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Original Article

The effect of preventive nursing on the duration of mechanical ventilation and the incidence of complications in neonates with respiratory distress syndrome

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Abstract: Objective: To explore the effect of preventive nursing on the duration of mechanical ventilation and the incidence of complications in neonatal respiratory distress syndrome (NRDS). Methods: This study was conducted in 114 NRDS patients who were admitted to our hospital for mechanical ventilation from March 10, 2018 to December 30, 2019. These neonates were randomly allocated into the experimental group (n=57) and the control group (n=57). In the control group, neonates received routine nursing. Meanwhile, neonates in the experimental group received both routine nursing and preventive nursing, which was composed of a series of nursing measures carried out to prevent complications like bronchopulmonary dysplasia, circulatory disorders (retinopathy), pulmonary hypertension, pneumothorax, intra-ventricular hemorrhage, and ventilator-related pneumonia. The amount of pulmonary surfactant (PS), the duration of mechanical ventilation, indicators of blood gas ($PaCO_2$, PaO_2, and SpO_2), the length of hospitalization, hospitalization expenses, the total incidence of complications, and satisfaction of neonates' family members were compared between the two groups. Results: Compared with the control group, the amount of PS and duration of mechanical ventilation in the experimental group were significantly decreased (both $P<0.001$); $PaCO_2$ level in the experimental group was significantly reduced when compared with the control group, while PaO_2 and SpO_2 level were significantly increased (all $P<0.01$); the length of hospitalization and hospitalization expenses in the experimental group were significantly lower than those in the control group (both $P<0.001$); the total incidence of complications in the experimental group was significantly reduced when compared with the control group ($P=0.001$); satisfaction of patients' family members in the experimental group was significantly higher than that in the control group ($P<0.05$). Conclusion: The application of preventive nursing in NRDS patients receiving mechanical ventilation contributes to significantly decreased complications, reduced amount of PS, shortened time of mechanical ventilation, reduced costs, improved clinical prognosis, and increased satisfaction of neonates' family members. As such, it is worthy of clinical promotion and application.

Keywords: Preventive nursing, respiratory distress syndrome, newborns, mechanical ventilation

Introduction

Neonatal respiratory distress syndrome (NRDS) is common in premature infants. The pulmonary surfactant (PS) and lung structure in premature infants are immature. As a result, these infants can suffer from progressive and exacerbated dyspnea and respiratory failure soon after birth [1]. The incidence of NRDS is about 1%, which is closely related to factors like infant birth weight and gestational age. The disability rate and mortality rate of NRDS are high. These not only seriously threaten the life and safety of newborns, but also present a huge economic burden to society [2]. Three concave signs, respiratory distress, and respiratory moaning within 6 hours after birth are typical clinical symptoms of NRDS. The neonates condition can progressively worsen. Apnea, bruising, and respiratory failure often develop. If intervention is not taken in time, the incidence of adverse events such as intracranial hemorrhage and pulmonary hemorrhage will increase. Accordingly, the prognosis of patients is seriously influenced [3].

In clinical practice, mechanical ventilation is usually used for the treatment of NRDS. It was reported that mechanical ventilation could significantly improve patients' lung function and increase their survival rate. However, there were severe complications, like ventilator-related pneumonia, retinopathy, pneumothorax, bronchopulmonary dysplasia, pulmonary hypertension, and intra-ventricular hemorrhage, prolonging the prognosis of patients [4]. Preventive nursing plays an important role in the reduction of complications and improvement of prognosis. However, there are few reports worldwide employing preventive nursing in NRDS patients receiving mechanical ventilation. A small sample size (only 45 cases) and incomprehensive outcome measures are drawbacks of these reports, requiring more studies to confirm the effectiveness of preventive nursing and its influence on indicators of blood gases [5]. In this study, we mainly explored the effect of preventive nursing on NRDS patients receiving mechanical ventilation, and primarily analyzed its impacts on indicators of mechanical ventilation, indicators of blood gas, prognosis related indicators, and satisfaction of patients' family members. In addition, statistical analysis of the etiological characteristics of patients with respiratory-related pneumonia was performed, in order to provide guidance for clinical nursing.

