A Two Year Experience in Continuous Positive Airway Pressure Ventilation Using Nasal Prongs and Pulse Oximetry

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Abstract

In a prospective study 26 of the 116 consecutive neonates suffering from respiratory distress survived on varying concentrations of humidified oxygen. Continuous positive airway pressure (CPAP) of 4-12 cm of water was applied through short nasal prongs to 90 neonates. Haemoglobin oxygen saturation (SaO_2) rose in all and it was maintained steadily above 85% in 46 (51%) infants who survived. The mean duration of CPAP among the survivors was 61 hours (range 8-190 hours). Common indications of CPAP ventilation were hyaline membrane disease (HMD) (27.7%), meconium aspiration syndrome (MAS) (20%), apnea of prematurity (18.8%) and asphyxia (17.7%). Neonates weighing >1000 gm fared well with overall survival of 60 to 82.35%. However, among the 16 babies weighing <1000 gm, only 3 (18.75%) survived. 4 infants on CPAP died due to pneumothorax, none had complications of oxygen toxicity. The 44 CPAP failures, fared poorly even when shifted to intermittent positive pressure ventilation (IPPV) regardless of their weight and 1 among the 5 survivors developed grade 1 intraventricular haemorrhage. It was concluded that nasal CPAP ventilation with pulse oximetry is a simple and efficient method of treating respiratory distress in newborns. This technique can be adopted even by smaller hospitals where the equipment and expertise for IPPV and arterial blood gas (ABG) monitoring are not feasible.

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Key Words : Nasal continuous positive airway pressure; Neonates; Respiratory distress

Introduction

Respiratory distress is one of the commonest problems of newborns the world over with an incidence of 3 to 7% of all live births [1-4]. Autopsy studies reveal that 32-52% of all perinatal deaths are due to respiratory disorders [2,5]. Respiratory distress in newborns presents with tachypnea, inspiratory retractions and expiratory grunting. During grunting the glottis is partially closed, which increases the transpulmonary pressure and prevents atelectasis. If grunting is prevented by intubation, PaO_2 falls and if the tube is removed and grunting, resumed PaO_2 rises [6,7]. Based on this principle, CPAP ventilation delivered through an endotracheal tube was first used in 1971 to treat cases of HMD successfully [8]. Since then many systems for delivery of CPAP have been devised including endotracheal tubes and tightly fitting face masks. However, nasal prongs/tubes have been found to be not only equally effective but also simple to use [9,10]. Monitoring of oxygenation and blood gases in infants on ventilation is essential. ABG sampling requires considerable expertise, is invasive and not easily available. Conversely, pulse oximetry not only monitors oxygen saturation of haemoglobin continuously but is also simple and noninvasive. This study was designed to find the efficacy of nasal CPAP ventilation using a pulse oximeter for continuous non-invasive oxygen monitoring.

Material and Methods

During the period July 1994 to June 1996, 116 consecutive neonates suffering from respiratory distress were included in this prospective study conducted at a large hospital. Respiratory distress was diagnosed if any of the two were present (i) Respiratory rate > 60/min during quiet breathing (ii) Inspiratory retractions of chest (iii) Expiratory grunting. Infants requiring short ventilation (< 6 hours) were excluded. All deliveries were attended by post graduate trainees. Oropharyngeal suction was done on delivery of the head if liquor was meconium stained and tracheal suction after birth if the vocal cords were found stained. Infants were nursed in a resuscitator with overhead radiant warmer. Routine investigations to diagnose the cause of respiratory distress were done including a radiograph of the chest in all cases. Apnea of prematurity was diagnosed if no other cause for apnea could be found in a preterm. Blood pressure was monitored with a non-invasive blood pressure monitor (Omega 1100). Hypotension of < 30 mm (mean) was corrected with plasma expanders and dopamine drip as and when indicated.

The sensor of a pulse oximeter was placed around the foot to continuously monitor the SaO_2 and heart rate and was shielded from light and heat. Babies with respiratory distress were first treated with humidified oxygen by hood at a rate of 4-6 litres/minute. Indications for shifting to CPAP ventilation were (i) Failure to maintain SaO_2 > 85% (ii) Persistent or increasing Downes score of 6 or more (iii) Recurrent apneic spells. A time cycled pressure limited

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neoventilator (Vickers) was used to deliver CPAP through short nasal prongs placed in both anterior nares and secured firmly with a cotton tape tied around the head. The nasal prongs were checked for any displacement regularly and for blockage due to secretions every 4 hours. Initial ventilator settings : (i) FiO_2 : was kept at the pretreatment (Oxygen hood) levels (ii) Flow rate : 5 to 10 litre/minute (iii) CPAP : 4 to 6 cm water with increment of 2 cm at a time, up to a maximum of 12 cm of water, to achieve SaO_2 of 85 to 90%. Weaning : When SaO_2 reached to 90% or more the FiO_2 was lowered in decrements of 0.05 to maintain a SaO_2 of > 85%. When the FiO_2 could be lowered to 0.5 or less CPAP was reduced in decrements of 2 cm of water. The nasal prongs were removed when the CPAP was < 3 cm of water at FiO_2 < 0.4. CPAP failure was defined as (i) Persistent SaO_2 of < 85% and/or rising Downes score over 6 (ii) Recurrent apneic spells or poor respiratory effort. The efficacy of CPAP ventilation was analysed in different weight groups and etiology wise; the success being defined as persistent > 85% and survival. CPAP failures were shifted to IPPV. Infants on IPPV were monitored by pulse oximetry as well as intermittent ABG through radial artery punctures done at 12 hourly intervals.

