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Exploration of the Multidimensional Effects of a New Sputum Drainage Strategy Using the Trendelenburg Position on Sputum Clearance Function in Children Undergoing Mechanical Ventilation

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Abstract: *Objective:* To investigate the multidimensional improvement effects of a new sputum drainage strategy combining a 30° Trendelenburg position, specialized position-changing pillows, and sedation intervention on sputum clearance function in pediatric patients undergoing mechanical ventilation. *Methods:* From January 2022 to December 2025, 95 children receiving mechanical ventilation were randomly divided into an observation group (48 cases) and a control group (47 cases). The observation group adopted a 30° Trendelenburg position, utilized specialized position-changing pillows, and received appropriate sedation, with drainage performed for approximately 2 hours per shift. The control group employed conventional sputum drainage methods. The effects of the new strategy were evaluated by comparing sputum volume, improvement in pulmonary rales, blood gas analysis indicators, and duration of mechanical ventilation between the two groups. *Results:* Sputum volumes on days 1, 3, and 5 in the observation group were (15.62±3.27) ml, (20.55±4.14) ml, and (22.38±4.55) ml, respectively, significantly higher than those in the control group, which were (10.24±2.82) ml, (15.36±3.52) ml, and (17.65±3.83) ml, respectively (all $P<0.001$). The overall improvement rate of pulmonary rales in the observation group was significantly higher than that in the control group ($x^2=7.251$, $P=0.007$). On day 3 post-ventilation, PaO_2 (85.67±6.25 mmHg) and OI (205.33±15.65 mmHg) in the observation group were significantly higher than those in the control group, while $PaCO_2$ (38.53±3.87 mmHg) was significantly lower (all $P<0.001$). The duration of mechanical ventilation in the observation group was significantly shorter than that in the control group ($t=4.850$, $P<0.001$). *Conclusion:* The new sputum drainage strategy using the Trendelenburg position can significantly enhance sputum clearance efficiency, improve pulmonary ventilation and oxygenation status, and shorten the duration of mechanical ventilation in children through precise positional control and synergistic interventions, demonstrating significant clinical application value.

Keywords: Pediatric mechanical ventilation; Trendelenburg position; Sputum drainage; Sputum clearance function

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1. Introduction

In the Pediatric Intensive Care Unit (PICU), mechanical ventilation is employed to provide life support for children with respiratory failure. Due to factors such as prolonged bed rest and general anesthesia, they are highly susceptible to bronchial obstruction by secretions, leading to pulmonary infections, which can subsequently result in severe atelectasis, pulmonary edema, or even secondary pulmonary embolism. Concurrently, a substantial accumulation of respiratory secretions in the distal ends of small bronchi increases inspiratory resistance and slows down the exhalation flow rate, ultimately contributing to ventilator-associated pneumonia (VAP), which seriously threatens the children's lives and recovery process [1]. In clinical practice, it has been observed that during the use of invasive ventilators in children, the conventional method of adopting a head-down position (i.e., the head is lower than the feet) is employed to facilitate the drainage of intrathoracic fluids and clear respiratory secretions [2]. This method is simple and safe; however, it has certain drawbacks, such as difficulty in precisely maintaining the body position angle, a lack of effective auxiliary tools, and insufficient consideration of the child's tolerance [3–4]. This study aims to propose a new strategy for sputum drainage in the head-down foot-high position and explore its multidimensional effects on sputum evacuation function during mechanical ventilation in children.

2. Materials and methods

2.1. General information

Children admitted to the PICU of our hospital and receiving mechanical ventilation treatment were selected as the study subjects from January 2022 to December 2025. Inclusion criteria: meeting the diagnostic criteria for respiratory failure, requiring mechanical ventilation due to respiratory failure caused by various reasons [5]; aged between 1 month and 12 years; requiring mechanical ventilation due to respiratory failure caused by various reasons; and an anticipated duration of mechanical ventilation exceeding 48 hours. Exclusion criteria: children with severe cardiovascular diseases; those with increased intracranial pressure or cerebral lesions; and those with spinal developmental abnormalities preventing the adoption of a head-down position. The children were randomly divided into an observation group (48 cases) and a control group (47 cases) using a random number table method. In the observation group, the male-to-female ratio was 26:22, with an age distribution of (5.2 ± 2.1) years; in the control group, the male-to-female ratio was 25:22, with an age distribution of (5.0 ± 2.3) years. The general clinical characteristics, such as gender and age, between the two groups were compared using the x^2 test ($P > 0.05$), indicating comparability.

