Application of nasal continuous positive airway pressure to early extubation in very low birthweight infants

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Abstract

Using a preset protocol for early extubation, 50 babies were randomly selected to post-extubation headbox or post-extubation nasal continuous positive airway pressure (N-CPAP). All infants weighed less than 1500 g, had a gestational age of less than 34 weeks, and had been weaning from mechanical ventilation within seven days of life. The criteria for extubation included stable condition, fraction of inspired oxygen (FiO_2) of $\leq 35\%$, peak inspiratory pressure (PIP) of ≤ 15 cm H_2O (1.47 kPa), and ventilator rate of 6/minute. Before extubation, a loading dose of aminophylline was given followed by maintenance treatment. If reintubation was not required within 72 hours of the initial extubation the procedure was considered successful. The reintubation criteria included FiO_2 of $\geq 70\%$ to maintain arterial oxygen tension (PaO_2) of ≥ 50 mm Hg (6.67 kPa) or pulse oximetry between 90–96% and pH of < 7.25 , and arterial carbon dioxide tension (PACO_2) of > 60 mm Hg (8.00 kPa) and severe or recurring apnoea. The overall success rate of early extubation was 66% (33/50). The individual successful extubation rate of post-extubation in the N-CPAP group and the post-extubation headbox group were 84% (21/25) and 48% (12/25), respectively ($p=0.017$; χ^2). There were no significant differences in clinical characteristics between the two groups. The most common cause of failure in early extubation was apnoea, and most occurred in the headbox group (9/12).

These results suggest that application of N-CPAP to a preset protocol for extubation can achieve a better success rate of early extubation in very low birthweight (VLBW) infants.

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Keywords: N-CPAP, very low birthweight, early extubation.

Reintubation of the very low birthweight (VLBW) infant after recovery from respiratory distress is common. Therefore, there is a tendency to prolong mechanical ventilation, with a low ventilator rate, in the hope that the infant's condition will stabilise before extubation. Under these circumstances some infants will develop complications, including

bronchopulmonary dysplasia (BPD),¹ subglottic stenosis,^{2,3} infection, increasing the risk of morbidity and mortality.⁴ Several reports have described the criteria for extubation, based on pulmonary function test.^{5–8} Pulmonary function testing, however, is not always routinely available, so we have designed a protocol for early extubation of VLBW infants. Two methods are usually used in post-extubation management – the headbox technique and nasal continuous positive airway pressure (N-CPAP). Because we have experience of using N-CPAP as an alternative treatment to the ventilator in respiratory distress syndrome (RDS),^{9,10} we tried in this study to estimate whether the concomitant use of the protocol and post-extubation N-CPAP would be more effective for early extubation in VLBW infants than the post-extubation headbox.

Methods

Infants with the following characteristics were enrolled into this study after informed consent had been obtained from their parents: (i) birthweight of < 1500 g; (ii) gestational age of < 34 weeks; (iii) mechanical ventilation after intubation initiated during the first few hours of life; (iv) weaning started within seven days of life; (v) absence of overwhelming infection and congenital abnormalities. All infants followed the protocol for early extubation as soon as their condition had stabilised. The FiO_2 was lowered by 2 to 10% to at least less than 35% before extubation to maintain a PaO_2 between 50 and 70 mm Hg (6.67 and 9.33 kPa). The peak inspiratory pressure (PIP) was reduced by 2 to 5 cm H_2O to 15 cm H_2O , and subsequently PIP was held constant unless breathing became disturbed, when it was lowered by 2 cm H_2O . The positive end expiratory pressure (PEEP) was maintained at 5 cm H_2O during the period of mechanical ventilation. The intermittent mandatory ventilation (IMV) rate was decreased by 5 to 10 per minute for maintaining the PACO_2 at < 50 mm Hg (6.67 kPa), until an IMV rate of 30/minute was reached, and subsequently by 2 to 5 per minute until reaching a rate of 10/minute. Then aminophylline was started with a loading dose of 4 mg/kg intravenously or by mouth followed by maintenance dose of 1 to 2 mg/kg every 12 hours adapted to maintain the serum concentration between 8 and 15 $\mu\text{g/ml}$. Extubation was undertaken when the IMV rate reduced to 6/min 12 to 24 hours after the loading dose of aminophylline.

