Effect of posture on oxygenation and respiratory muscle strength in convalescent infants

G Dimitriou, A Greenough, L Pink, A McGhee, A Hickey, G F Rafferty

Original Article

Methods

Objective: To determine if differences in respiratory muscle strength could explain any posture related effects on oxygenation in convalescent neonates.

Methods: Infants were examined in three postures: supine, supine with head up tilt of 45°, and prone. A subsequent study was performed to determine the influence of head position in the supine posture. In each posture/head position, oxygen saturation (SaO₂) was determined and respiratory muscle strength assessed by measurement of the maximum inspiratory pressure (PIMAX).

Patients: Twenty infants, median gestational age 34.5 weeks (range 25–43), and 10 infants, median gestational age 33 weeks (range 30–36), were entered into the first and second study respectively.

Results: Oxygenation was higher in the prone and supine with 45° head up tilt postures than in the supine posture (p<0.001), whereas PIMAX was higher in the supine and supine with head up tilt of 45° postures than in the prone posture (p<0.001). Head position did not influence the effect of posture on PIMAX or oxygenation.

Conclusion: Superior oxygenation in the prone posture in convalescent infants was not explained by greater respiratory muscle strength, as this was superior in the supine posture.

In the perinatal period, infants with respiratory distress placed prone rather than supine have higher oxygen saturation (SaO₂) levels and better respiratory mechanics. Impaired respiratory muscle strength and lung compliance has also been noted in premature infants recovering from respiratory disease. In term infants with lower respiratory tract infections aged between 2 and 11 months, however, only a modest (1.7%) improvement in oxygenation was noted with prone posture. The effect of posture and the mechanism of any posture related benefits have been less well investigated in convalescent preterm infants. The limited data available suggest that prone posture may still in such infants be associated with improved oxygenation. In addition, healthy preterm infants have a better response to a carbon dioxide challenge and reduced frequency of central and mixed apnoeas, bradycardias, and desaturations when nursed prone. The diaphragm is the primary respiratory muscle in the neonate and performs most of the work of breathing. Changes in posture by alterations in respiratory system mechanics or lung volume could affect diaphragm function by influencing the resting length of the diaphragm or the degree to which it shortened during inspiration. We therefore hypothesised that any posture related changes in oxygenation in convalescent infants could be explained by alterations in respiratory muscle strength. The aims of two consecutive studies were to test that hypothesis.

Methods

Protocols

Infants were eligible for entry into the studies if they had no continuing respiratory problems and were nursed in air. In the first study (study A), infants were examined in three postures: supine, supine with a tilt of 45°, and prone. The supine head up tilt posture was achieved by putting the infant on a firm cot mattress maintained at 45° tilt. When supine, the infant’s head was kept in the midline, but when prone it was turned to the right. The second study (study B) was performed to examine whether the position of the infant’s head in the supine posture affected the results of the comparison of the supine and prone postures. Infants were examined as follows: supine with head in the midline, supine with head to the right, and prone with head to the right. The order in which the postures/ head positions were studied was randomised between babies.

Respiratory muscle strength and oxygen saturation were measured in each posture/head position. Infants were studied when awake and about one hour after a feed. All the infants were on full enteral feeds. To assess respiratory muscle strength, the maximum inspiratory pressure (PIMAX) generated during an end expiratory occlusion was measured (fig 1). A face mask was placed over the infant’s nose and mouth, with a pneumotachograph (GM Engineering, Kilwinning, Ayrshire, UK) fitted snugly into the distal end of the facemask. Airway pressure changes were measured from a side port on the pneumotachograph using a differential pressure transducer (Validyne MP 45, range ± 100 cm H₂O; Validyne Corporation, Northridge, California, USA). The pressure transducer was calibrated before each recording using a Universal Pressure Meter (Co-Mark, Welwyn Garden City, Herts, UK). The signal from the pressure transducer was amplified using a Gould CD 280 carrier amplifier (Gould, Ilford, Essex, UK). The results were displayed in real time on a Toshiba laptop running Labview software version 4.0 (National Instruments, Austin, Texas, USA) with a 100 Hz analogue to digital sampling (DAQ 16XE-50; National Instruments). A two way valve was inserted in the distal end of the pneumotachograph. Occlusion of the valve at end expiration allowed expiration but not inspiration. At least three occlusions were performed at end expiration. The exact timing of the manual occlusion was determined by observation of the infant’s respiratory movements. Occlusions were maintained until the infant had made at least five respiratory efforts. From the series of occlusions, PIMAX was identified as the largest negative pressure generated. During the measurements the infants were observed for episodes of chest wall distortion. During and immediately after the occlusion, on no occasion did SaO₂ fall below 85%. SaO₂ was monitored using an Ohmeda Biox 3470-pulse oximeter with an Ohmeda flex II reusable probe. Infants remained in each posture/position for 30 minutes, and then the saturation level was recorded for a five minute period just before the next measurement.

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Statistical analysis

Data were tested for normality using the Sharpiro-Wilk W test.

Before the measurement of PIMAX, a spot reading was written down once a minute, and the mean SaO₂ for the five minute period was reported. From the infant’s medical records, gestational age, birth weight, postnatal age, and weight at the time of measurement were obtained.

