ORIGINAL ARTICLE

Sleeping position, oxygen saturation and lung volume in convalescent, prematurely born infants

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Objective: To determine whether the effects of sleeping position on lung volume and oxygenation are influenced by postmenstrual age (PMA) and oxygen dependency in convalescent prematurely born infants.
Design: Prospective study.
Setting: Tertiary neonatal unit.
Patients: 41 infants (21 oxygen dependent), median gestational age 28 weeks (range 24–31 weeks) and birth weight 1120 g (range 556–1780 g).
Intervention: Infants were studied both supine and prone at two-weekly intervals from 32 weeks' PMA until discharge. Each posture was maintained for 1 h.
Main outcome measures: Pulse oximeter oxygen saturation (Spo_2) was monitored continuously, and at the end of each hourly period functional residual capacity (FRC) was measured.
Results: Overall, lung volumes were higher in the prone position throughout the study period; there was no significant effect of PMA on lung volumes. Overall, Spo_2 was higher in the prone position ($p = 0.02$), and the effect was significant in the oxygen-dependent infants ($p = 0.03$) (mean difference in Spo_2 between prone and supine was 1.02%, 95% CI 0.11% to 1.92%), but not in the non-oxygen-dependent infants. There was no significant influence of PMA on Spo_2.
Conclusion: In the present study, prone sleeping did not improve oxygenation in prematurely born infants, 32 weeks' PMA or older and with no ongoing respiratory problems. However, the infants were monitored in each position for an hour, thus it is recommended that oxygen saturation should continue to be monitored after 32 weeks' PMA to be certain that longer periods of supine sleeping are not associated with loss of lung volume and hypoxaemia.

Prematurely born infants are often nursed prone in the initial stage of illness, because such positioning is associated with superior oxygenation and lung function.[1–3] However, there has been little research on the effect of sleeping position on convalescent infants. Available data indicate that any benefit of the prone position on oxygen saturation at 30–33 weeks' postmenstrual age (PMA) may be small ($\leqslant 2\%$)[4] and at 36 weeks' PMA may be restricted to only those infants who are oxygen dependent. Similarly, lung volumes have been shown to be superior in the prone position at 36 weeks' PMA only in infants who are oxygen dependent.[5] Improvement in oxygenation in prone compared with supine position is related to changes in lung volume as well as changes in thoracoabdominal synchrony,[6] ventilation–perfusion heterogenicity[7] and/or intrapulmonary shunting.[8] The latter abnormalities reduce as respiratory distress lessens and PMA increases.

We hypothesised that in infants without acute respiratory distress, the effect of prone positioning on lung volume and oxygenation would be influenced by PMA and oxygen dependency, and infants who were not dependent on oxygen would not benefit from prone positioning with regard to oxygenation.

METHODS

Protocol

Infants born before 32 weeks of gestation, who were at least 32 weeks' PMA and tolerating hourly feeds, without requirement for continuous positive airway pressure or mechanical ventilation, were eligible for entry into the study. We measured lung volume and oxygenation saturation in infants whose parents gave informed written consent. The measurements were repeated at two-weekly intervals until the infant was discharged. Infants were studied in supine and prone on each occasion. Each position was maintained for 1 h. Infants who were sleeping prone prior to the measurements were first studied supine and vice versa. Supplementary oxygen or extra inspired oxygen was given as appropriate if the oxygen saturation fell below 85%; additional oxygen, however, was not required during any of the examinations conducted for the study.

At the end of each hourly period, lung volume was assessed by measurement of functional residual capacity (FRC) using a helium gas dilution technique and a specifically designed infant circuit (total volume 95 ml). The FRC system (Equilibrated Biosystems Inc, Series EBS 2615, Melville, New York) contained a re-breathing bag as the system reservoir, enclosed in an airtight cylinder. A facemask (Rendell Baker, Laerdal, Norway) was held snugly over the infant's nose and mouth and silicone putty used around the mask to achieve a tight seal. The facemask was connected to the re-breathing bag via a three-way valve. The three-way valve allowed the infant to be switched into the circuit at the end of expiration. The FRC system contained a helium analyser (Equilibrated Biosystems Inc, Series 7700) with a digital display. During the measurement, if there was no change in the helium concentration over 15 s, equilibration was deemed to have occurred. Only recordings during quiet breathing were analysed, and if the infant cried or sighed the measurement was stopped and repeated. The initial and equilibration helium concentrations were used in the calculation of FRC, which was corrected for