Materials and methods

General information

In total, 114 neonates admitted to the Neonatology Department of Taizhou People's Hospital from March 10, 2018 to December 30, 2019 were enrolled in this study. According to a random number table, these neonates were assigned to the experimental group (n=57) and the control group (n=57). The general information of neonates in both groups was shown in **Table 1**. This study was approved by the Ethics Committee of Taizhou People's Hospital.

Inclusion criteria

Neonates met the diagnostic criteria of respiratory distress syndrome (RDS) [6]; all individuals were premature infants; neonates needed mechanical ventilation, and the expected treatment time was not less than 1 day; neonates needed to be treated with PS, which was used in neonates with confirmed NRDS or was used to prevent RDS. The gestational age of these neonates were below 28 weeks or 28 to 32 weeks if the following factors were present: (1) very low birth weight of premature infants; (2) glucocorticoids were not taken or non-standardly taken before delivery; (3) male infants; (4) perinatal asphyxia; (5) tracheal intubation was required at birth; (6) cesarean section; (7) twins or multiple births; (8) mother had diabetes; (9) neonates with a family susceptible physique; neonates' family members agreed to participate in this study and informed consent was signed by them; neonates' family members had normal cognitive function.

Exclusion criteria

Neonates with no signs of life when researchers arrived at the Neonatology Department; neonates family members had mental illness; neonates' family members had cognitive impairment; neonates had no family members; neonates' family members failed to communicate with others smoothly.

Methods

Treatment: Exogenous PS (Kelisu, 70 mg/kg/times, batch number: 20052128, purchased from China Resources Double-Crane Pharmaceutical Co., Ltd., Beijing, China) was intratracheally injected within 12 hours after the diagnosis of NRDS. If there were signs of RDS progression, like continuous aerobic or mechanical ventilation, a second or third dose of PS (70 mg/kg) was administrated. Meanwhile, therapies such as providing mechanical ventilation, maintaining the stability of internal environment, supplying nutritional support, and applying homeostasis to prevent infections, were taken [7].

During hospitalization, neonates in the control group received routine nursing: (1) when entering the department, neonates' vital signs, including body temperature, blood pressure, respiratory rate, and pulse rate, were routinely checked. (2) neonates' consciousness, changes in skin and oral cavity, and other conditions were closely observed and recorded. (3) the working status of ventilator was monitored in real-time, and ventilator parameters were proofread; abnormalities were reported to the physician in charge and the head nurse immediately. (4) airway sputum suction was provided in conditions when neonates were irritable, blood oxygen saturation was declined, and there were obvious phlegm sounds. (5) back percussion nursing: neonates were assisted to turn over once at an interval of 3 hours; appropriate strength of percussion was completed from top to bottom with a hollow fist. (6) arterial catheterization was performed in neonates; real-time level of blood gas was analyzed; it was reported to the physician for reintubation or parameter adjustment when the blood gas value was abnormal. (7) ventilator disinfection: the ventilator circuit was replaced and disinfected by immersing in 84 disinfectants for 30 min every day; after rinsing with sterile water, the ventilator was dried for subsequent application; terminal disinfection was performed after weaning from the ventilator. (8) human-machine confrontation and the intubation depth were observed; it was fixed when the intubation was loose, and it was reintubated when the intubation was too deep. (9) weaning from the ventilator nursing: before extubation, 0.5 mg/kg dexamethasone (Tianjin KingYork Group Hubei Tianyao Pharmaceutical Co., Ltd., Xiangyang, China) was intravenously administered to prevent airway edema after extubation; after extubation, budesonide (AstraZeneca Pharmaceutical Co., Ltd., Wuxi, China) aerosol was supplied; in addition, positive airway pressure (nCPAP) through the nose was used for the transition of oxygen therapy [8, 9].

