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Effect of Bubble and Ventilator-derived Continuous Positive Airway Pressure on the Management of Respiratory Distress Syndrome in Premature Neonates

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ABSTRACT

Background: In this study, we aimed to compare ventilator-derived and bubble continuous positive airway pressure (CPAP) in neonates with respiratory distress syndrome admitted to Neonatal Intensive Care Unit of Vali-e-Asr Hospital, Birjand, Iran, in 2014.

Methods: This cohort study was conducted among 68 patients assigned into two groups. The neonates in group A (32 infants) were treated with bubble CPAP and those in group B (36 infants) were treated with a ventilator-derived CPAP. The protocol of treatment was applying CPAP with the positive end-expiratory pressure (PEEP) of 5-6 cm H_2O and fraction of inspired oxygen equivalent to 30-40%, depending on the gestational age. In case of need for higher oxygen levels to maintain oxygen saturation of arterial blood (SpO_2) (90-95%), surfactant was administered and additional PEEP was applied (up to 8 cm H_2O). Data analysis was performed using independent t-test and Chi-squared in the SPSS software, version 18.

***Results*:** The duration of CPAP and oxygen therapy was 1.67±1.22 days and 3.57±2.67 days in group A and 2.09±1.53 days (P=0.21) and 4.67±3.74 days (P=0.16) in group B, respectively. There was a significant difference between the groups in terms of discharge weight and surfactant dosage (P=0.042 and P=0.007, respectively). Moreover, although the length of stay in hospital in the ventilation group was almost 4 days longer than the other group, there was no significant difference between the groups in this regard.

Conclusion: There was no significant difference between bubble CPAP and ventilator-derived CPAP. Moreover, further studies with larger sample size are recommended.

Keywords: CPAP, Bubble CPAP, Prematurity, RDS, Ventilator CPAP

Introduction

Respiratory distress syndrome (RDS) or hyaline membrane disease is the most prevalent respiratory disease in premature neonates and the leading cause of death in this population (1, 2). In premature neonates, respiratory failure is mainly caused by the lack of pulmonary surfactant (2). Respiratory distress syndrome can be treated using adjunct therapy and surfactant. Among respiratory support methods, mechanical ventilation and continuous positive airway pressure (CPAP) are said to be helpful in reducing mortality and morbidity rates (3).

Mechanical ventilation is invasive and associated with several complications. Therefore, various strategies are designed to reduce the use of mechanical ventilation (4). CPAP was firstly used to support the breathing of neonates in early 1970. The neonatal application of CPAP reduces extubation failure and apnea rates in addition to providing an alternative to intubation and ventilation in RDS (3, 5, 6).

In addition, the early use of CPAP, even without the use of surfactant, in infants with RDS can improve the prognosis (7). There are different types of CPAP, two commonly used of which include bubble CPAP and ventilator-derived CPAP

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(8). However, few studies have been conducted to compare the efficacy of different CPAP machines (8). Previous studies that have taken into account the demographic factors, study context, and socioeconomic conditions have shown different results, indicating a preference for the treatment methods (9, 10).

The goal of any CPAP delivery device is to prevent atelectasis and airway closure (11). An ideal CPAP delivery system should have an easy and immediate application, as well as several features such as being technically simple, avoiding trauma to the neonate, including a patient-system capable of producing stable pressures at the desired levels and humidify supplemental oxygen, having practical and understandable instruction on maintenance, as well as being easy to sterilize, safe to use, and finally cost-effective (12, 13).

In fact, not all healthcare centers are equipped with different CPAP tools. Various CPAP methods are available that are different from each other in terms of effectiveness and medical expenses. It is important for the healthcare system to evaluate these methods in order to select the most effective and cost-efficient one. Therefore, this study was performed to compare two CPAP methods in terms of their effectiveness in the treatment of infant RDS.

Methods

In this cohort study, the inclusion criteria entailed obtaining parental consent, having birth weight between 1000 and 2500 g, suffering from RDS with the symptoms of cyanosis, tachypnea, nasal flaring, and retraction, as well as chest x-ray changes indicating a reticulogranular pattern, air bronchogram, and reduced lung volume. The sampling method is simple non-probable.

