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Exploration on the Application of Airway Care Measures During the Coma Period in Pediatric Patients with Severe Craniocerebral Injury

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Abstract: *Objective*: This study aims to systematically evaluate the practical effects of an integrated airway care protocol in the clinical management of pediatric patients with severe craniocerebral injury in a coma, with the core objective of reducing airway-related complications and optimizing treatment outcomes. *Methods*: A prospective study was conducted involving 76 pediatric patients with severe craniocerebral injury in a coma who were admitted to the paediatrics of our hospital from January 2022 to December 2023 and met the inclusion criteria. These patients were randomly divided into an intervention group and a conventional group, with 38 cases in each group. The conventional group received standard neurosurgical airway care, while the intervention group implemented a systematic care strategy encompassing precise humidification, programmed suctioning, individualized positioning adjustments, and early respiratory function intervention. The incidence of ventilator-associated pneumonia and airway mucosal injury, duration of invasive ventilation, length of stay in the paediatrics, and improvements in arterial oxygen and carbon dioxide partial pressures before and after intervention were recorded and compared between the two groups. *Results*: The incidence of ventilator-associated pneumonia in the intervention group was 13.16%, significantly lower than the 34.21% in the conventional group. The incidence of airway mucosal injury in the intervention group was 10.53%, also lower than the 28.95% in the conventional group. In terms of time indicators, the intervention group had shorter average durations of mechanical ventilation and paediatrics stay compared to the conventional group. Blood gas analysis results showed that the intervention group had greater increases in arterial oxygen partial pressure and decreases in carbon dioxide partial pressure than the conventional group, with statistically significant differences between the groups. *Conclusion*: Comprehensive and proactive airway care interventions during the coma period in pediatric patients with severe craniocerebral injury can effectively safeguard airway function integrity, significantly reduce the risk of major complications, accelerate the critical care process, and thereby provide more stable support conditions for neurological recovery. This protocol holds clinical practical value.

Keywords: Children; Severe craniocerebral trauma; Consciousness disorder; Airway management; Ventilator-associated pneumonia

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1. Introduction

Pediatric severe craniocerebral trauma is a critical condition with high mortality and disability rates, and coma is a common and severe clinical state. During this stage, due to the inhibition of higher nervous activities, pediatric patients lose key airway defense mechanisms such as coughing and swallowing, making airway management a core challenge and a weak link in determining the success of treatment. Improper airway maintenance can directly induce or exacerbate pulmonary infections, atelectasis, physical airway injuries, and even respiratory failure. These secondary problems not only aggravate the primary brain injury but also pose significant mortality risks. Previous nursing practices have often been fragmented and reactive, lacking a proactive, evidence-based intervention system that spans the entire course of the disease and is difficult to cope with the complex and changing pathological conditions of pediatric patients. Therefore, exploring and establishing a scientific, standardized, and suitable airway maintenance strategy for the physiological structure of children to achieve proactive defense, reduce complications, and support the treatment of primary diseases has become an urgent need in the development of pediatric critical care nursing. This study focuses on this aspect, aiming to analyze the application efficacy of a comprehensive airway care protocol through clinical control and provide references for improving the nursing quality of such pediatric patients.

2. Materials and methods

2.1. General information

This research protocol has been approved by the institutional ethics committee. The study subjects comprised 76 children with severe traumatic brain injury and coma admitted to the paediatrics of our hospital from January 2022 to December 2023.

2.1.1. Inclusion criteria

Age between 1 and 12 years; confirmed diagnosis of severe traumatic brain injury with a Glasgow Coma Scale (GCS) score ranging from 3 to 8; anticipated duration of coma exceeding 72 hours; and established artificial airway for respiratory support.

2.1.2. Exclusion criteria

Pre-existing severe pneumonia, chronic respiratory diseases, or airway developmental abnormalities prior to admission; concurrent severe thoracoabdominal trauma directly affecting respiration; incomplete clinical data records; or withdrawal of active treatment by family members during the study.