During hospitalization, neonates in the experimental group received both routine nursing and preventive nursing. (1) bronchopulmonary dysplasia: Fluid input was strictly limited on the first 3 days after birth (<100 mL/kg/d). The fluid input and output in 24 hours were recorded, and close attention was paid to blood oxygen saturation. When there were abnormalities, the physician was immediately notified to adjust respiratory parameters to control peak airway pressure and oxygen concentration within the allowable range. (2) circulatory disorders (retinopathy): Changes in blood pressure were observed. When blood pressure was low, low positive end-expiratory pressure (PEEP) and small tidal volume ventilation were used to immediately replenish blood volume. The bed-head was appropriately raised at 15°-20° to ensure adequate cerebral perfusion. (3) pulmonary hypertension and pneumothorax: The respiratory parameters were adjusted to high frequency and short inhalation time when the peak airway pressure of neonates was less than 25 cmH_2O. The occurrence of pneumothorax or pulmonary hypertension was considered when neonates had one of following symptoms: pale; bruised; slowed heart rate; spontaneous breathing and mechanical breathing were out of sync; dropped blood pressure. These were reported to the physician in time. (4) intra-ventricular hemorrhage: Peak inspiratory pressure (PIP) was reduced, and expiratory frequency was reduced 10 minutes/times every 30 minutes. The infusion volume and application of vasoactive drugs were controlled. (5) ventilator-related pneumonia: Environmental cleaning and disinfection; appropriate temperature and humidity in the department were maintained; air disinfection machine was used daily to disinfect the air twice; the floor and surface of equipment were wiped and disinfected 3 times a day. In order to prevent reflux and aspiration of gastric contents, a proper position was taken to assist patients maintaining the head-high-foot-low position. Disposable sterile humidification tanks and disposable sterile ventilator tubing were employed to strengthen the disinfection of the surface and pipeline of ventilator. Daily dynamic evaluation of offline extubation indicators was performed to minimize the time of mechanical ventilation. Invasive-noninvasive sequential ventilation was implemented as much as possible. The management of the respiratory tract was strengthened: oral cavity care was conducted more than 2 times a day; oral cavity was thoroughly cleaned; respiratory secretions were promptly removed. Reasonable use of antibiotics: according to the results of blood culture and sputum culture, appropriate antibiotics were administrated for targeted therapy. (6) Regular professional training was performed among medical staff. (7) Director of the department, head nurse, and quality control personnel were supposed to strengthen the supervision of implementation of nursing measures. To be specific, regular assessment was completed; deficiencies were found and timely corrected; improvements were continuously made [10, 11].

Mechanical ventilation: neonatal ventilator (Fritz Stephan, Germany, type: STEPHANIE) was used for mechanical ventilation. Initial parameters were as follows: PIP: 20 to 22 cmH_2O; PEEP: 4 to 6 cmH_2O; inspiratory time (Ti): 0.35-0.40 s; inhaled oxygen concentration (FiO_2):

0.30-0.45; flow rate (Flow): 8-10 L/min; breathing rate (R) 40-50 times/min. Parameters were adjusted in accordance with the results of blood gas analysis, PIP=2 cmH_2O, PEEP=2 cmH_2O, Ti=0.05 s, FiO_2=0.05, R=5 times/min.

Weaning from the ventilator: Neonates were weaned off the ventilator when the following indicators reached the expected value: PIP= 15 cmH_2O; PEEP=3 cmH_2O; FiO_2=0.3, R=20 times/min; neonates breathing improved; the transcutaneous blood oxygen saturation (SpO_2) was 90%.

Outcome measures

Main outcome measures: Time to be weaned from ventilators, indicators of mechanical ventilation, such as the number of PS and time of mechanical ventilation, were compared between the two groups.

From the morning of the first day of treatment, indicators of blood gas, like $PaCO_2$, PaO_2, and SpO_2 were compared between the two groups. Abbott mobile blood gas analyzer was used to detect $PaCO_2$ and PaO_2.

The incidence of complications during hospitalization, including ventilator-related pneumonia, retinopathy, pneumothorax, bronchopulmonary dysplasia, pulmonary hypertension, and intra-ventricular hemorrhage were compared between the two groups. If a patient had multiple complications, all these complications were counted into the total incidence of complications. The total incidence of complications = number of complications/the total number of cases * 100%.

Secondary outcome measures: Hospitalization-related indicators, such as the length of hospitalization and hospitalization expenses, were compared between the two groups.

Each patient was accompanied by one family member. In order to assess the satisfaction in nursing, family members were asked to fill out the self-made satisfaction survey scale when patients were discharged from the hospital. Satisfied: 90-100 points; basically satisfied: 60-89 points; dissatisfied: <60 points. Satisfaction in nursing = (satisfied + basically satisfied)/the total number of patients * 100%.

Statistical methods

The whole data were analyzed using SPSS statistical software version 20.0. The enumeration data were expressed as number/percentage (n/%); comparison was conducted with chi-square test. The normally distributed measurement data were calculated as mean ± standard deviation ($\bar{x}$ ± sd); independent sample t test was used for inter-group comparison. The non-normally distributed measurement data were expressed in median and interquartile range; rank sum test was applied for inter-group comparison. The difference was statistically significant when *P* value was less than 0.05.

