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Evaluation of the Application Effect of Intelligent Empowerment Standardized Airway Management Process in Patients Receiving Mechanical Ventilation

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Abstract: *Objective*: To investigate the application effect of intelligent empowerment standardized airway management process in patients receiving mechanical ventilation. *Methods*: A retrospective analysis was conducted on the clinical data of 79 EICU inpatients who underwent tracheal intubation and mechanical ventilation treatment at our hospital from January 2023 to May 2025. The patients were divided into a control group (conventional airway management process, n = 40) and a study group (intelligent empowerment standardized airway management process, n = 39) based on the intervention protocols they received. Oral health scores, dental plaque index, oral odor, serum inflammatory markers [C-reactive protein (CRP), procalcitonin (PCT)], clinical pulmonary infection score (CPIS), as well as the incidence of ventilator-associated pneumonia (VAP), duration of mechanical ventilation, and length of stay in the EICU were assessed before and after treatment. *Results:* The baseline values of all indicators were consistent between the two groups before intervention ($p > 0.05$). After corresponding interventions, both groups showed significant improvements in Beck oral health scores, dental plaque index, and oral odor, with more pronounced improvements observed in the study group ($p < 0.05$). After the intervention, the research group showed a significant decrease in serum CRP and PCT levels, as well as CPIS scores ($p < 0.05$). In contrast, the control group experienced an increase in these three indicators to a certain extent ($p < 0.05$). Moreover, the incidence of ventilator-associated pneumonia (VAP), duration of mechanical ventilation, and length of stay in the EICU were all lower in the research group compared to the control group, while the nurse's compliance rate with the protocol was higher in the research group ($p < 0.05$). *Conclusion:* The standardized airway management protocol empowered by intelligent technology can significantly improve nursing compliance, benefit oral health status, reduce the risk of pulmonary infection and systemic inflammation levels, and promote rapid patient recovery, demonstrating considerable potential for widespread adoption.

Keywords: Intelligent management; Airway management; Mechanical ventilation; Protocol compliance

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1. Introduction

While mechanical ventilation provides critical life support for critically ill patients in the Emergency Intensive Care Unit (EICU), the tracheal intubation procedure can disrupt the normal anatomical and physiological barriers of the upper respiratory tract. Given the often-compromised immune function in these patients, this disruption facilitates the translocation of oral pathogens, thereby increasing the risk of ventilator-associated pneumonia (VAP). VAP not only significantly affects patient prognosis but also prolongs the duration of mechanical ventilation and EICU stay, imposing an additional burden on healthcare resources [1]. Currently, bundled care protocols for VAP prevention have been proposed clinically, often encompassing evidence-based interventions such as standardized oral care and positioning management. However, compliance with standard care protocols remains a persistent issue in clinical practice, particularly in the high-pressure environment of the EICU, where incomplete or inconsistent implementation of nursing measures can compromise the effectiveness of VAP prevention [2]. In view of this, this study examined the clinical data of 79 patients admitted to the EICU of XXX Hospital who underwent tracheal intubation and mechanical ventilation from January 2023 to May 2025. The aim is to deeply integrate information technology with medical resources and explore the application effects of a standardized airway management process empowered by intelligent technology in patients undergoing mechanical ventilation. The findings are reported as follows.

2. Data and methods

2.1. General data

A retrospective analysis was conducted on the clinical data of 79 EICU inpatients who underwent tracheal intubation and mechanical ventilation from January 2023 to May 2025. Based on the intervention protocols received, patients were divided into a control group (conventional airway management process, n = 40) and a study group (standardized airway management process empowered by intelligent technology, n = 39). A comparison of the general data between the two groups was presented in **Table 1**, demonstrating comparability. This study complied with the Declaration of Helsinki and received informed consent exemption.

Table 1. Comparison of baseline demographic and clinical characteristics between the two groups [$\bar{x} \pm s$, n]

Group	Number of cases (n)	Age (years)	Gender (M/F, n)	BMI (kg/m^2)	APACHE II score
Control group	40	60.15 ± 10.02	23 / 17	23.44 ± 2.15	18.55 ± 3.41
Research group	39	61.24 ± 9.67	25 / 14	23.19 ± 2.08	18.98 ± 3.17
Test statistic (χ^2/t)	-	-0.492	0.361	0.525	-0.580
p-value	-	0.624	0.548	0.601	0.564

2.2. Inclusion criteria

(1) Patients receiving mechanical ventilation for the first time via oral or nasal tracheal intubation;
(2) Aged 18 years or older;
(3) Expected mechanical ventilation duration exceeding 48 hours;
(4) Complete baseline data.