Results

Of the 4022 neonates born at our hospital during the

two-year study period, 116 (2.88%) infants were admitted to the neonatal intensive care unit (NICU) with the diagnosis of respiratory distress. There were 60 males and 56 females. Most cases of transient tachypnoea of new born (TTNB) (15 out of 19) and 26 infants (22.4%) in all survived on humidified oxygen alone. CPAP up to 12 cm of water was applied to 90 infants, SaO_2 rose in all and it was maintained steadily above 85% in 46 (51%) infants who survived. The mean duration of CPAP among the survivors was 61 hours (range 8-190 hours), 80% of the time the CPAP used was between 5-8 cm of water. The mean time of starting CPAP among the survivors was 17 hours (range 3-80 hours). Among the 44 CPAP failures, 11 (25%) failed within the first 24 hours. While 22 did well for the first 24 hours and 11 up to 48 hours after which they failed to maintain the desired SaO_2 and had to be shifted to IPPV.

The incidence of respiratory distress etiology wise along with the survival in relation to mode of ventilation is depicted in Table 1. Common indications of CPAP ventilation were HMD (27.7%), MAS (20%), apnea of prematurity (18.8%) and asphyxia (17.7%). The mean birth weight of the babies under study was 1782 gm (780-3600 gm). The overall prognosis of babies weighing more than 1500 gm was good with survival of 73-82%. Survival of babies in the weight group 1000-1500 gm was 60% and only 18.75% among the

Table 1

Incidence of respiratory distress in newborn and survival in relation to disease and mode of ventilation

Disease	Incidence n/(%)	Survived on			Overall survival	
		Oxygen	CPAP	IPPV	n	%
HMD	26 (22.41%)	1	14	2	17	65.38
TTNB	19 (16.37%)	15	4		19	100
MAS	18 (15.51%)	0	11	1	12	66.66
Asphyxia	18 (15.51%)	2	8	1	11	61.11
Apnea of prematurity	17 (14.65%)	0	7	1	8	47.05
Septicemia	10 (8.62%)	1	2	0	3	30
Cong pneumonia	3 (2.58%)	3			3	100
Hypoglycemia	2 (1.72%)	2			2	100
CHD	1 (0.86%)	0	0	0	0	0
Hypothermia	1 (0.86%)	1			1	100
Laryngomalacia	1 (0.86%)	1			1	100
Total	116	26	46	5	77	66.37

HMD - Hyaline membrane disease; TTNB - Transient tachypnoea of new born MAS - Meconium aspiration syndrome; CHD - Congenital heart disease

Table 2

Survival in relation to birth weight and mode of ventilation

Weight (gm)	Oxygen		Survival on CPAP		IPPV		Overall survival	
	n	survived	n	survived	n	survived	n	%
< 1000	16	0	16	1	15	2	3	18.75
> 1000 < 1500	25	1	24	12	12	2	15	60
> 1500 < 2000	30	5	25	16	9	1	22	73.33
> 2000 < 2500	17	10	7	4	3	0	14	82.35
> 2500	28	10	18	13	5	0	23	82.14
Total	116	26	90	46	44	5	77	66.37

CPAP - Continuous positive airway pressure; IPPV - Intermittent positive pressure ventilation

babies weighing < 1000 gm. Survival in relation to birth weight and mode of ventilation is depicted in Table 2.

Displacement of the nasal prongs was a very common problem whereas blockage due to secretions occurred rarely. Mild ulcerations of nasal mucosa occurred in 9 (10%) infants that healed without scarring. Pneumothorax occurred in 4 (4.44%) infants while on CPAP, all of them died. None had the complications of oxygen toxicity. CPAP failures fared poorly on IPPV also, irrespective of their weight, with only 5 out of 44 (11.36%) surviving (Table 2). The smallest survivor was an infant weighing 850 gm suffering from HMD, who required prolonged IPPV (92 hours) and was found to have grade I intraventricular haemorrhage. There was no incidence of skin injury or burn due to the probe of the pulse oximeter.