Results

Baseline data

There were no significant differences concerning gestational age, age in days, birth weight, gender, etiology, Apgar score, mother's age, and delivery method between the two groups (all $P>0.05$, **Table 1**).

Indicators related to mechanical ventilation

Compared with the control group, the amount of PS and time of mechanical ventilation in the experimental group were decreased (both $P<0.001$, **Table 2**).

Indicators of blood gas

$PaCO_2$ level in the experimental group was significantly declined when compared with the control group, while PaO_2 and SpO_2 level were significantly increased (all $P<0.01$, **Table 3**).

Indicators related to clinical prognosis

The length of hospitalization and hospitalization expenses in the experimental group were significantly lower than those in the control group (both $P<0.001$, **Figures 1** and **2**).

The incidence of complications

The incidence of complications in the experimental group, which was composed of ventilator-related pneumonia (3 cases), pneumothorax (3 cases), bronchopulmonary dysplasia (1 case), pulmonary hypertension (1 case), intra-

Table 1. Baseline data ($\bar{x}$ ± sd)

Group	Experimental group (n=57)	Control group (n=57)	X^2/t	P
Gestational age (weeks)	33.1±1.3	32.9±1.5	1.687	0.094
Day-old (d)	1.4±0.2	1.4±0.3	1.856	0.066
Birth weight (kg)	2.30±0.30	2.35±0.28	0.864	0.314
Gender			0.140	0.704
Male	32	34		
Female	25	23		
Etiology			0.490	0.920
Meconium aspiration syndrome	16	17		
Asphyxia	23	25		
Pneumonia	11	10		
Septicemia	7	5		
Apgar score at 1 min after birth (points)	3.55±2.57	3.81±3.75	1.354	0.132
Mother's age (age)	30.5±4.9	33.7±4.8	1.289	0.200
Delivery method			0.140	0.7058
Cesarean section	31	33		
Normal delivery	26	24		

Table 2. Indicators related to mechanical ventilation ($\bar{x}$ ± sd)

Group	Experimental group	Control group	t	P
The number of PS (times)	1.8±0.6	2.5±0.5	6.767	0.000
The time of mechanical ventilation (h)	95.62±14.95	132.51±22.57	10.288	0.000

Note: PS: pulmonary surfactant.

Table 3. Indicators of blood gas ($\bar{x}$ ± sd)

Group	Experimental group	Control group	t	P
$PaCO_2$ level (mmhg)	43.21±3.23	47.98±2.98	8.195	0.000
PaO_2 level (mmhg)	82.01±3.25	60.76±2.34	3.378	0.001
SpO_2 level (%)	97.32±3.26	90.12±4.21	10.209	0.000

ventricular hemorrhage (1 case), and death (1 case), was significantly lower than that in the control group (17.54% vs 47.37%, P=0.001, **Table 4**), which consisted of ventilator-associated pneumonia (6 cases), retinopathy (1 case), pneumothorax (3 cases), bronchopulmonary dysplasia (2 cases), pulmonary hypertension (5 cases), intra-ventricular hemorrhage (8 cases), and death (2 cases).

Satisfaction of patients' family members

Satisfaction of patients' family members in the experimental group, which consisted of 34 cases of satisfied, 19 cases of basically satisfied, and 4 cases of dissatisfied, was significantly increased when compared with the control group (92.98% vs 77.19%, P<0.05, **Table 5**); which was composed of 24 cases of satisfied, 20 cases of basically satisfied, and 13 cases of dissatisfied.

