1028 neonatal electrocardiograms

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SUMMARY Electrocardiograms were recorded from 1028 (99.4%) of 1034 consecutively born babies on the 1st or 2nd day of life. Abnormalities of cardiac rhythm or conduction were found in 49 (4.8%) babies. 17 babies had single or multiple premature beats during the recordings, and 7 babies showed sudden increases in R-R interval possibly due to sinoatrial node dysfunction. One baby had pre-excitation, 6 babies had superior QRS axes with clinically normal hearts, and 17 had sinus or junctional bradycardia of <80 beats/min. One baby had an incessant reciprocating tachycardia and subsequently required digoxin for heart failure. Continuous 24-hour ECG monitoring in 25 babies with abnormalities of the screening ECG, and 25 babies without such abnormalities, failed to show any additional tachyarrhythmias or bradyarrhythmias warranting treatment. In view of the uncertain clinical significance of many neonatal arrhythmias and cardiac conduction disorders, more information concerning their natural history and relationship to sudden unexpected death in infancy is needed before recommending that neonatal ECG screening be generally adopted.

Investigation of the neonatal electrocardiogram by both standard and continuous recording techniques has revealed a high incidence of asymptomatic arrhythmias and cardiac conduction disorders in the newborn period (Michaëlsson, 1959; Morgan *et al.*, 1965; Morgan and Guntheroth, 1965; Urbach *et al.*, 1965; Välimäki, 1969, 1971; Välimäki *et al.*, 1974). The importance of arrhythmias as a cause of infant morbidity has been increasingly recognised (Engle and Ehlers, 1973; Ferrer, 1977), while Southall *et al.* (1976, 1977) have drawn attention to potentially life-threatening ECG abnormalities in otherwise healthy newborn infants. These workers have suggested a link between such abnormalities and sudden unexpected death in infancy, and that an ECG performed as part of the routine neonatal examination might identify some babies at risk (Keeton *et al.*, 1977). In the present study we assessed the incidence of arrhythmias and cardiac conduction disorders, together with the feasibility of routine neonatal ECG screening, by performing a 6-lead ECG on a large number of consecutively born infants from a well defined neonatal population.

Methods

Six-lead ECGs (leads I, II, III, aVR, aVI, and aVF; Siemens Cardiostat Electrocardiograph) were performed on 1028 (99.4%) of 1034 babies born consecutively between 1 May and 21 September 1977 at this hospital. During 1977 88% of all deliveries in the Brighton health district (population 300 000) took place in the maternity department of this hospital. The recordings, which included a 10-second rhythm strip (lead II), were performed by one of two residents at the end of the routine neonatal examination on the 1st or 2nd day of life while the baby was resting or feeding in his mother's arms. Some babies were studied in the special care baby unit. Each mother had previously been issued with a typewritten explanatory note. Three babies who died within 7 hours of birth, 2 normal babies, and one baby transferred elsewhere at 2 hours for treatment of a large diaphragmatic hernia were not studied. Babies in whom a heart murmur was heard had a full 12-lead ECG performed.

24-hour ECG tape recordings (Medilog Cassette Recorder, Oxford Electronics Co. Ltd) were performed on 25 babies with abnormalities of the screening ECG, and on a further 25 control babies. These tapes were analysed on a playback system and computerised arrhythmia detector (Pathfinder, Reynolds Medical Electronics Ltd).

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Results

Positive findings are summarised in the Table.

Premature beats. These were found in 17 (1.7%) babies, and were atrial in 12, ventricular in 3, and both atrial and ventricular in 2. They were multiple in 12 cases. 24-hour recordings, performed in 14 babies, showed that premature beats accounted for between 0.4 and 5% of all beats during a 24-hour period. Two babies had 2 consecutive ventricular premature beats, one baby had multifocal ventricular premature beats, and one baby had periods of atrial bigeminy. In 4 babies with atrial premature beats on the initial ECGs, 24-hour recordings showed sudden increases in R-R interval suggesting sinoatrial node dysfunctions. Three of the tapes were normal. No episode of ventricular or supra-ventricular tachycardia was seen.

Sinoatrial node dysfunction. Many infants showed sinus arrhythmias. Seven showed sudden increases in R-R interval unrelated to respiration and possibly indicating sinoatrial node dysfunctions (Fig. 1). Four of these babies had 24-hour tapes; all showed frequent sudden increases in R-R interval, one showed multiple atrial premature beats, and one showed episodes lasting up to 10 seconds of sinus bradycardia with junctional escape beats at an interval corresponding to a rate of 48 beats/min (Fig. 1).