Abbreviations: FRC, functional residual capacity; PMA, postmenstrual age; Spo_2, pulse oximeter oxygen saturation

Table 1 Demographics of the study population

	Non-oxygen-dependent (n = 20)	Oxygen-dependent (n = 21)
Birthweight (g)	1235 (786–1780)	884 (556–1550)
Gestational age (weeks)	29 (26–31)	26 (24–31)
Antenatal steroids	14	18
Surfactant	10	21
Ventilated	11	21
Duration of ventilation (days)	2 (0–11)	14 (1–46)
Duration of supplementary oxygen (days)	4 (0–30)	85 (36–455)
Receiving caffeine		
32 weeks' PMA	8	6
34 weeks' PMA	3	9
36 weeks' PMA	NA	7
38 weeks' PMA	NA	4
Receiving diuretics		
32 weeks' PMA	0	4
34 weeks' PMA	0	6
36 weeks' PMA	NA	10
38 weeks' PMA	NA	5

Data are median (range) or number.
NA, not applicable, PMA, postmenstrual age.

oxygen consumption (assumed to be 7 ml/kg/min)[9] and to body temperature, pressure and water vapour-saturated conditions. FRC was measured twice in each position with an interval of 10 min between measurements. An individual's FRC was expressed as ml/kg body weight and the mean of the paired measurements in each position. The mean intra-subject coefficient of variation of the measurement of FRC was 8%.

Throughout each study, oxygen saturation was continuously monitored using a pulse oximeter (Spo_2) (Ohmeda Biox 3900; BOC Health Care, Louisville, CO) and a reusable infant oxygen saturation probe (Flex II). The pulse oximeter had an accuracy of ±2.1% between oxygen saturation levels of 80% and 89% and ±1.5% between 90% and 100%. The mean oxygen saturation for each hourly period was calculated using a software program (Oximeter Download for Windows; Stowood Scientific Instruments, Oxford, UK).

Statistical analysis

We analysed the differences between the two groups using Wilcoxon's signed rank or the χ^2 test as appropriate. There were repeated measures in variables, namely position and postnatal age. Therefore, to further assess the significance of any differences in FRC or Spo_2 a preliminary measures analysis of variance with random effect for subject was applied, followed by a linear mixed regression model to estimate the effects of position, while adjusting for other influential factors.

Sample size estimation

Prematurely born, convalescent infants previously cared for on the neonatal unit had a mean oxygen (SD) saturation of 93.8% (3.8%) and FRC of 27.2 (7.3) ml/kg. Assessment of at least 12 infants at each PMA allowed detection of differences between the positions in oxygen saturation of 4.25% and in FRC of 8.2 ml/kg with 80% power at the 5% level. Thus, we continued to recruit infants until we had studied—on at least two occasions—12 oxygen-dependent infants and 12 infants not dependent on oxygen.

Patients

The study included 41 preterm infants with a median gestational age of 28 weeks (range 24–31 weeks) and birth weight of 1120 g (range 556–1780 g), of whom 21 were oxygen dependent. The oxygen-dependent infants were lighter ($p = 0.001$) and more immature at birth ($p<0.001$) than those not dependent on oxygen (table 1). In addition, more oxygen-dependent infants had received surfactant ($p<0.001$) and required ventilatory support ($p = 0.002$). The duration of ventilatory support and requirement for supplementary oxygen were longer in those infants who were oxygen dependent compared with those who were not oxygen dependent ($p<0.001$) (table 1). At the time of the study, the only drugs the infants were receiving were caffeine and/or diuretics (table 1).

Our unit's policy is to discharge infants who are not oxygen dependent as soon as they are fully bottle or breast fed and at least 34 weeks' PMA. Thus, we studied the infants not dependent on oxygen up to and including 34 weeks' PMA. Oxygen-dependent infants were discharged when they were no longer oxygen dependent and met the above criteria, or, if the parents agreed and the home circumstances were appropriate, oxygen-dependent infants who were fully bottle or breast fed were discharged on supplementary oxygen.[10] Oxygen-dependent infants were given sufficient supplementary oxygen to maintain their oxygen saturation levels between 90% and 92%.