Discussion

Neonates with NRDS have immature lung development. When the lungs are injured, alveolar epithelial cells and capillary endothelial cells are damaged, and secondary deficiency in PS are developed. As a result, alveolar surface tension is increased and alveoli gradually atrophy. The normal oxygen and carbon dioxide gas exchange fails to occur when the blood flow through these alveoli is dysregulated, directly leading to the imbalance of the ventilation-perfusion ratio and accumulation of carbon dioxide. In clinical practice, PS and assist-

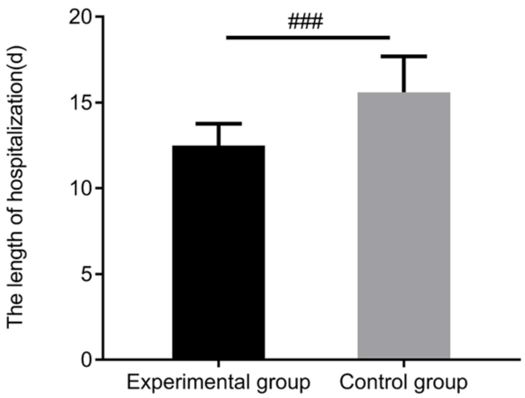

Figure 1. Comparison of the length of hospitalization. Compared with control group, ###P<0.001.

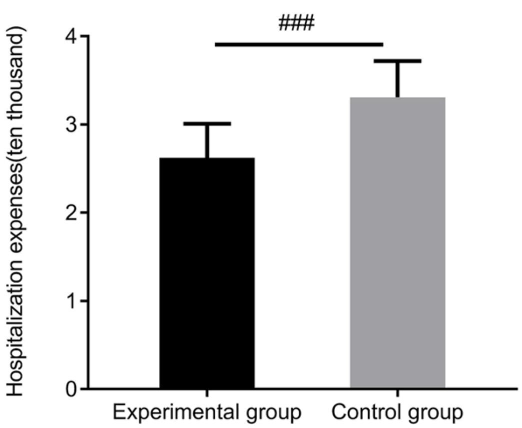

Figure 2. Comparison of hospitalization expenses. Compared with control group, ###P<0.001.

ed ventilation are the primary treatments for NRDS [12]. PS, which is a lipoprotein chemically composed of DL-α-dipalmitoylphosphatidylcholine, is secreted by alveolar type II cells and distributed on the surface of alveolar liquid layer. The synthesis of PS initiates as early as 18-20 weeks of gestation, and reaches its peak at 35-36 weeks of gestation. PS in the body can reduce alveolar surface tension and improve lung compliance. Accordingly, the volume of air in the alveolar is stabilized and alveolar collapse is prevented. What's more, it helps to stabilize intra-pulmonary pressure, reduce leakage of liquid in the capillaries into the lungs, and prevent pulmonary edema, improving ventilatory function [13]. Mechanical ventilation refers to a ventilation method that replaces, controls or changes spontaneous breathing with the help of a ventilator. By doing so, airway patency is maintained; ventilation and oxygenation are improved; hypoxia and carbon dioxide accumulation are prevented. The application of mechanical ventilation in patients with NRDS can reopen recruitable collapsed alveoli, increase residual volume, rectify blood flow and ventilation-perfusion ratio, increase lung compliance, and improve alveolar oxygenation function [14]. The effect of PS combined with mechanical ventilation in neonates with NRDS is significant. However, the combination also increases the incidence of complications like ventilator-related pneumonia, retinopathy, pneumothorax, bronchopulmonary dysplasia, pulmonary hypertension, and intra-ventricular hemorrhage, and even the risk of death [15]. Therefore, targeted clinical nursing needs to taken before the occurrence of complications. The reduction of complications and improvement of prognosis are the center of the nursing.

Compared with routine nursing, preventive nursing is a kind of prospective care. In this model, the patients' condition is fully considered, and targeted nursing measures are formulated based on nursing experience and relevant risk factors, making nursing measures more scientific. As a result, the risk of complications is declined, and clinical prognosis is improved [16]. In recent years, preventive nursing has been widely used in the prevention of complications such as ventilator-associated pneumonia, nosocomial infections of patients with respiratory diseases, wound infections of patients undergoing surgical operations, and deep vein thrombosis in the lower extremities, and significant effects have been realized [17-20]. In this study, preventive nursing was applied to reduce the incidence of complications in NRDS neonates receiving mechanical ventilation, and the effect was significant. It indicates that preventive nursing can reduce the occurrence of mechanical ventilation-related complications, which was consistent with the conclusion reported by Weiss et al. [21]. There were three main reasons contributing to the result. Firstly, strict disinfection measures were carried out in preventive nursing, and the flow of visitors and unnecessary personnel was controlled. These were keys to prevent ventilator-related pneumonia. Secondly, inappropriate mechanical ventilation parameters, pulmonary hypertension, and ventilator resistance were high-risk factors for pneumothorax,

Table 4. Incidence of complications (n, %)

