Neither physical examination nor the EEG discriminated clearly between the two groups on follow-up. Only 1 normal patient had abnormal physical signs and an abnormal EEG on presentation, whereas 6 of 9 patients in the poor outcome group had both abnormal physical signs and abnormal EEGs, and all 9 had abnormal neurological signs. The abnormal signs in 3 patients in the good outcome group were only briefly sustained. A good response to treatment clearly differentiated those with a good from those with a bad outcome. Rose and Lombroso⁶ reported that the EEG was of prognostic value in neonatal seizures. They found that 86% of infants with neonatal seizures and a normal interictal EEG developed normally, while only 12% of those with multifocal abnormality on EEG were subsequently normal.

We concluded from our small study that, in a general paediatric practice, the prognosis of convulsions occurring between 1 and 6 months of age was considerably better than had been thought. Provided physical examination and EEG were normal, and the convulsions easily controlled, a good outlook might be expected.

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References

- 1 Chevie J J, Aicardi J. Convulsive disorders in the first year of life: neurological and mental outcome and mortality. *Epilepsia* 1978; **19**: 67-74.
- 2 O'Donohoe N V. Convulsions in early infancy and infantile spasms. In: *Epilepsies in childhood*. London: Butterworth, 1979: 30-48.
- 3 Sheridan M D. *Children's developmental progress from birth to five years*, third edition. Windsor: NEFR Publishing Company, 1975.
- 4 Chevie J J, Aicardi J. Convulsive disorders in the first year of life: etiologic factors. *Epilepsia* 1977; **18**: 489-97.
- 5 Rossiter E J R, Luckin J, Vile A, Ganly N, Hallows R, Pearson R D. Convulsions in the first three years of life. *Med J Aust* 1977; **ii**: 735-40.
- 6 Rose A L, Lombroso C T. Neonatal seizure states. *Pediatrics* 1970; **45**: 404-25.

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Bradycardia and associated respiratory changes in neonates

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SUMMARY Electrocardiogram and patterns of respiration were recorded continuously in 9 newborn infants having episodes of bradycardia. The episodes were not associated with demonstrable apnoea, either by using an apnoea mattress or by visual observation. The 'non-apnoea' associated bradycardia was always associated with changes in respiratory pattern, of which three different forms could be identified. These were prolonged apnoea if the apnoea alarm failed to trigger, short episodes of respiratory abnormalities associated with body movement (possibly in rapid eye movement sleep), and minor changes in respiratory pattern. It may be appropriate to incorporate a period of delay in heart rate monitoring systems before the alarm sounds, in a similar manner to apnoea alarm systems. We should rely more on heart rate in conjunction with apnoea alarms to detect problems, or produce better systems which detect respiratory flow.

The advent of intensive neonatal care has necessitated an increase in the monitoring of many

physiological parameters including heart rate and respiratory activity. Apnoea and associated cardiovascular changes have been widely investigated in preterm babies. However, we have been aware that many bradycardias occur without obvious associated respiratory change being noted by nursing or medical attendants. The object of this study was to investigate whether these heart rate changes in preterm babies were isolated events or accompanied by changes in respiratory activity.

Method and definitions

The babies were studied in the prone and supine positions using the respiratory jacket previously described by Milner¹ while nursed in incubators on thermister apnoea mattresses² (Vickers Medical). Respiratory pattern and electrocardiogram (ECG) were recorded simultaneously on heat-sensitive paper, using a Devices 2-channel recorder (M2R) and preamplifier (M2P). The jacket was inflated to a pressure of 4 to 5 cmH₂O (0.4-0.5 kPa) and any pressure change was recorded by a pressure

transducer (Proden Control Ltd, type 1). The heart rate was calculated by measuring the R-R intervals on the ECG relayed from a Life Trace 12 monitor (Albury Instruments). A bradycardia was defined as a heart rate less than 100 beats a minute, lasting for at least 2 beats.

Subjects

Nine babies having recurrent bradycardias were studied on 11 occasions, their gestational ages ranging between 30 and 34 weeks (mean 31.1) and birthweight ranging from 1.08 to 1.7 kg (mean 1.42). Their ages at the time of each study ranged from 2 to 16 days (mean 8), and the time studied extended between 30 and 60 minutes (mean 42). None of the babies had been ventilated or was receiving respiratory stimulants during the study, all were deemed well before investigation. All patients were having recurrent bradycardias which were triggering the ECG alarm with no associated apnoeas, either detected visually or by monitor; however, 4 of the babies were in addition having attacks of apnoea, defined as being a cessation of breathing for more than 15 seconds.