2.3. Exclusion criteria

(1) Patients with a hospital stay in the EICU of less than 48 hours due to rapid deterioration or transfer;
(2) Patients diagnosed with or highly suspected of having pneumonia within 48 hours of admission or the initiation of mechanical ventilation;
(3) Pregnant or lactating women;
(4) Patients with severe infections or diseases in other organs;
(5) Patients with severe immunodeficiency, such as AIDS or neutropenia following chemotherapy;
(6) Patients with severe craniofacial trauma, oral and maxillofacial deformities, or a recent surgical history, presenting contraindications for oral care procedures;
(7) Patients with a history of severe chronic pulmonary diseases, such as chronic obstructive pulmonary disease or bronchiectasis.

2.4. Methods

The control group received routine standardized airway management. Nurses trained in airway management theory performed the interventions, relying on individual awareness and empirical judgment for practical operations. Information such as body position, cuff pressure measurements, and oral care timing was manually recorded.

The study group received smart technology-enabled interventions in addition to the control group's routine care.

(1) Smart-enabled visual management

A large electronic bulletin board was installed at the nursing station, connected in real-time to the hospital's HIS system. Given the multitasking nature of EICU care, the right side of the board featured a dynamic "bulletin" section and task reminder area, transforming implicit airway management orders (such as cuff pressure measurement, subglottic suctioning, and oral care) into intuitive task lists with numerical sequences (1, 2, 3...). The system automatically sorted tasks based on order times, ensuring nurses had up-to-date information on pending nursing tasks. Additionally, a small whiteboard was placed beside each bed as an extension of the electronic system, used to record personalized handover priorities, such as specific information like "thick sputum requiring enhanced humidification".

(2) Inspection and evaluation closed loop

Based on the standardized system template, print the dedicated "Oral Care Management Implementation Form for Patients with Artificial Airways" and hang it at the foot of the bed. This form integrates the core elements of the modified Beck Oral Assessment Scale, mandating that nurses must first conduct real-time observations of the patient's oral cavity and manually check and score it before performing the prescribed frequency of operations at 08:00, 16:00, 22:00, etc. After completing the operation, they should check the corresponding time slot and sign.

(3) Standardized intervention process

Complete the initial assessment within 6 hours of the patient's mechanical ventilation, and then assess every 8 hours using the Beck Oral Assessment Scale. Elevate the head of the bed to more than 30° provided there are no contraindications. Use a cuff pressure gauge to maintain the tracheal tube cuff pressure between 25–30 cmH_2O, measuring and adjusting it every 6 hours. Perform oral care every 8 hours using an irrigation-type oral suction tube, and perform subglottic secretion suctioning before and after the procedure.

(4) Medical-nursing collaboration and dynamic quality control

Establish a data-driven feedback decision-making mechanism. The department appoints a quality control team leader who regularly reviews the "Implementation Form" at the foot of the bed daily to calculate the trend of changes in Beck scores. If an increase in score or abnormal recording is detected, the medical-nursing collaboration procedure is initiated immediately. The nurse reports the quantitative data to the attending physician, who dynamically adjusts the intervention plan based on the score, such as "increasing the nursing frequency from q8h to q6h", "adjusting the type of irrigation solution", or "requesting an oral surgery consultation".

2.5. Observation indicators

2.5.1. Oral health indicators

The modified Beck Oral Assessment Scale was used to evaluate oral damage in patients at the time of enrollment and after 7 days of treatment. This evaluation mainly covered five aspects: lips, tongue, teeth, saliva, and gums/mucous membranes, with each aspect scored from 0 to 4 points, for a total possible score of 20 points. A higher score indicated more severe oral damage. The sense measurement method was employed to assess patients' oral malodor, with scores ranging from 0 to 5 points; a higher score indicated more severe oral malodor. The dental plaque index of patients was also evaluated, with scores assigned from 0 to 3 points based on the severity of dental plaque, from low to high; a higher score indicated more severe dental plaque.

