subglottic suctioning proved effective in inhibiting the proliferation of pathogens within the cuff retention, thereby reducing bacterial colonization. In clinical practice, it is crucial to be attentive to common colonizing bacteria, especially antibiotic-resistant strains. Colonizing bacteria, often opportunistic pathogens, have the potential to transform into pathogenic forms when the immune system of critically ill patients is compromised. Therefore, the inhibition of colonizing bacteria proliferation can be instrumental in effectively reducing the occurrence of infections.[19,20]

There was no significant difference in the quantity and proportion of colonizing bacteria cultured from the cuff secretions at 48h and 72h of mechanical ventilation in this study. This finding suggests that both suctioning methods effectively reduce the quantity of colonizing bacteria in the cuff, consequently decreasing the occurrence of infections. Furthermore, the conclusive results of this study revealed no statistically significant difference in the 28-day mortality rate between the two groups of patients. This finding could be attributed to the relatively small sample size, the advanced age, and the compromised baseline cardiopulmonary function of intensive care unit patients. Additionally, there is a tendency for the condition to recur during the later treatment period in regular wards.

Study Limitations

A few limitations must be acknowledged in this study. Firstly, the relatively small sample size may introduce the potential for chance influencing the study results, and therefore, caution should be exercised in generalizing the findings. Additionally, the short duration of follow-up limits our ability to assess the long-term prognosis of the studied groups comprehensively. Furthermore, the results are contingent on the variables considered, and unaccounted factors may impact the study's outcomes. Future investigations should address these limitations by expanding the sample size, extending the follow-up period, and incorporating a more extensive array of variables for a more nuanced understanding of the subject matter.

CONCLUSION

In conclusion, the practice of oropharyngeal suctioning prior to endotracheal intubation emerges as an effective strategy for mitigating the risk of VAP. This approach not only alleviates the workload of nurses but also enhances the overall comfort of suctioning procedures. We advocate for an emphasis on reinforcing oral hygiene practices for patients undergoing mechanical ventilation, coupled with the implementation of routine oral care. Furthermore, the integration of the modified suctioning technique stands out as an additional measure to decrease the nursing workload while optimizing the efficacy of suctioning procedures. This comprehensive approach offers a promising avenue for improving patient outcomes in the context of mechanical ventilation.

CONFLICTS OF INTEREST

The authors report no conflict of interest.

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Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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