2.1.3. Study design

Using a randomization method, the selected children were assigned to either the intervention group or the conventional group, with an equal number of 38 children in each group. Analysis of baseline information, including demographic characteristics, causes of injury, and neurological function scores at admission, revealed no statistically significant differences between the two groups, providing a comparable foundation.

2.2. Nursing methods

Children in the conventional group received standard airway care in the neurosurgical intensive care unit, which

included: regularly injecting humidified fluids into the airway as prescribed; performing superficial secretion aspiration based on clinical needs; regularly replacing the external ventilator circuit and humidification device; and performing basic oral hygiene care. Children in the intervention group received the above conventional care along with a structured comprehensive nursing intervention that integrated four key components: optimized humidification control, intelligent suctioning procedures, dynamic positioning adjustment, and early maintenance of respiratory muscle function. The implementation of this system emphasized proactivity, precision, and individualization.

2.3. Observation indicators

To comprehensively evaluate the intervention effects, the following observation indicators were set in this study. The primary endpoint indicator was the incidence rate of ventilator-associated pneumonia (VAP) during hospitalization, diagnosed strictly in accordance with the criteria issued by relevant domestic professional societies. Secondary endpoint indicators included: the incidence rate of visible airway mucosal injury; the total duration of invasive mechanical ventilation received; and the total number of days spent in the paediatrics. Additionally, laboratory physiological indicators, namely arterial partial pressure of oxygen (PaO_2) and partial pressure of carbon dioxide ($PaCO_2$), were measured before the initiation of the intervention measures and one week after continuous imple-mentation, and the changes in their values were calculated.

2.4. Statistical methods

All research data were statistically processed using the SPSS 26.0 software package. For measurement data conforming to a normal distribution, the mean ± standard deviation was used for representation. Comparisons of differences between groups were conducted using independent samples *t*-tests, while paired *t*-tests were used for comparisons within groups before and after the intervention. Categorical data were described in terms of case numbers and percentages, and comparisons of rates between groups were performed using the chi-square test or Fisher's exact probability method. A *p*-value less than 0.05 was used as the threshold for determining whether differences were statistically significant.

3. Implementation and evaluation of comprehensive airway nursing measures

3.1. Refined airway humidification and temperature management strategies

This section abandoned the traditional intermittent medication administration mode and instead adopted a dual-guarantee mode that combined continuous heating and humidification of the ventilator circuit with continuous infusion of humidified fluids via an external micro-pump. Specifically, the temperature of the ventilator humidifier was set and maintained within the physiological range of 34–37 ℃ to ensure that the absolute humidity of the delivered gas met the standard. Simultaneously, based on the graded assessment results of the children's sputum viscosity, a heated micro-pump was used to continuously infuse humidification media such as 0.45% sodium chloride solution at a rate of 0.5 to 2.0 milliliters per hour. The sputum properties were reassessed every four hours, and the pump rate was adjusted accordingly. This strategy aimed to create a stable and suitable intratracheal environment, ensure efficient ciliary movement, and prevent secretion crusting. The effects were evaluated by comparing the distribution proportions of sputum with different viscosities and the number of severe sputum plugs requiring bronchoscopy treatment between the two groups of children. See **Table 1**.

Table 1. Comparison of airway humidification management-related indicators between the two groups of children

Group	Number of cases	Proportion of grade I sputum viscosity (%)	Proportion of grade III sputum viscosity (%)	Number of cases requiring bronchoscopic sputum aspiration (%)
Intervention group	38	28 (73.68)	2 (5.26)	1 (2.63)
Conventional group	38	17 (44.74)	9 (23.68)	6 (15.79)
χ^2/t value		6.272	5.208	3.934
p value		0.012	0.022	0.047