2.5.2. Infection and inflammation indicators

Fasting venous blood samples were collected from patients at the time of enrollment and after 7 days of treatment. An automatic biochemical analyzer was used to measure serum levels of C-reactive protein (CRP) and procalcitonin (PCT). Additionally, patients underwent a Clinical Pulmonary Infection Score (CPIS), which primarily included six items such as body temperature, white blood cell count, and airway secretions, with a total possible score of 12 points. A higher score suggested more severe infection.

2.5.3. Clinical outcome indicators and procedural compliance rate

The occurrence of ventilator-associated pneumonia (VAP), duration of mechanical ventilation, and length of stay in the EICU were observed and compared between the two groups of patients. Additionally, the comprehensive compliance rate of nurses with the five core measures of the procedure (positioning, cuff pressure, subglottic suctioning, frequency of oral care, and tool usage) was evaluated. The compliance rate was calculated as follows: Compliance rate = (number of times accurately performed in practice / total number of times required to be performed) × 100%.

2.6. Statistical methods

Data analysis was performed using SPSS 22.0 statistical software. After confirming normal distribution through the Shapiro-Wilk test, measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), and comparisons between groups were made using the independent samples *t*-test. Categorical data were expressed as rates (%), and differences between the two groups were compared using the χ^2 test. A *p*-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of oral health indicators between the two groups of patients

The baseline Beck oral scores, oral malodor scores, and dental plaque indices were consistent between the two groups before intervention. After corresponding interventions, all three indicators significantly decreased in both groups, with the study group showing lower Beck oral scores, oral malodor scores, and dental plaque indices than the control group ($p < 0.05$). See **Table 2**.

Table 2. Comparison of oral health indicators between the two groups of patients ($\overline{x} \pm s$, points)

Group	Number of cases (n)	Beck oral assessment scale (BOAS) score		Oral malodor score		Plaque index (PI)	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Control group	40	11.52 ± 1.60	9.88 ± 1.54*	3.11 ± 0.50	2.65 ± 0.45*	2.12 ± 0.51	1.75 ± 0.43*
Research group	39	11.15 ± 1.93	6.45 ± 1.12*	3.23 ± 0.61	1.14 ± 0.32*	2.19 ± 0.62	0.90 ± 0.26*
t-value	-	0.929	11.297	-0.957	17.149	-0.549	10.599
p-value	-	0.356	$p < 0.001$	0.341	$p < 0.001$	0.585	$p < 0.001$

Note: Compared with before intervention, *$p < 0.05$.

3.2. Comparison of infection and inflammation indicators between the two groups of patients

The baseline levels of infection and inflammation indicators were consistent between the two groups before intervention. After corresponding interventions, the control group showed increased levels of CRP, PCT, and CPIS scores, while the study group showed significant decreases. After intervention, the study group had significantly lower levels of CRP, PCT, and CPIS scores than the control group ($p < 0.05$). See **Table 3**.

Table 3. Comparison of infection and inflammation indicators between the two groups of patients ($\overline{x} \pm s$)

Group	Number of cases (n)	CRP (mg/L)		PCT (ng/mL)		CPIS (points)	
		Pre-intervention	Post-intervention	Pre-intervention	Post-intervention	Pre-intervention	Post-intervention
Control group	40	74.11 ± 10.29	88.43 ± 12.05*	0.63 ± 0.20	0.89 ± 0.25*	4.15 ± 1.02	5.01 ± 1.10*
Research group	39	74.88 ± 9.68	45.10 ± 9.81*	0.67 ± 0.17	0.30 ± 0.11*	4.03 ± 0.95	3.12 ± 0.88*
t-value	-	-0.342	17.502	-0.957	13.516	0.541	8.420
p-value	-	0.733	$p < 0.001$	0.342	$p < 0.001$	0.590	$p < 0.001$

Note: Compared with before intervention, *$p < 0.05$.

3.3. Comparison of clinical outcomes and process compliance rates between the two groups of patients

The incidence of VAP, duration of mechanical ventilation, and length of stay in the EICU were significantly lower in the study group compared to the control group, while the process compliance rate was higher in the study group ($p < 0.05$). See **Table 4**.