Results

Forty-five bradycardic episodes ranging between 2 and 8 per study were observed. These episodes lasted between 2 and 62 seconds (mean 11); 25 persisted for less than 5 seconds, 10 for 6–10 seconds, 3 for 11–20 seconds, and 7 for more than 21 seconds. Bradycardia was on all occasions preceded by associated change in respiratory pattern. Three different patterns could be identified from the tracings: (1) Prolonged apnoea ($n = 11$). (2) Associated with body movement ($n = 22$). (3) Altered respiratory pattern ($n = 12$).

Bradycardias associated with prolonged apnoea (Fig. 1). The apnoeas lasted between 20 and 126 seconds (mean 46.4) and occurred in 8 babies. Despite the apnoea alarm being set at 15 seconds no warning of these events was given until the heart rate

Fig. 1 Respiratory trace showing bradycardia with prolonged apnoea, the apnoea alarm failing to trigger. Respiratory trace shows small respiratory movements.

showed a bradycardia. The bradycardia occurred at intervals ranging from 9 to 70 seconds (mean 25) from the start of the apnoea. Cardiac impulse was visualised on the respiratory trace in 6 of the 11 recordings. In 9 of the respiratory traces there were small respiratory movements starting between 2 and 24 seconds (mean 10.4) after the start of the apnoea.

Bradycardia associated with body movements (Fig. 2).

When these bradycardias occurred the babies were noted to have frequent facial, eye, limb, and gross body movements described in rapid eye movement (REM) sleep.^{3,4} Sleep state was not formally monitored by EEG or other methods but the babies were not clinically awake. Movement is shown on the trace by a sudden rapid upward swing of the respiratory trace. In 17 of the traces there was an episode of respiratory activity after the movement lasting between 2 and 20 seconds after which the bradycardia began. In the other 5 tracings movement progressed into prolonged apnoea, lasting between 34 and 70 seconds, the apnoea alarm being ineffective, similar to the first group.

Fig. 2 Respiratory trace showing bradycardia associated with body movement. Sudden upward movement in respiratory trace and distortion of the ECG trace is a result of body movement.

Fig. 3 Bradycardia associated with change in respiratory pattern.

Bradycardia associated with change in respiratory pattern (Fig. 3). These were episodes where there was a change from normal to erratic respiratory activity. The bradycardia occurred early in the respiratory change (2–12 seconds); shortly after the bradycardia began normal respiratory activity returned, usually within 4 seconds, and the bradycardia resolved between 2 and 4 seconds later.

Discussion

This study shows that falling heart rate is always accompanied and preceded by a change in respiratory pattern and not necessarily in association with an apnoea. However, in clinical practice, half these bradycardias would be associated with movement and hence not immediately be correlated with respiratory changes. It is difficult, with the jacket, to be sure what is happening to respiratory activity at these times but it is likely that such babies are in REM sleep.

Only 11 out of 45 episodes followed prolonged apnoea, thus three-quarters of the bradycardias, sufficient to trigger an alarm set at 90 beats a minute, appeared to be a physiological response to movements or change in respiratory activity, which we suspect were respiratory efforts (grunt) against closed or partially closed upper airways.⁵ These

babies were probably not representative of all preterm infants as they had been chosen for investigation on the grounds that they were bradycardic rather than apnoeic. Nevertheless, many babies do create anxiety in the neonatal unit as a result of their tendency to have frequent episodes of bradycardia without significant respiratory changes. The episodes were generally brief and self-correcting and it might be appropriate to incorporate an alarm delay in heart rate monitoring systems. However, bradycardia may herald severe respiratory symptoms because of the failure of the apnoea alarm system but even with such a heart rate alarm delay the episodes would still be monitored, and the number of alarms would decline, so reducing anxiety.

The failure of the apnoea alarm to trigger has been demonstrated before in impedance systems where the cardiac impulse is said to be augmented because of increase in stroke volume.⁶ The apnoea mattress can be affected in a similar way⁷ since small respiratory movements are seen during prolonged apnoea (Fig. 1). This together with cardiac impulse may delay the alarm trigger if set too sensitively.^{2,8} In view of this we would support the suggestion of Southall *et al.*⁶ that heart rate should always be monitored in addition to respiration whichever system is used.