3.2. Stepwise airway suctioning technique based on multimodal assessment

The core of this technique lies in integrating the principles of "necessary suctioning" and "safe suctioning". Firstly, a multi-indicator assessment system is established: the decision to perform suctioning is not solely based on abnormal ventilator parameters and decreased oxygen saturation but also takes into comprehensive consideration factors such as the pediatric patient's agitation, the presence of crackles during lung auscultation, and the effectiveness of physical airway clearance methods. Secondly, a step-by-step suctioning protocol is implemented: before the procedure, a few milliliters of humidification fluid are routinely instilled into the airway; during the procedure, a soft suction catheter with an appropriate diameter is selected, and a rotational withdrawal technique is employed, with strict control to ensure that each suctioning operation lasts no more than 15 seconds. The suction pressure is precisely set according to the patient's age. For thick secretions in the deep airway, a sequential approach of "instillation-dilution-suctioning" is adopted. This technique aims to efficiently clear secretions while minimizing the risk of airway injury and hypoxia. Quantitative assessment is conducted by statistically analyzing the average daily number of suctioning procedures, the number of instances of significant oxygen desaturation following suctioning, and cases of airway mucosal bleeding. See **Table 2**.

Table 2. Comparison of the incidence of adverse events related to suctioning procedures between the two groups of pediatric patients

Group	Number of cases	Mean daily suction frequency (times)	Number of Events with Post-Suction SpO_2 Decrease > 5% (%)	Number of cases with visible airway mucosal bleeding (%)
Intervention group	38	8.5 ± 2.1	42/532 (7.89)	3 (7.89)
Routine group	38	11.2 ± 3.4	89/510 (17.45)	9 (23.68)
t/χ^2 value		4.215	22.146	3.385
p value		< 0.001	< 0.001	0.066

3.3. Goal-oriented postural management and percussion vibration therapy

Based on the intracranial pressure level, circulatory stability status, and chest imaging findings of the pediatric patients, an individualized postural plan is formulated. When intracranial pressure permits, ensure that pediatric patients maintain a semi-reclined or lateral position with their head and chest elevated by 30–45 degrees for a cumulative total of no less than 6 hours per day, thereby utilizing gravity to promote diaphragmatic movement and the drainage of deep sputum. To prevent pressure injuries and pulmonary congestion, strictly adhere to a protocol of turning the patient along the axial line every two hours. Before and after turning, assist in the application of a high-frequency chest wall oscillation device to perform regular percussion on the bilateral hilar regions and the back, with the frequency set within the range of 15–25 Hz. Administer this treatment 3 to 4 times daily, with each

session lasting 10–15 minutes. This therapy facilitates the loosening of sputum adhering to the bronchial walls through external mechanical vibrations. The effectiveness of this section is evaluated by comparing the incidence of atelectasis cases and the time required for chest imaging improvement between the two groups. See **Table 3**.

Table 3. Comparison of imaging improvement in pulmonary complications between two groups of pediatric patients

Group	Number of cases	Incidence of atelectasis during hospitalization, n (%)	Median time to improvement on chest X-ray (days)	Number of cases requiring fiberoptic bronchoscopy alveolar lavage n (%)
Intervention group	38	4 (10.53)	5.0	2 (5.26)
Routine group	38	11 (28.95)	8.0	8 (21.05)
χ^2/Z/χ^2 value		4.110	-2.893*	4.145
p value		0.043	0.004	0.042

*Note: The Mann-Whitney U test was used.

3.4. Early respiratory muscle functional exercise and preparation for weaning from mechanical ventilation

Once the pediatric patient's vital signs are stable and intracranial pressure is well-controlled, even if they remain in a coma, passive respiratory muscle maintenance measures should be initiated. Specific methods include: using a respiratory trainer twice daily to perform manual lung volume retention exercises at the end of ventilator inspiration; implementing diaphragmatic electrical stimulation therapy by placing electrode patches on specific bilateral sites to induce regular diaphragmatic contractions with low-frequency electrical currents; performing several passive limb movements daily, with a focus on enhancing shoulder and thoracic cage stretching exercises to maintain chest wall elasticity. Twenty-four to forty-eight hours before planned weaning from mechanical ventilation, systematically conduct spontaneous breathing trial assessments and preparatory work, including gradually reducing ventilator support, evaluating signs of weak cough reflex, and performing thorough airway clearance. See **Table 4**.