The patients treated with nasal bubble CPAP were identified as group A, and those receiving nasal ventilator-derived CPAP were allocated to group B. After receiving CPAP during the first 6 hours after birth, surfactant was prescribed if positive end-expiratory pressure (PEEP) was greater than 6 cm H_2O and the fractions of inspired oxygen (FIO_2) were more than 30% and 40% in neonates with the gestational ages less and more than 26 weeks, respectively.

A total of 68 patients were enrolled in this study, 32 of whom were assigned into group A and the rest were allocated to group B. The main reason for uneven group distributions was that the random usage of CPAP was not possible because it was based on its availability in the unit. Therefore, the number of samples were unfortunately unequal. However, our preliminary goal was to have at least 20 samples in each group in order to increase the validity of the study.

The samples were selected from the patients admitted to Neonatal Intensive Care Unit (NICU) of Vali-e-Asr Hospital, in Birjand, Iran, 2014. Newborns with RDS and a specific cryptographic diagnosis determined by a neonatologist were enrolled in the study. The neonates in group A were treated by bubble CPAP with PEEP of 5-6 cm H_2O and FIO_2 of 30-40%, depending on the gestational age.

If higher oxygen levels were needed to maintain the SpO_2 at the range of 90-95%, surfactant was prescribed and CPAP increased up to 8 cm H_2O. Otherwise, treatment with a bubble CPAP with the constant flow of gas of 6 L/min. The bubble CPAP was used according to the standard method developed by Pillow et al. (14). Neonates who were treated with ventilator CPAP were assigned to group B and received the treatment according to the protocols of Yadav et al. and Kugelman et al. (15, 16).

They were treated by ventilator CPAP with the PEEP of 5-6 cm H_2O and FIO_2 of 30-40%, depending on the gestational age. If a higher oxygen level was needed to maintain the SpO_2 at the range of 90-95%, surfactant was prescribed and the CPAP pressure increased up to 8 cm H_2O. Otherwise, treatment with a ventilator-derived CPAP with a constant flow of 6 L/min with the range of 4-8 L was implemented.

In each of the above conditions, if the patient receiving CPAP could not maintain the SpO_2 range beyond 90%, synchronized intermittent-mandatory ventilation was utilized. The duration of CPAP therapy, the amount of oxygen needed, the need for mechanical ventilation or surfactant injection, and the presence of possible complications were all considered as the measuring criteria for treatment effectiveness.

These criteria, as well as demographic data of the patients and their parents, were collected and analyzed after treatment follow-up. CPAP treatment was considered as successful if the RDS improved and it was possible to wean off the CPAP. The absence of respiratory distress was considered as the weaning criteria (minimal or no retractions and respiratory rate between 30 and 60 breaths per minute) and $SpO2>90\%$ on $FiO_2<30\%$ and PEEP<5 cm H_2O.

Mechanical ventilation was considered in case of CPAP failure in the several conditions including neonates with $PaO_2<50$ mmHg or $PaCO_2>60$ mmHg and pH<7.25 with $FiO_2>0.6$, those with a clinical deterioration (increased respiratory distress) including severe retractions on PEEP >7 cm H_2O or prolonged (>20 seconds) or recurrent apneas (>2 episodes within 24 hours associated with bradycardia) requiring bag and mask ventilation.

For the group A, the Fisher and Paykel Bubble CPAP System (BC161, New Zealand) was used that involves a gas flow source (6-8 L/min), an air-oxygen blender (Bio-Med Devices Inc., USA), a humidifier (MR410, Fisher and Paykel Health Care, New Zealand), and a respiratory circuit. The Dräger Babylog 8000 plus neonatal ventilator (Dräger Medical Systems, Lübeck, Germany) was used for group B.

Ethics approval was obtained from the Ethics Committee of the Birjand University of Medical Sciences, Birjand, Iran, under code No. IR.BUMS. REC.1394.441. Data analysis was performed using Chi-squared and independent samples t-test in SPSS software, version 18. In all the measurements, P-value less than 0.05 was considered statistically significant.