RESULTS

Eight infants were studied on one occasion, 27 on two occasions, 3 on three occasions and 3 on four occasions. Initial analysis revealed that both in infants dependent and in infants not dependent on oxygen, the FRC was higher in the prone than in the supine position throughout the study period (table 2). The differences were statistically significant in the non-oxygen-dependent infants at 32 weeks (median difference 3.8, range 7.3 ml/kg to –5.8 ml/kg, $p = 0.01$) and 34 weeks (median difference 3.3, range 11.9 ml/kg to –3.5 ml/kg, $p = 0.003$), and in the oxygen-dependent infants at 32 weeks (median difference 5.2, range 12 ml/kg to –2.0 ml/kg, $p = 0.04$) and at 38 weeks (median difference 2.5, range 10.2 ml/kg to –2.8 ml/kg, $p = 0.04$). However, we found no significant differences

Table 2 Lung volume according to position

	PMA (weeks)	No.	Postnatal age (days)	Weight (g)	Prone FRC (ml/kg)	Supine FRC (ml/kg)	p Value
Non-oxygen-dependent infants							
	32	12	17 (7–41)	1432 (885–1720)	22.1 (17.1–30.2)	18.2 (12.9–36.0)	0.01
	34	15	33 (21–53)	1782 (1180–2004)	24.4 (17.5–33.9)	20.4 (13.6–37.4)	0.003
Oxygen-dependent infants							
	32	7	37 (18–58)	1453 (954–1546)	22.7 (17.9–37.1)	19.0 (14.2–25.1)	0.04
	34	13	47 (30–72)	1762 (1312–2170)	20.9 (14.8–24.6)	17.9 (13.9–26.3)	0.3
	36	16	73 (39–92)	1916 (1168–2834)	20.8 (12.7–27.8)	17.5 (9.8–30.8)	0.2
	38	11	84 (54–103)	2325 (1534–3080)	23.2 (12.6–27.7)	18.7 (12.6–27.2)	0.04

FRC, functional residual capacity; PMA, postmenstrual age.
Data are median (range).

Table 3 Oxygen saturation according to position

	PMA (weeks)	No.	Prone Spo_2 (%)	Supine Spo_2 (%)	p Value
Non-oxygen-dependent infants					
	32	12	96.6 (90.7–98.8)	96.7 (90.4–99.8)	0.8
	34	15	95.3 (94.0–99.5)	95.5 (94.5–99.5)	0.3
Oxygen-dependent infants					
	32	7	92.3 (90.0–95.3)	92.1 (89.8–95.2)	0.3
	34	13	95.1 (91.4–97.3)	92.7 (87.4–96.8)	0.1
	36	16	94.5 (88.5–97.6)	92.6 (88.1–97.7)	0.3
	38	11	92.7 (84.1–94.4)	90.1 (86.2–95.4)	0.5

Spo_2, pulse oximetry oxygen saturation; PMA, postmenstrual age.
Data are median (range).

in the Spo_2 levels in the two positions in both groups of infants (table 3).

The analysis of variance with repeated measures for FRC showed a significant effect of position on lung volume ($p = 0.001$). There was no significant interaction of position and PMA. The multivariate linear mixed model for FRC showed position to have a highly significant effect on FRC; FRC was higher in the prone position ($p<0.001$). On average, the mean difference in FRC between the two positions was 2.62 ml/kg (95% CI 1.3 to 3.6 ml/kg). The analysis of variance with repeated measures for Spo_2 showed a borderline significant effect of position on Spo_2 ($p = 0.06$). In the multivariate linear mixed model, no significant influence of either postnatal age or PMA was seen, but the oxygen-dependent infants had significant lower Spo_2 than those infants who were not oxygen dependent ($p<0.001$). After adjusting for these effects, Spo_2 was significantly higher in the prone position ($p = 0.02$), but overall the effect was small (mean difference 0.78%, 95% CI 0.11% to 1.44%). In the oxygen-dependent infants, the Spo_2 was on average 1.02% (95% CI 0.11% to 1.92%) higher in the prone compared with the supine position ($p = 0.03$) and the infants who were not oxygen dependent. The Spo_2 on average was 0.45% (95% CI –0.53% to 1.43%) higher in the prone position ($p = 0.37$).

DISCUSSION

We have shown that in prematurely born infants prone positioning is associated with higher lung volumes from 32 weeks' PMA onwards. In addition, overall oxygen saturation was higher in the prone position. On group analysis, as we previously found in more mature prematurely born infants,[5] this effect was only significant in the oxygen-dependent infants. Indeed, most of the infants who were not dependent on oxygen had saturation levels over 95% in both positions.