2.2. Methods

The control group received conventional sputum drainage methods, including regular turning and back tapping (every 2–3 hours), tracheal intubation or tracheotomy suction with negative pressure aspiration when necessary, and intermittent nasal catheter suction.

The observation group adopted a new strategy for sputum drainage in the head-down foot-high position, as follows: (1) Body Position Setting: A specially designed turning pillow was used to place the child in a head-down foot-high supine position, with the head of the bed adjusted to approximately 30° below the horizontal plane to ensure accuracy and stability. (Generally, this position was maintained for 2 hours daily and could be extended as needed based on the child's tolerance.) (2) Sedation Management: For children with poor tolerance and obvious agitation, an appropriate amount of midazolam sedative was administered,

with the dosage determined based on body weight and clinical manifestations, to ensure the child remained calm in the head-down foot-high position and improve sputum drainage effectiveness. (3) Sputum Drainage Operation: In the head-down foot-high position, chest physiotherapy was performed, including back tapping and vibration sputum evacuation device-assisted drainage. During back tapping, the palm was cupped, and the chest wall was continuously tapped from the lung base upwards and from the outside inwards, with moderate force to avoid inducing coughing (approximately 40–50 times per minute). The vibration sputum evacuation device was selected based on the child's age and specific conditions, with a duration of 10–15 minutes. Vital signs and the child's tolerance were closely monitored, and adjustments were made as needed. If symptoms such as worsening dyspnea or decreased blood pressure occurred, the above measures were immediately terminated, and adjustments were made accordingly.

2.3. Observation indicators

(1) Sputum Drainage Volume: The total sputum drainage volume was recorded and compared between the two groups on the 1st, 3rd, and 5th days after mechanical ventilation [6].

(2) Improvement in Pulmonary Rales: A dedicated person was responsible for performing pulmonary auscultation on the patients and determining whether the pulmonary wet rales had decreased based on the auscultation results. If they had decreased, a corresponding score was given, categorized as significant improvement (pulmonary rales basically disappeared), partial improvement (pulmonary rales significantly decreased), or no improvement (pulmonary rales unchanged or increased).

(3) Blood Gas Analysis Indicators: Arterial blood was drawn for blood gas analysis before and on the 3rd day after mechanical ventilation to observe changes in PaO_2, $PaCO_2$, and OI [7].

(4) Ventilator Use Time: The time from the initiation of mechanical ventilation to weaning was recorded for both groups of children.

2.4. Statistical methods

SPSS 22.0 statistical software was used. Measurement data were expressed as (Mean ± SD) and compared using the *t*-test; count data were expressed as the number of cases (n) and rate (%), and compared between groups using the x^2 test. A *P*-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of sputum drainage volume

The sputum drainage volume in the observation group was significantly higher than that in the control group on the 1st, 3rd, and 5th days after mechanical ventilation ($P < 0.05$), with specific data shown in **Table 1**.

Table 1. Comparison of sputum drainage volume between the two groups (Mean ± SD, ml)

Group	Number of Cases	Day 1	Day 3	Day 5
Observation Group	48	15.62±3.27	20.55±4.14	22.38±4.55
Control Group	47	10.24±2.82	15.36±3.52	17.65±3.83
t value	-	8.593	6.588	5.486
P value	-	<0.001	<0.001	<0.001

3.2. Comparison of improvement in pulmonary rales

The proportion of children in the observation group showing significant and partial improvement in pulmonary rales was higher than that in the control group ($P < 0.05$). Specific data are presented in **Table 2**.

Table 2. Comparison of improvement in pulmonary rales between the two groups of children (cases, %)

Group	Number of Cases	Significant Improvement	Partial Improvement	No Improvement	Total Effective Rate (%)
Observation Group	48	20 (41.7)	22 (45.8)	6 (12.5)	87.5
Control Group	47	12 (25.5)	18 (38.3)	17 (36.2)	63.8
x^2 value	-	-	-	-	7.251
P value	-	-	-	-	0.007

3.3. Comparison of blood gas analysis indicators

Before ventilation, there were no significant differences in blood gas analysis indicators such as PaO_2, $PaCO_2$, and OI between the two groups of children ($P > 0.05$). On the 3rd and 5th days after ventilation, the PaO_2 and OI values in the observation group were higher than those in the control group, while the $PaCO_2$ value was lower than that in the control group ($P < 0.05$). Specific data are shown in **Table 3**.