Results

In this study, 32 and 36 neonates were assigned into groups A and B, respectively. The frequency and percentage of quantitative variables are shown in Table 1. Obviously, there was no significant difference between the two groups in terms of the variables listed in Table 2. The qualitative variables are presented in Table 2. No significant difference was observed between the groups considering mean parity, maternal age, 1- and 5-minute Apgar scores, birth weight, gestational age, and Silverman Andersen respiratory severity score.

As shown in Table 3, after treatment, there was a significant difference in the discharge weight and the dose of surfactant (P=0.042, P=0.002, respectively). The complications in the groups including CPAP failure, retinopathy of prematurity (ROP), septicemia, pulmonary hemorrhage, pneumothorax, and mortality are demonstrated in Table 4. No significant difference was observed between the groups regarding medical complications.

Table 1. Frequency of quantitative variables

Variables	Group	Frequency	P-value
NVD*	A	10 (31.2%)	0.792
	B	13 (36.1%)	
Normal amniotic fluid	A	29 (90.7%)	0.338
	B	35 (2.7%)	
Normal umbilical cord	A	28 (87.6%)	0.308
	B	34 (94.4%)	
Male	A	18 (56%)	0.404
	B	24 (66.7%)	
Cephalic position	A	26 (81.4%)	0.346
	B	32 (88.8%)	
Mother's health	A	26 (81%)	0.602
	B	30 (83.3%)	
Singleton	A	25 (87.1%)	0.585
	B	26 (72.7%)	

* NVD: normal vaginal delivery

Table 2. Comparison of qualitative variables between the groups

Variables	Group	Mean±SD	P-value
Parity	A	2.27±1.41	0.252
	B	2.67±1.27	
Maternal age (years old)	A	27.88±7.43	0.747
	B	27.23±5.90	
1-minute Apgar score	A	7.92±1.46	0.613
	B	7.74±1.29	
5-minute Apgar score	A	8.81±0.87	0.246
	B	8.54±0.85	
Birth weight (g)	A	1760±436.04	0.126
	B	1600±442.52	
Gestational age (week)	A	32.26±2.53	0.172
	B	31.4±2.51	
Silverman Andersen respiratory severity score	A	5.6±1.07	0.780
	B	5.75±1.35	

Table 3. Comparison of the variables between the groups after treatment

Variables	Group	Mean±SD	P-value	T (Pearson test)
Duration of CPAP* therapy (day)	A B	1.67±1.22 2.09±1.53	0.214	N/A
Duration of oxygen therapy (day)	A B	3.57±2.69 4.69±3.74	0.168	N/A
Duration of ventilation (day)	A B	0.49±0.12 0.65±0.22	0.999	N/A
Dose of surfactant	A B	1.32±0.76 1.84±1.83	0.007	-2.717
Discharge weight (g)	A B	1834.4±405.46 1625.6±415.67	0.042	-2.078
Length of hospital stay (day)	A B	11.31±7.50 15.09±9.49	0.075	N/A

* Continuous positive airway pressure

Table 4. Frequency of medical complications in the groups

Complication	Group	Frequency	P-Value
CPAP* failure	A B	2 (6.2%) 6 (16.7%)	0.226
ROP**	A B	3 (9.4%) 5 (13.9%)	0.713
Septicemia	A B	0 (0%) 2 (5.6%)	0.494
Pulmonary hemorrhage	A B	0 (0%) 2 (5.6%)	0.494
Pneumothorax	A B	1 (3.1%) 2 (5.6%)	0.999
Mortality	A B	0 (0%) 2 (5.6%)	0.494

* Continuous positive airway pressure, ** Retinopathy of prematurity

Discussion

CPAP is a non-invasive respiratory treatment method that generates a positive dilating pressure during a respiratory cycle (17). There are several devices for delivering nasal CPAP, some of which are less expensive and/or less effective than the rest. It is confirmed that delivering nasal CPAP by ventilators are more expensive than bubble CPAP devices. The main goal of the study was to discover the most effective method of delivering CPAP. Lee et al. showed that bubble CPAP is significantly more effective than ventilator-derived CPAP (18).