The effect of position in infants who were oxygen dependent was relatively modest, with a 1.02% overall mean difference in Spo_2 between the two positions. As the infants were only examined in each position for an hour, the nurses were requested to alter the supplementary oxygen level only when the Spo_2 fell below 85%. This resulted in wider variations in Spo_2 than in our previous study[5] and may have influenced the magnitude of any overall effect. We did not randomise the order of sleeping positions because we noted that infants were slept supine or prone arbitrarily, which further highlighted the lack of data to inform an appropriate sleeping position from 32 weeks' PMA. Therefore we first studied infants in the position opposite to that in which they had been previously sleeping. As we always assessed infants after only an hour in a particular position, we avoided introducing bias related to a longer time being spent in one position. It is possible that if we had left the oxygen-dependent infants in the supine position for longer, we might have seen greater effects on oxygenation. However, many of the younger infants were studied while still receiving hourly feeds, and it was not possible to study them undisturbed for longer than an hour. Consequently, for consistency, we studied infants at all ages for an hour in each position.

Infants who were oxygen dependent had significantly lower Spo_2 compared with the infants who were not dependent on oxygen at both 32 weeks' and 34 weeks' PMA. Our policy, following publication of the STOP-ROP[11] and BOOST[12] trials, is to keep oxygen-dependent infants' Spo_2 between 90% and 92% saturation. Both trials[11 12] had reported disadvantages of maintaining higher oxygen saturation levels. The STOP-ROP trial found higher oxygen saturation was associated with more respiratory infections and exacerbations of chronic lung disease,[11] and the BOOST trial found that it was associated with more infants being oxygen dependent at term and requiring home oxygen therapy.[12] It is interesting, however, that the median Spo_2 of our non-oxygen-dependent infants was at least 95%, regardless of position or PMA.

Prone compared with supine sleeping is associated with an increased risk of sudden infant death syndrome (SIDS), and some studies have shown that prone sleeping may be particularly a risk factor in prematurely born infants.[13] Although the significant association of prone sleeping and SIDS is well known, some babies, including those born prematurely, are still slept prone at the high-risk age for SIDS.[14] Several studies have highlighted that parents are strongly influenced by health professionals with regard to their choice of sleeping position for their infant. In a survey of 100 healthy infants,[15] perceptions by parents of instructions from a doctor or nurse regarding the position in which the infants should be placed in the nursery were associated with the position parents reported placing their infants to sleep at home. Similarly, mothers of prone sleeping very low birthweight infants in one prospective cohort study[16] often reported the influence of medical professionals and nursery practices as most important in their choice of sleeping practice. Worryingly, the results of a national survey in the UK[17] revealed that in some neonatal units prematurely born infants were slept prone even just prior to discharge. We hope our data encourage

What is already known on this topic

- Prone positioning improves oxygenation and lung function in prematurely born infants with acute respiratory distress.
- At 36 weeks' postmenstrual age only oxygen-dependent infants have been shown to have superior lung volumes and oxygenation when nursed prone. Therefore, although not tested, the effect of prone position on lung volume and oxygenation may be affected by postmenstrual age and oxygen dependency.

What this study adds

- In infants born at less than 32 weeks' postmenstrual age, there were no significant effects of prone positioning on oxygenation from 32 weeks' postmenstrual age.
- At 32 weeks' and 34 weeks' postmenstrual age, those infants who were not oxygen dependent had similar oxygenation levels in the prone and supine positions.

neonatal practitioners to nurse non-oxygen-dependent infants supine from 32 weeks' PMA. Such a strategy would mean that parents would see their baby being nursed supine for several weeks before discharge and reinforce the message to sleep their baby supine at home.

In conclusion, we found that position influenced lung volumes in prematurely born infants from 32 weeks' PMA. The changes in lung volume, however, were not associated with appreciable changes in oxygenation in infants without respiratory distress. We thus advocate that infants who are not dependent on oxygen, from 32 weeks' PMA, should be nursed supine on the neonatal unit. As our infants were only monitored in each position for an hour, we recommend continuing monitoring oxygen saturation beyond 32 weeks' PMA to be certain that longer periods of supine sleeping are not associated with loss of lung volume and hypoxaemia. This should be done routinely in clinical practice. At 32 weeks' PMA, prematurely born infants are relatively mature. The optimal sleeping position for infants without respiratory problems and of younger PMA merits testing.

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