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Table 1 Clinical characteristics

	N-CPAP	Headbox
Gestational age (weeks)	28.1 (1.9) (25–33)	28.4 (2.1) (24–33)
Birthweight (g)	1090 (231) (610–1490)	1130 (231) (690–1490)
Apgar score at 1 minute	3.6 (2.2) (0–7)	4.3 (1.5) (1–8)
at 5 minutes	7.0 (1.4) (4–9)	7.2 (2.0) (1–9)
Extubation age (days)	5.1 (2.6) (0.3–9)	6.0 (2.2) (1–9)

Values are mean (SD) (range).

Before extubation the infants were given CPAP 5 cm H₂O through the endotracheal tube for one hour. If respiratory acidosis (pH <7.25, PACO₂ >60 mm Hg) (8.00 kPa) and severe or frequent apnoea did not develop, the infant was extubated. After extubation, it is not unusual to register a fall in PACO₂ below that noted with endotracheal tube CPAP. This is probably attributable to the lower airway resistance after extubation. When extubation and spontaneous breathing were well established, aminophylline was stopped after 35 weeks of gestational age.

Before extubation, each infant was randomly assigned to either N-CPAP or headbox. Infants assigned to headbox received an appropriate concentration of humidified oxygen or air for at least 24 hours after the extubation. Infants assigned to N-CPAP used the CPAP system without the ventilator as reported before.¹⁰ In brief, the system consists of (i) an oxygen blender with a flow meter, (ii) a heated humidifier, (iii) an inspiratory tubing with a thermometer inserted in the midway, (iv) a nasal prong⁹ with a manometer connected to the expiratory end, (vi) an expiratory tubing, and (vii) a bottle containing sterile distilled water to a depth of 7 cm. We achieved the desired level of CPAP (5 cm H₂O) by simply immersing the expiratory tubing in water to a desired depth (5 cm).

After extubation transcutaneous PO₂ and PCO₂, pulse oxymetry saturation, heart and respiratory rate were monitored continuously. Arterial blood gases were checked when clinically indicated. All infants received chest physiotherapy to prevent atelectasis.^{11 12} Extubation was considered successful if the reintubation was not required within 72 hours of the initial extubation. The criteria for reintubation were (i) Pao₂ <50 mm Hg (6.67 kPa) with FIO₂ ≥70%; (ii) a respiratory acidosis with pH <7.25 and PACO₂ >60 mm Hg (8.0 kPa); (iii) severe or frequent

apnoea. Apnoea was defined as a respiratory pause of ≥20 seconds or less, but associated with bradycardia or cyanosis. Severe apnoea was considered if three or more apnoeic episodes in one hour or one requiring vigorous stimulation or mask and bag ventilation developed.

According to previous experience, about 40% of infants similar to those enrolled into this study are successfully extubated to a headbox. We anticipated that using N-CPAP could double the success rate to about 80%. If so, then post-extubation N-CPAP could be adopted as a routine practice in our unit.

The statistical differences were assessed using the unpaired, two tailed Student's *t* test or the χ^2 test as appropriate. A *p* value of less than 0.05 was considered significant.

Results

Fifty infants were included in the study, 25 assigned to post-extubation headbox and 25 to N-CPAP. The infants of both groups were comparable in terms of gestational age, birthweight, Apgar scores, postnatal age at extubation, incidence of patent ductus arteriosus (PDA), incidence of intraventricular haemorrhage (IVH), incidence of necrotising enterocolitis (NEC), surfactant supplement, use of aminophylline and gender (tables 1 and 2).

The extubation was successful in 21 (84%) infants in the N-CPAP group and in 12 (48%) infants in the headbox group (*p*=0.017, χ^2). The clinical characteristics of gestational age, birthweight, postnatal age at extubation, PDA, IVH, diagnosis of BPD (defined as oxygen dependency at 28 days with characteristic changes on a chest radiograph) and gender of the successfully extubated infants and of those who were not showed no significant difference (table 2).

The causes for and the number of infants not successfully extubated in each group are shown in table 3. There were no significant differences between the two groups. The most common cause of failure in early extubation was apnoea, and most occurred in the headbox group (9/12).