Table 4. Comparison of clinical outcomes and process compliance rates between the two groups of patients [$\overline{x}$ ± s, n(%)]

Group	Number of cases (n)	VAP incidence	Duration of mechanical ventilation (days)	EICU length of stay (days)	Compliance rate (%)
Control group	40	8 (20.00)	10.22 ± 3.11	13.89 ± 4.05	62.33 ± 5.15
Research group	39	1 (2.56)	7.14 ± 2.02	10.35 ± 3.15	95.12 ± 2.04
Test statistic (χ^2/t)	-	4.345	5.206	4.329	37.026
p-value	-	0.037	< 0.001	< 0.001	< 0.001

4. Discussion

The colonization of oral flora and micro-aspiration in patients undergoing mechanical ventilation are the primary causes of VAP, and meticulous oral care targeting these factors is a crucial aspect of VAP prevention. However, the disconnect between traditional nursing management processes and their execution limits the effectiveness of nursing care [3]. Therefore, this study aimed to overcome the compliance challenges of traditional management by intelligently empowering standardized airway management. The specific intervention effects are as follows.

In the results of this study, the average process compliance rate among nurses in the study group was 95.12 ± 2.04%, significantly higher than the 62.33 ± 5.15% observed in the control group. This suggests that intelligent empowerment significantly improved compliance with airway management processes. The reason for this is that traditional nursing management methods have limitations in terms of timeliness and initiative when defining nursing management procedures. In contrast, the study group adopted an airway management process empowered by information technology, which first triggered nurses' attention to tasks through intuitive and visual bulletin boards, transforming abstract time concepts into intuitive visual stimuli. Furthermore, small whiteboards were placed at the bedside to remind nurses of key handover points, avoiding potential omissions in high-pressure environments and allowing them to focus on the quality of nursing care itself [4]. On the other hand, the application of nursing management implementation forms can compel nursing staff to conduct secondary confirmations during operations, helping them transition from subconscious actions to conscious verifications, thereby effectively overcoming potential oversights in their work [5]. Through the feedback decision-making mechanism of daily inspections of implementation forms by head nurses, nursing interventions can shift from empirical execution to precise decision-making. This ensures nurses' compliance with nursing interventions on one hand and enhances the precision of interventions on the other [6]. After intervention, both groups of patients showed significant improvements in Beck oral health scores, odor scores, and dental plaque indices. The reason for this lies in the fact that standardized procedures ensure the proper implementation of oral care measures. Through mechanical rinsing and negative pressure suction, these measures effectively disrupt the dental plaque biofilm, flush out debris between teeth, and remove dental plaque, improving the oral microenvironment while preventing the accumulation of dislodged plaque and waste fluids in the oropharynx [7]. The improved adherence to procedures directly translates into benefits for patients' oral health, as evidenced by more significant improvements in oral health scores [8]. Additionally, this study observed that in the control group, CPIS, CRP, and PCT levels increased after intervention, whereas in the study group, these levels significantly decreased. The reason for this is that intelligent nursing procedures may improve patients' oral environments, reduce the colonization of pathogenic bacteria in patients' mouths, significantly lower the proportion of bacteria entering the lower respiratory tract, thereby significantly reducing the risk of VAP and the associated systemic inflammatory response, and avoiding prolonged mechanical ventilation and EICU stays as a result [9]. This is consistent with the viewpoint proposed by Liao Mingyu et al. in their study that the combined detection of indicators such as CPIS, CRP, and PCT can effectively evaluate the risk of VAP occurrence and prognosis [10].

5. Conclusion

In conclusion, the standardized airway management process empowered by intelligence can significantly improve the compliance of EICU nurses in implementing nursing measures. It may be beneficial for improving the oral health status of mechanically ventilated patients, reducing the risk of infection and systemic inflammatory response, and shortening the duration of mechanical ventilation and EICU hospitalization. However, this study still has certain limitations. As a retrospective study, there may be unobserved selection bias, and since it is a single-center study, the extrapolation of its intervention effects may be limited. In the future, multi-center, prospective randomized controlled trials are needed to enhance the credibility of the research results.

Disclosure statement

The author declares no conflict of interest.

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