Table 4. Comparison of outcome indicators related to ventilator weaning between two groups of pediatric patients

Group	Number of cases	Number of first SBT success (%)	Number of transitions to non-invasive ventilation (%)	Number of reintubations within 72 hours after weaning (%)
Intervention group	38	30 (78.95)	5 (13.16)	2 (5.26)
Routine group	38	22 (57.89)	10 (26.32)	7 (18.42)
χ^2 value		3.935	2.053	3.385
p value		0.047	0.152	0.066

4. Discussion

For pediatric patients in a coma due to severe traumatic brain injury, airway management represents a comprehensive and dynamic clinical endeavor that integrates respiratory physiology, neurocritical care, infection prevention and control, and early rehabilitation. The fundamental concept behind the integrated nursing protocol developed in this study is to achieve a transition from passive response to proactive planning, from isolated measures to

a coordinated system, and from experience-based to evidence-guided practices. The research findings clearly demonstrate that this protocol offers distinct advantages in reducing ventilator-associated pneumonia, minimizing airway injury, shortening support duration, and optimizing gas exchange, directly attributable to its holistic and forward-looking design.

Optimized humidification and temperature control management constitute the foundational elements for protecting the airway's physiological barrier [1]. Previous intermittent humidification methods often led to fluctuations in the airway's internal environment, potentially promoting the formation of hard crusts in secretions due to alternating dry and wet conditions. The continuous constant-temperature and constant-humidity combined with controlled-rate humidification employed in this study provides a consistently stable moist environment for the airway mucosa. The data in **Table 1** fully confirm that the physical and chemical properties of sputum in the intervention group significantly improved, with a notable increase in the proportion of thin sputum and a significant reduction in highly viscous sputum and sputum plug events requiring invasive bronchoscopy. This not only serves as a prerequisite for preventing mechanical obstruction but also lays a solid foundation for subsequent safe suctioning, reducing mucosal damage caused by difficulties in aspirating viscous sputum [2].

The programmed suctioning technique based on multi-parameter assessment represents a concrete application of precision nursing principles. The fragile airway tissues in children make arbitrary, high-frequency, and rough suctioning operations the primary cause of iatrogenic mucosal injury. This study expanded the suctioning trigger signals from device parameters to an integrated analysis of the pediatric patient's overall clinical signs, reducing unnecessary operations. The step-by-step, parameterized operational process, particularly the strict control of suction negative pressure and duration, significantly reduced shear damage to the airway's inner wall. The data in **Table 2** indicate that while effectively clearing the airway, the intervention group experienced a reduction in the average daily number of suctioning attempts, as well as a lower incidence of acute hypoxic events induced by suctioning and visible mucosal bleeding compared to the conventional group. This proves that the technique successfully reconciles the potential conflict between "effective clearance" and "tissue protection" [3].

Goal-oriented postural management and adjuvant physical therapy represent effective means of actively promoting airway clearance by utilizing physical principles. Such pediatric patients often require a supine position to facilitate intracranial pressure management, but prolonged supination is a key risk factor for the accumulation of secretions in the dorsal lung regions and the occurrence of ventilator-associated pneumonia [4]. Under close monitoring, this protocol safely implemented phased elevation of body position and regular turning, combined with high-frequency chest wall oscillation, simulating the clearing effects of physiological postural changes and coughing. The results in **Table 3** demonstrate that this combined strategy significantly reduced the incidence of atelectasis and accelerated the recovery of pulmonary imaging findings. This shows that even for comatose pediatric patients without autonomous ability, simulating physiological mechanisms through external means can effectively promote pulmonary ventilation and secretion drainage [5].

5. Conclusion

In conclusion, airway maintenance during the coma phase of pediatric severe traumatic brain injury necessitates the establishment of a management framework that provides full-course coverage, synergizes multiple techniques, and dynamically adapts to the disease progression. The comprehensive intervention implemented in this study constructed an interconnected nursing chain through the organic integration of four dimensions: humidification,

suctioning, postural management, and exercise. This chain achieves closed-loop management by preventing secretion accumulation beforehand, optimizing clearance methods during the process, promoting secretion drainage afterward, and maintaining respiratory function throughout.

Disclosure statement

The authors declare no conflict of interest.

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