Discussion

The overall success rate in this study using the protocol for early extubation was 66% (33/50). We did not measure pulmonary function before extubation, therefore we are unable to comment on whether this testing would improve our success rate. In a study of extubating VLBW infants based on pulmonary function test, 79.5% (58/73) infants were successfully extubated.¹³ We achieved a similar success rate based on a preset protocol for early extubation in VLBW infants. Our protocol is based on the precise criteria for early weaning from mechanical ventilation and use of aminophylline. Aminophylline has proved effective in the prevention of post-extubation respiratory failure.^{14–16} Pulmonary function tests have a definite role in understanding the pulmonary mechanics of various respiratory diseases, but the practical values of such measurements

Table 2 Comparison of success (S) and failure (F) in both groups

	N-CPAP		Headbox	
	S (n=21)	F (n=4)	S (n=12)	F (n=13)
Gestational age (weeks)	28.3±2.0	27.3±1.0	28.8±2.1	28.0±1.9
Birth weight (g)	1100±225	1040±290	1143±199	1124±255
Extubation age (days)	4.7±2.8	7.0±1.6	5.7±2.1	6.2±2.2
Surfactant supplement	10 (48)	4 (100)	8 (67)	7 (54)
Success rate	21 (84)	–	12 (48)	–
Sex (M/F)	11/10	2/2	5/7	9/4
PDA	7 (33)	2 (50)	5 (42)	5 (38)
IVH	1 (5)	1 (25)	1 (8)	2 (15)
BPD	1 (5)	2 (50)	2 (17)	3 (23)
NEC	1 (5)	0	1 (8)	0
ROP	1 (5)	1 (25)	1 (8)	1 (8)

Values are mean ±SD or number (per cent). There were no significant differences within each group (N-CPAP or headbox). PDA, patent ductus arteriosus. IVH, intraventricular haemorrhage. BPD, bronchopulmonary dysplasia. NEC, necrotising enterocolitis. ROP, retinopathy of prematurity.

Table 3 Causes and numbers of extubation failure

	N-CPAP (n=4)	Headbox (n=13)
FIO ₂ >0.7 required	1	1
pH<7.25, P _a CO ₂ >60	0	1
Apnoea	3	9
Atelectasis	0	2

before extubation in VLBW infants has been questioned.^{5,6}

The individual success rate of infants in the post-extubation N-CPAP group and those in the post-extubation headbox group are 84% and 48%, respectively. Post-extubation N-CPAP was more successful in preventing extubation failure. Several studies of the application of N-CPAP to extubation have been reported. Some reported a higher success rate,¹⁷⁻¹⁹ while another did not.²⁰ The conflicting results might be attributable firstly to the gestational ages of the infants. But several studies applying N-CPAP post-extubation on much more premature infants also had a higher successful extubation rate.^{18,19,21} The second factor could be the level of nasal CPAP used. The best CPAP level may be different for each infant and the optimal CPAP^{22,23} requires serial determination of cardiovascular and respiratory response in each infant. We usually set the CPAP at 5 cm H₂O. Severe inspiratory retractions may point to a decreasing compliance as a result of the falling functional reserve capacity (FRC) and an indication to increase CPAP. For these infants, CPAP is increased to 7 cm H₂O and the response is assessed by observing retractions and oxygenation. We don't use CPAP over 7 cm H₂O. CPAP should be decreased if a chest radiograph reveals overexpansion of lungs, particularly in the infants with CO₂ retention.

The extubation failure rate differed significantly between infants who were assigned to N-CPAP or headbox. The most common cause of failure in both groups was apnoea, and most of this occurred in the headbox group. Many premature infants do not require oxygen as much as they require CPAP for their respiratory distress. This can be shown clinically by the fact that the decreased oxygen saturation on a pulse oxymeter and the lowered PO₂ on a transcutaneous monitor rise immediately after closing the infant's mouth to decrease the escape of CPAP but without increasing FIO₂ or CPAP. If a premature infant is extubated to headbox, the alveoli are prone to collapse during expiration, breathing becomes increasingly difficult, and the available surfactant in the alveoli is rapidly depleted.²⁴ When an infant is placed on N-CPAP immediately after extubation, this cycle can be interrupted and post-extubation respiratory failure can be prevented. N-CPAP works by improving FRC, preventing atelectasis, and reducing the breathing work. A 5 cm H₂O N-CPAP produced a decrease in supraglottic resistance and total pulmonary resistance considered to be a primary means of reducing apnoea in premature infants.²³

In conclusion, this study shows that a preset protocol can achieve early extubation in VLBW infants. And this effect can be further reinforced by applying N-CPAP immediately after extubation to prevent post-extubation respiratory failure. Moreover, we used the N-CPAP system without a ventilator, therefore addressing the shortage of ventilators in neonatal intensive care.

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