Pre-excitation. One baby had a short PR interval and delta wave suggesting pre-excitation, and this persisted at follow-up 6 months later. Repeated 24-hour tapes failed to show any clear episodes of supraventricular tachycardia.

Reciprocating tachycardia. One baby, noted to have an irregularity of the fetal heart from the 30th week

Table Positive findings in 1028 neonatal electrocardiograms

Abnormalities	No. of babies
Premature beats (n=17)	
Atrial	12
Ventricular	3
Both	2
Sinoatrial node dysfunction	7
Pre-excitation	1
Reciprocating tachycardia	1
Bradycardia <80 beats/min (n=17)	
Sinus	13
Junctional	4
Superior QRS axis 0 to -120	6
Total	49
Other findings	
Superior QRS axis -120 to -150	15
Variation in P wave shape in lead II	65

Fig. 1 Sinoatrial node dysfunction. Upper trace: lead II showing sudden increase in R-R interval. This is preceded by a progressive decrease in P-P interval suggesting 2nd degree (Wenckebach) sinoatrial block. Lower trace: 24-hour tape of same infant showing sinus bradycardia with junctional escape beats at an interval corresponding to a rate of 48 beats/min.

of gestation and a persistent fetal tachycardia during labour, was found at birth to have a continuous tachycardia of 210 beats/min (Fig. 2). ECG showed inverted P-waves in leads II, III, and aVF, indicating retrograde atrial activation; subsequent recordings showed intermittent brief returns to sinus rhythm. 24-hour tape recordings showed in addition multiple interpolated ventricular premature beats. The P-wave vector and decrease in sinus cycle lengths preceding each initiation of the tachycardia distinguished this abnormality as an 'incessant' or 'permanent' reciprocating tachycardia (Coumel, 1975). It persisted at a rate of 170-210 beats/min, and at age 4 months heart failure necessitated digitalisation. He subsequently returned to sinus rhythm and has remained well.

Sinus and junctional bradycardia. Heart rates of <80 beats/min were seen in 17 (1.7%) babies, the

Fig. 2 Incessant or permanent reciprocating tachycardia. Upper trace: lead II on day 1 showing tachycardia of 210 beats/min, the inverted P-waves indicating retrograde atrial activation. Middle trace: day 2 showing brief return to sinus rhythm followed by recurrence of the tachycardia, the premature impulse showing a slightly altered QRS configuration due to aberrant conduction. Lower trace: sinus rhythm after digitalisation at age 4 months.

slowest rate being 60. The bradycardia was sinus in 13 cases, and junctional in 4. 24-hour tapes, performed in 5 of these babies, did not show any bradycardias of <60 beats/min, nor did they reveal additional arrhythmias.

Superior QRS axis. The frontal plane QRS axis was 0 to -120 in 6 babies, none of whom had any clinical evidence of structural heart disease. Of 4 of these babies followed up, only one had a persistently superior axis at age 3 months.

Other screening ECG findings. The QRS axis was between -120 and -150 in 15 babies, all of whom had clinically normal hearts. Variation in P-wave shape in lead II was observed in 65 (6.4%) babies (Fig. 3) and was associated with the occurrence of atrial premature beats ($\chi^2 = 45.7$, $P < 0.001$).

Control 24-hour tapes. These were performed in 25 babies whose screening ECGs had been normal. Sinus rates varied between 60 and 240 beats/min. Two babies showed occasional atrial premature beats, and one baby had 2 isolated ventricular premature beats. Two babies had sudden increases in R-R interval, suggesting sinoatrial node dysfunctions. One preterm baby had repeated episodes of sinus bradycardia at a rate of 50 beats/min lasting up to 10 seconds. No sustained tachyarrhythmias or bradyarrhythmias were seen.

No significant association was found between any ECG abnormality and preterm delivery, birthweight, birth asphyxia, or neonatal respiratory illness. Except for one baby who developed heart failure due to reciprocating tachycardia (Fig. 2), there was no clinical disturbance in any baby with an abnormal ECG, and none had any evidence of structural congenital heart disease.