Conclusion

Bradycardias do not occur without respiratory changes; in more than 20% they were associated with severe prolonged apnoeas not monitored by the mattress system. It may be more prudent to monitor apnoeas by changes in heart rate,⁸ rather than rely on present apnoea systems alone. Alternatively more accurate systems which detect respiratory flow should be produced.

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References

- 1 Milner A D. The respiratory jacket. *Lancet* 1970; ii: 80–1.
- 2 Lewin J E. An apnoea-alarm mattress. *Lancet* 1969; ii: 667–8.
- 3 Gabriel M, Albani M, Schulte F J. Apneic spells and sleep states in preterm infants. *Pediatrics* 1976; 57: 142–7.
- 4 Krauss A N, Solomon G E, Auld P A M. Sleep state, apnea, and bradycardia in pre-term infants. *Dev Med Child Neurol* 1973; 19: 160–8.

- ⁵ Milner A D, Boon A W, Saunders R A, Hopkin I E. Upper airways obstruction and apnoea in preterm babies. *Arch Dis Child* 1980; **55**: 22-5.
- ⁶ Southall D P, Richards J M, Lau K C, Shinebourne E A. An explanation for failure of impedance apnoea alarm systems. *Arch Dis Child* 1980; **55**: 63-5.
- ⁷ Rolfe P. Monitoring in newborn intensive care. *Biomed Eng* 1975; **10**: 399-404.

- ⁸ Warburton D, Stark A R, Taeusch H W. Apnea monitor failure in infants with upper airway obstruction. *Pediatrics* 1977; **60**: 742-4.

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Nebulised cromoglycate, theophylline, and placebo in preschool asthmatic children

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SUMMARY Sixteen children aged under 5 years with chronic asthma completed a double-blind crossover trial of treatment with oral choline theophyllinate (6.7 mg/kg four times daily) and nebulised sodium cromoglycate (20 mg four times daily). The trial comprised three 8-week treatment periods during which active sodium cromoglycate, active choline theophyllinate, and placebo were given in random order. Symptom scores for sleep disturbance, cough, wheeze, and daily activities were similar during the three treatment periods if results were analysed using Friedman's non-parametric analysis of variance. However the Mantel-Haenszel test showed that sodium cromoglycate was superior to placebo ($P < 0.05$) in maintaining normal daily activities. Either regimen is safe and well tolerated by young children.

Sodium cromoglycate (SCG) and oral theophylline have been shown to be of value in the long-term management of asthma in childhood.¹⁻³ In a collaborative study in children aged over 5 years both drugs were shown to be equally effective.⁴ However, there have been few long-term studies in young preschool asthmatic children of drugs known to be effective in controlling symptoms in older children or adults. In such an age group, nebulised SCG was shown to be superior to placebo.⁵ Choline theophyllinate (CT) is a widely used theophylline preparation in young asthmatic children and we know of no long-term controlled study confirming its efficacy. We set out to compare the relative usefulness of oral CT and nebulised SCG in a group of preschool asthmatic children who were unable to use the spinhaler effectively.

Patients

Sixteen patients, 11 boys and 5 girls, took part in the study. Their ages ranged from 1 year 9 months to 4 years 5 months (mean 3 years 5 months). All were within $\pm$ one standard deviation of the mean predicted for age for height and weight on standard centile charts.⁶ Fifteen gave a personal or family history of associated atopic disorders. Ten children suffered from eczema, 6 from recurrent rhinitis, and 2 from urticaria. Symptoms had started in the first year of life in 4 and during the second year in a further 8. Wheezing attacks were precipitated by upper respiratory tract infections in 15, by exercise in 11, and by specific allergens in 5. Of 11 children in whom skin tests were performed, 7 had multiple positive reactions to common antigens—such as house dust mite, pollens, and animal dander.

For the group there had been 39 hospital admissions in the year preceding the trial, a range of 1-5 (median 2) admissions per child. Fifteen children had received systemic treatment with steroids previously, but none was on maintenance steroids. The control of asthma was poor on routine treatment and all had had at least 2 wheezing episodes during the 6 weeks preceding the trial. Treatment regimens were intermittent or regular salbutamol (in 7), salbutamol combined with CT (in 6), a theophylline preparation alone (in 2), and regular orciprenaline (in 1). Five of the patients on oral salbutamol had salbutamol respirator solution 0.5% available at home for use by an air pump nebuliser unit as required (2.5 mg 3-4 hourly).

Methods

A double-blind crossover trial was carried out comprising three 8-week treatment periods during