Based on the result of this study, no significant difference was observed between the two CPAP methods. In other words, despite the fact that several variables including length of time receiving CPAP, duration of receiving oxygen, and the duration of ventilation were shorter in the recipients of bubble CPAP in comparison to ventilator CPAP. Nevertheless, this difference was not significant. There was a significant relationship between the length of hospital stay and surfactant dose and weight. In addition, Bahman-Bijari et al. in 2011 indicated no significant difference between the two groups in terms of the duration ventilation (2). Mohammadzadeh et al. in their study showed no significant difference in the duration of receiving CPAP and the duration of receiving ventilator in terms of oxygen administration between the two groups (19).

The results of the mentioned studies were in congruence with those obtained in the present study. However, Noori Shadkam et al. found significant differences between the two groups of CPAPs with regards to the duration of the ventilation in the bubble CPAP group (20). However, the duration of receiving CPAP and the duration of exposure to oxygen were not found to be significantly different between the two groups. Moreover, a study performed in 2001 stated that oxygen usage was higher in patients received bubble CPAP compared to the other group (21). However, no significant difference was found between the groups regarding the duration of ventilation and CPAP administration.

The difference between bubble CPAP and the ventilator CPAP was not statistically significant but is clinically meaningful. Bubble CPAP with fine pressure oscillation mechanism improved the airflow in distal airways and alveoli (18). Further, previous studies confirmed that the results of bubble CPAP depend on the skills of the healthcare team, as well as the physical condition of the infant (2). Additionally, bubble CPAP with vibration bubbling mechanism and air conditioning produces high-frequency ventilation and improves hemodynamics and oxygenation in the lungs (2, 22).

In this study, a significant difference was found between surfactant dosage and discharge weight in both groups, which means that surfactant dosage was less and discharge weights increased when bubble CPAP was applied.

This improvement in weight gain can be justified by the results of previous studies, which demonstrated better oxygenation and fewer complications in the bubble CPAP group leading to a better weight gain (2). Moreover, due to better oxygenation in the bubble CPAP group, surfactant therapy was less than the ventilator-derived CPAP group. The evaluation of duration of CPAP therapy, oxygen therapy, and mechanical ventilation after CPAP failures indicated nasal CPAP effectiveness. Our findings showed that there were no significant differences between the two methods. This result was inconsistent with those of Tagare et al. and Bahman-Bijariet al. (2, 23). On the other hand, other studies demonstrated that bubble CPAP increases the respiratory effort in the neonate more than ventilator-derived CPAP (14, 24).

In the study carried out by Noori Shadkam et al., no significant difference was found between the two groups in terms of several complications (20). Among the complications assessed by them, the rate of ROP was similar to this study, which did not show significant differences. Although the results of the current study demonstrated no significant difference in terms of length of hospital stay, other studies showed that this variable was shorter in the group treated by bubble CPAP (2, 25). In addition, Tagare et al. determined that the length of hospital stay was longer in case of using bubble CPAP in comparison to ventilator CPAP (26).

In this study, several variables such as length of stay in hospital (4 days), CPAP failure (more than 2.5 times), ROP (1.5 times), septicemia, pulmonary hemorrhage, death, and pneumothorax were more in the group treated by bubble CPAP than those in the ventilator CPAP group. Nevertheless, the difference between these two groups was not statistically significant. Few similar studies have been conducted in this area; however, the results of this study can be considered to have high reliability due to the larger sample size, duration of patient follow-up, as well as positive results of the bubble CPAP group (2, 18, 23).

The limitation of our NICU unit affected the results. Bubble CPAP devices were not available in our unit; therefore, we could not perform a double-blind randomized controlled trial. The patients received a CPAP-free device were randomly assigned to patients. The number of nurses and their experiences in the field was different in each working shift. Taking into consideration that working with the above tools required monitoring by the nurses, this matter also played a significant role in the result section.

Conclusion

According to our results, there was no significant difference between the two methods of CPAP. There was no need to provide new devices for creating better treatment conditions. Treatment can be continued with existing tools and with the same results.

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Conflicts of interests

The authors declare that there is no conflict of interest.

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