Group	Experimental group	Control group	X^2	P
Ventilator-related pneumonia	3 (5.27)	6 (10.53)	1.092	0.297
Retinopathy	0 (0.00)	1 (1.75)	1.012	0.315
Pneumothorax	3 (5.27)	3 (5.26)	0.000	1.000
Bronchopulmonary dysplasia	1 (1.75)	2 (3.51)	0.381	0.537
Pulmonary hypertension	1 (1.75)	5 (8.77)	2.810	0.093
Intra-ventricular hemorrhage	1 (1.75)	8 (14.04)	5.912	0.015
Death	1 (1.75)	2 (3.51)	0.381	0.537
In total	10 (17.54)	27 (47.37)	10.730	0.001

Table 5. Satisfaction of patients' family members (n, %)

Group	Satisfied	Basically satisfied	Dissatisfied	Satisfaction rate
Experimental group (n=57)	34 (59.65)	19 (33.33)	4 (7.02)	53 (92.98)
Control group (n=57)	24 (42.10)	20 (35.09)	13 (22.81)	44 (77.19)
X^2		6.512		5.601
P		0.039		0.018

retinopathy, and intraventricular hemorrhage. In this study, breathing parameters were promptly adjusted according to patients' vital signs. Under the premise of unobstructed patients' trachea, fluid input was controlled to reduce the occurrence of pneumothorax, pulmonary hypertension, retinopathy, and intraventricular hemorrhage. Thirdly, flexible adjustment of ventilator parameters could also prevent excessive oxygen delivery, reducing the incidence of bronchopulmonary dysplasia caused by oxygen poisoning.

In preventive nursing, the vital signs of patients are monitored in real-time, and ventilator parameters close to patients are adjusted in a timely to maintain the oxygenation function of the lungs within the physiological range. Therefore, the time of mechanical ventilation and amount of PS are both reduced. Zheng et al. studied the effect of preventive nursing on NRDS neonates receiving mechanical ventilation [5]. In their study, 90 NRDS neonates were recruited, and were randomly divided into 2 groups. In the control group, neonates received routine nursing, while neonates in the experimental group received both routine nursing and preventive nursing, which was used to reduce ventilator-related complications. Results showed that the amount of PS, the time of mechanical ventilation, the length of hospitalization, hospitalization expenses, and the incidence of complications in the experimental group were significantly improved when compared with the control group. These results suggest that preventive nursing is beneficial for the significantly reduced amount of PS, decreased complications, shortened time of mechanical ventilation, and reduced costs. In our study, patients in the experimental group received both routine nursing and preventive nursing, while patients in the control group merely received routine nursing. Our results showed that the amount of PS, the time of mechanical ventilation, the length of hospitalization, and hospitalization expenses in the experimental group were significantly less than those in the control group, indicating that preventive nursing can significantly reduce the amount of PS and duration of mechanical ventilation.

Changes of patients' vital signs were closely monitored in this study. Oxygen flow, PEEP, and oxygen concentration were promptly adjusted as soon as abnormalities were detected. In this way, the blood oxygen content in patients was rapidly increased, and indicators of blood gas were then improved in a short time. Consequently, oxygen poisoning was prevented. Here, we observed the effect of preventive nursing on indicators of blood gas in NRDS patients receiving mechanical ventilation. Our results showed that indicators of blood gas in the experimental group were better than those in the control group, suggesting that preventive nursing can significantly improve indicators of blood gas. It was consistent with the result reported by Huo et al. [22].

Preventive nursing is beneficial for the reduction of complications and risk of death. As a result, more patients are saved; satisfaction of patients' family members is improved; and the risk of doctor-patient disputes is reduced. In our study, we investigated the satisfaction of patients' family members during hospitalization. Our results displayed that satisfaction of patients' family members in the experimental group was significantly increased when compared with the control group.

However, the sample size of this study is small. Subsequent study will be conducted in a larger number of patients to confirm the feasibility and importance of preventive nursing in NRDS neonates receiving mechanical ventilation.

In summary, the application of preventive nursing in NRDS neonates receiving mechanical ventilation contributes to reduced complications, less PS, shortened time of mechanical ventilation, reduced costs, improved clinical prognosis, and increased satisfaction of patients' family members. As such it is worthy of clinical promotion and application.

Disclosure of conflict of interest

None.

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