Table 3. Comparison of blood gas analysis indicators between the two groups of children (Mean ± SD, mmHg)

Group	PaO_2		$PaCO_2$		OI	
	Before ventilation	Day 3 after ventilation	Before ventilation	Day 3 after ventilation	Before ventilation	Day 3 after ventilation
Observation group (*n*=48)	62.33±5.14	85.67±6.25	45.62±4.28	38.53±3.87	150.23±12.34	205.33±15.65
Control group (*n*=47)	61.92±5.38	78.20±5.89	46.13±4.56	42.35±4.14	148.91±13.14	180.55±14.27
t value	0.380	5.996	0.562	4.644	0.504	8.067
P value	0.705	<0.001	0.576	<0.001	0.615	<0.001

3.4. Comparison of ventilator usage duration

The ventilator usage duration in the observation group was significantly shorter than that in the control group ($P < 0.001$). Specific data are presented in **Table 4**.

Table 4. Comparison of ventilator usage duration between the two groups of children (Mean ± SD, days)

Group	Number of Cases	Duration of Ventilator Use (days)
Observation Group	48	7.5±2.1
Control Group	47	9.8±2.5
t	-	4.850
p	-	<0.001

4. Discussion

During mechanical ventilation in children, effectively clearing secretions has become one of the clinical focuses [8]. During invasive mechanical ventilation, the presence of an artificial airway and the impact of suctioning can prevent secretions from being promptly expelled to the oral or nasal cavity, leading to local

and systemic infections. This can result in various serious complications, including atelectasis, ventilator-associated pneumonia, aspiration pneumonia, etc., all of which are detrimental to patient recovery and may further progress to hospital-acquired pneumonia, potentially leading to death. Additionally, poor sputum drainage during mechanical ventilation can extend ventilator use by 3 to 5 days and increase the incidence of pulmonary infections by approximately 20% to 30% compared to conventional groups, highlighting the importance of optimizing sputum drainage strategies [9]. Based on this, this study proposes a new strategy for sputum drainage in the Trendelenburg position and explores its effects from multiple dimensions.

Maintaining airway patency and effectively removing secretions are crucial during mechanical ventilation in children [10]. Trendelenburg position sputum drainage utilizes gravity to facilitate the downward movement of fluids from dependent areas to promote their expulsion. This method is simple, non-invasive, and easy to perform, but requires precise control of the body position angle to achieve optimal results [11]. The new strategy for Trendelenburg position sputum drainage proposed in this study is an improvement over existing methods, involving elevating the foot of the bed to a 30° angle and using appropriate specialized positioning pillows for auxiliary support and fixation as needed. This approach better addresses the aforementioned issues, enhances safety, facilitates nursing operations, and improves sputum drainage effectiveness.

The study results showed that the observation group had significantly higher sputum drainage volumes than the control group, indicating that the new strategy enabled children to effectively cough up more sputum. The removal of large amounts of sputum facilitated airway patency, as evidenced by the higher proportion of significant and partial improvements in pulmonary rales in the observation group, further confirming the advantages of the new strategy in improving pulmonary conditions. In terms of blood gas analysis indicators, the observation group exhibited increased PaO_2 and OI values and decreased $PaCO_2$ values on the 3rd and 5th days after ventilation, suggesting that the new strategy improved oxygenation and gas exchange in children, closely related to better sputum drainage effects [12]. From the perspective of gravity-driven sputum clearance mechanisms, using a 30° Trendelenburg position for sputum drainage therapy utilizes gravity to move secretions from lower and deep bronchial areas into the upper respiratory tract for expulsion. Compared to conventional turning and percussion, this position creates a continuous and directional driving force, avoiding fluctuations in drainage efficiency caused by unstable body position angles in traditional methods. Additionally, it shortens the duration of ventilator support and reduces the risk of prolonged mechanical ventilation in patients.

However, when implementing the new strategy for Trendelenburg position sputum drainage, several issues require attention. For example, the Trendelenburg position may increase the incidence of gastroesophageal reflux and aspiration, especially in young children with poor lower esophageal sphincter tone. It is essential to monitor for signs of reflux and vomiting and adjust the position accordingly (e.g., slightly elevating the foot of the bed) or take appropriate measures. Prolonged use of the same position can also cause local pressure, leading to skin damage or even pressure ulcers in children. Therefore, skin management should be strengthened, with regular inspections and careful examination of the skin at pressure points.

5. Conclusion

In summary, the new strategy for Trendelenburg position sputum drainage can improve sputum drainage function, increase sputum volume, promote improvement in pulmonary rales, enhance oxygenation, and

shorten ventilator use time in children undergoing mechanical ventilation from multiple dimensions.

Disclosure statement

The authors declare no conflict of interest.

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