Patients

In study A, 20 infants (12 boys), 12 born less than or equal to 37 weeks of gestational age, were studied. They had a median gestational age of 34.5 weeks (range 25–43) and birth weight of 2.228 kg (range 0.684–3.740). At the time of study the infants had a median postnatal age of 12.5 days (range 4–91), postconceptional age of 38.5 weeks (range 31–44), and weight of 2.456 kg (range 1.686–4.286).

In study B, 10 infants (seven boys) were examined. They had a median gestational age of 33 weeks (range 30–36) and birth weight of 1.940 kg (range 1.152–2.130). At the time of study their median postnatal age was 19.5 days (range 15–63), postconceptional age was 36 weeks (range 35–39), and weight 2.175 kg (range 1.800–2.360).

The studies were approved by King’s College Hospital National Health Service Trust research ethics committee and parents gave informed written consent for their infants to be examined.

RESULTS

Study A

Compared with the prone posture, PIMAX was higher in the supine posture and supine with 45° tilt posture (p<0.001) (table 1). There were no significant differences between the supine and supine with 45° tilt postures. Compared with in the supine posture, SaO₂ was significantly higher in the prone and supine with 45° tilt postures (p<0.001) (tables 1 and 2). There were no significant differences between the prone and supine with 45° tilt postures (table 1). Analysis of the results of the 12 infants born at or less than 37 weeks of gestational age also showed the median PIMAX to be higher in the supine than the prone posture (74.4 (range 46.2–118.2) v 66.5 (range 39.7–89.5) cm H₂O, p<0.01), and the median SaO₂ to be higher in the prone than the supine posture (median 98% (range 96–100%) v 96.5% (range 94–99%), p<0.001).

Study B

Compared with in the prone posture, PIMAX was higher in the supine posture both with the head in the midline (p<0.001) (table 3) and with the head to the right (p<0.01), and SaO₂ was lower in the supine posture both with the head in the midline (p<0.001) and with the head to the right (p<0.05) (table 3). In the supine position, there was no significant difference in PIMAX measured with the infant’s head in the midline or to the right.

DISCUSSION

We have shown that respiratory muscle strength, as assessed by measurement of PIMAX, is higher in the supine than the prone posture, whereas the reverse was found with regard to oxygenation. Many factors affect muscle strength. After only a few days of mechanical ventilation, disuse atrophy has been noted in healthy adult baboons. In addition, respiratory muscle strength is related to maturity at birth, PIMAX being...
higher in term than preterm infants. To avoid such biases, in each of the two studies the infants acted as their own controls. To assess respiratory muscle strength, the inspiratory pressure generated against an occluding valve was measured. Pmax was measured in the infants during spontaneous crying, and thus we felt was a reflection of respiratory muscle strength rather than respiratory drive. Two occlusion methods can be used: one involves total airway occlusion and the second a unidirectional expiratory valve that permits exhalation but prevents inspiration. During total airway occlusion and the second a unidirectional expiratory valve that permits exhalation but prevents inspiration.

Marini et al showed that, although the timing of the maximum pressure generated was not affected by the choice of methods, the maximum pressure achieved was almost invariably higher when a unidirectional expiratory valve was used. Pmax varies with the lung volume at the time of airway occlusion. The likely explanation for the findings of Marini et al is that use of a unidirectional expiratory valve resulted in lower lung volumes with improved operating characteristics of the inspiratory muscles. At low lung volumes, the length of the inspiratory muscles and the geometry of the diaphragm are optimised. Also, outward recoil of the relaxing chest wall near residual volume assists the inspiratory musculature in achieving inspiratory force. In this study, we used an occlusion method, which allowed exhalation but not inspiration, and showed significant differences in Pmax between the prone and supine postures.

In the first study, Pmax was higher in the supine and prone with 45° head up tilt postures than in the prone posture. In the second study, the infant’s head position was in the midline, whereas, in the prone posture, it was held to the right. Thus we could not exclude the possibility that our results were due to differences in head position. In all postures and head positions. Thus our results indicate that Pmax is influenced by posture.

Changes from the supine to the prone posture in healthy full term infants has been reported to be associated with less severe gastro-oesophageal reflux in both symptomatic and asymptomatic infants and with less gastric residual. In addition, prone positioning resulted in a decreased number of apnoeic episodes in preterm infants with gastro-oesophageal reflux and theophylline resistant apnoea.

Oxygenation was significantly higher in the supine with 45° head up tilt posture than in the supine posture. A head tilt of 15° has been associated with a reduction in the frequency of hypoxaemic episodes in prematurely born infants. In addition, head elevation by 20–45° has been shown to improve oxygenation. Possible mechanisms include improved ventilation/perfusion matching. It has been suggested that tilting may also improve diaphragm activity. Our results, however, do not support this hypothesis, because, although Pmax was higher in the supine with 45° head up tilt posture than in the prone posture, there was no significant difference in the Pmax results obtained in the supine with 45° head up tilt posture compared with the supine posture.

We conclude that oxygenation is significantly better in convalescent preterm and term infants when they are nursed prone rather than supine. Differences in respiratory muscle strength seem unlikely to explain these posture related changes in oxygenation.

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A G and G F R were responsible for the study design. G D and A H were research fellows involved in data collection. L P and M McC, BSc students, assisted the research fellows in data collection. All authors were involved in data analysis and producing the manuscript.

Authors’ affiliations

G Dimitriou, A Greenough, L Pink, A McGhee, A Hickey, G F Rafferty, Children Nationwide Regional Neonatal Intensive Care Unit, King’s College Hospital, London, UK.
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