Discussion

CPAP ventilation acts by applying positive end expiratory pressure to a spontaneous breath without increasing inspiratory work. It improves ventilation perfusion (V/P) ratio by expanding partially obstructed or collapsed small airways. It increases functional residual capacity (FRC) and enhances oxygen exchange. It also improves lung compliance and decreases work of breathing [11,12]. Because of these effects, CPAP has been extensively used in the treatment of HMD successfully with survival rates of 67-83% [4,8,11,13,14]. In our study 14 (56%) of the 25 neonates with HMD survived on CPAP. In MAS, there are alternating areas of atelectasis and hyperperfusion leading to ventilation perfusion mismatch. Therefore, hypoxia cannot be relieved by increasing the FiO_2 , whereas CPAP results in improvement of V/P mismatch and FRC. The oxygenation benefits of CPAP in MAS should be weighed against barotrauma that may result from preferential distension due to ball valve effect. The effectiveness of end expiratory pressure (EEP) was studied in 14 patients of MAS where a maximum pO_2 response was observed in the EEP range of 4 to 7 cm of water [15]. The response was similar in patients breathing spontaneously or being mechanically ventilated. We treated 18 infants of MAS with CPAP ventilation, of which 11 (61.11%) survived. The distending pressure of CPAP directly stimulates the pulmonary stretch receptors increasing the ventilatory drive. We found it useful in the treatment of apnea of prematurity, with survival of 7 (41.17%) of the 17 infants treated, although survival of more than 60% has been reported [16]. Infants suffering from septicemia had high mortality, with only 2 of the 9 cases treated surviving, however, the cause of death in such cases is multifactorial. Most cases of TTNB (15 out of 19) required nothing more than humidified oxygen alone. Only 4 of these required to be put on CPAP, all survived.

Of the 44 CPAP failures 11 (25%) babies had to be shifted to IPPV in less than 24 hours, these were suffering from severe respiratory disorders. But a larger group of 33 (75%) infants did well in the first 24 hours and then deteriorated on the second and the third day. While CPAP failure amongst these was attributable to pneumothorax in four, the cause of deterioration in the remaining 29 infants could not be explained well. As the lungs improve during this period, they become more compliant and therefore a greater percentage of CPAP may be transmitted to the intrathoracic space resulting in substantial reduction in cardiac output and tissue perfusion leading to progressive metabolic acidosis [8]. Prolonged and high CPAP may also result in excessive CO_2 retention. Failure to monitor arterial pCO_2 and pH could be an important factor for higher CPAP failures in our study but needs further appraisal.

The efficacy of ventilation was encouraging in infants weighing more than 1500 gm (Table 2) with overall survival of 73 to 82%. Infants weighing <1000 gm fared poorly on CPAP, with only 1 out of 16 maintaining the desired oxygen saturation and the rest had to be shifted to IPPV. While 4 of the 18 babies of <1000 gm survived on IPPV in the series of Meherban Singh et al, one developed retinopathy of prematurity and 2 had bronchopulmonary dysplasia [4]. There were hardly any complications of nasal CPAP in our study. It has been postulated that by delivering CPAP into the nasopharynx the mouth acts a blow valve for excess pressure [9]. The incidence of pneumothorax of 4.4% in our study is similar to 2.6% in the series of Risemberg et al [10]. This is significantly lower than the incidence of 10-14%, when CPAP was given by other means [3,8]. Although ABG monitoring has distinct advantages, it requires considerable expertise, is invasive and not easily available. Conversely, pulse oximetry not only monitors oxygen saturation of haemoglobin continuously but is also simple and noninvasive. SaO_2 is more indicative of total oxygen content of blood than is PaO_2 and is more sensitive of hypoxemia specially when the steep portion of the oxygen dissociation curve is reached. But with hyperoxemia large increase may be associated with only small changes in SaO_2 . To avoid hypoxemia as well as hyperoxemia, SaO_2 may be kept around 90%. When reading is more than 96%, FiO_2 should be decreased pending the results of PaO_2 [17] where available. This is particularly important for premature infants with high foetal haemoglobin who may be at risk for retrolental fibroplasia.

We found nasal CPAP ventilation complemented with pulse oximetry, a simple and efficient method for treating neonates with respiratory distress. Displacement of nasal prongs was quite troublesome and requires dedicated

staff to replace it frequently. However, this has to be seen in comparison with the expertise required for intubation, the problems of keeping it free of secretions and its long-term complications. As such, the efficacy of CPAP delivered through nasal prongs, endotracheal tube or tightly fitting masks is similar [4,8,11,13,14]. Most of our hospitals treat respiratory distress in newborns with oxygen alone and accept high mortality and morbidity. Establishing a NICU in smaller hospitals with equipment, expertise and staffing for IPPV and ABG analysis is neither economically viable nor practical. Although the value of IPPV where available with its full complements can not be overemphasised the outcome of CPAP failures when shifted to IPPV is poor universally [11]. In our study, only 5 of these 44 infants could be salvaged with IPPV and one of them was found to have IVH. Considering that inexpensive CPAP resuscitators and pulse oximeters are now available, we conclude that, this form of therapy should be adopted even by the smaller hospitals.

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A man goes to the doctor and says to the doctor:

“It hurts when I press here” (pressing his side)

“And when I press here” (pressing the other side)

“And here” (his leg)

“And here, here and here” (his other leg, and both arms)

So the doctor examined him all over and finally discovered what was wrong... “You’ve got a broken finger!”

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