One baby in the study died suddenly and unexpectedly at home at age 6 months. She had been born at 35 weeks' gestation, and the screening ECG, apart from showing tall P-waves in lead II suggesting right atrial hypertrophy, was normal. No cause of death was found at necropsy and detailed histology of the cardiac conducting tissue (Dr R. Anderson, Brompton Hospital) was normal.

Fig. 3 Variation in P-wave shape in lead II. Note suppression of sinoatrial node activity after atrial premature beat (arrowed).

Discussion

Although the present study confirms that arrhythmias and cardiac conduction disorders may be detected by routine ECG screening in otherwise healthy newborn infants, the relationship of these abnormalities to subsequent morbidity remains uncertain. Both premature beats and pre-excitation may occur as transient phenomena in early infancy (Friedman *et al.*, 1969; Välimäki, 1971), but may also be associated with tachyarrhythmias (Moene and Roos, 1973; Silver *et al.*, 1973; Southall *et al.*, 1977), although in the present study we were unable to document any such association using either standard ECGs or 24-hour recordings. We also failed to detect any tachyarrhythmias or bradyarrhythmias requiring treatment in 25 control babies studied by 24-hour taped ECGs. Although the range of ECG abnormalities was similar, the incidence of potentially serious arrhythmias was therefore low compared with that found by Southall *et al.* (1976, 1977). One baby, however, developed heart failure due to an incessant reciprocating tachycardia (Fig. 2), an arrhythmia previously described in infancy and shown by intracardiac electrophysiological studies to be due to a re-entry mechanism in the region of the atrioventricular node and upper His bundle (Coulmel, 1975). This arrhythmia was detected antenatally, underlining the importance of considering the possibility of fetal arrhythmia when persistent fetal tachycardia or heart irregularity is noted during pregnancy or labour.

Supraventricular tachycardia is a well documented cause of heart failure in the perinatal period (Radford *et al.*, 1976), and has also been found in some cases of 'near miss' sudden unexpected death in infancy (Keeton *et al.*, 1977). The significance of bradyarrhythmias is less certain, and in many cases occurs secondarily to apnoea (Girling, 1972) or increase in vagal tone (Cordero and Hon, 1971), junctional escape rhythms reflecting the relatively high intrinsic firing rates of the subsidiary pacemaker tissues in this age group. Sinus arrhythmia and sudden changes in heart rate are common in the newborn, especially when preterm, and may reflect autonomic immaturity (Lipton *et al.*, 1965; Church *et al.*, 1967). The abrupt increases in R-R interval noted in babies in the present study may have a similar aetiology, but might alternatively be a manifestation of dysfunction of the sinoatrial node, especially in those cases associated with episodes of sinus or junctional bradycardia (Fig. 1). Although sinoatrial node dysfunction has recently been recognised as a cause of syncopal attacks in older children even in the absence of structural heart disease (Scott *et al.*, 1976), its significance in the newborn period is

uncertain. Variation in P-wave shape (Fig. 3) has previously been ascribed in adults to variability in the site of formation and subsequent atrial conduction of the sinoatrial node impulse (Brody *et al.*, 1967). This phenomenon in the newborn, together with the occurrence of sinoatrial node dysfunction and the tachycardia-bradycardia syndrome (Southall *et al.*, 1977), supports the concept of continuing functional maturation of the sinoatrial node in early postnatal life. Confirmation of this hypothesis awaits more detailed study of sinoatrial node function in this age group.

A superior QRS axis is often associated with structural congenital heart disease, most frequently an atrioventricular canal or ventricular septal defect in the acyanotic infant (Shinebourne *et al.*, 1974). Only one baby in the present study had a persistently superior QRS axis which, in the absence of any clinical evidence of structural defects, probably represents isolated left anterior hemiblock.

Sudden unexpected death in infancy represents a spectrum of diseases and social situations, and Emery (1977) considers that only a few, perhaps 10%, are likely to be due to cardiac arrhythmias. From this figure, it has been estimated that more than 40 000 neonates would have to be screened before a significant association could be shown (D. Southall, personal communication). In addition, it is not certain that an infant who dies suddenly from cardiac arrhythmia will necessarily have any abnormality detected by a screening ECG in the neonatal period. It nevertheless seems reasonable to investigate cases of 'near miss' sudden unexpected deaths with a standard ECG and, if possible, with 24-hour ECG combined with respiratory tape monitoring, the latter in order to assess the incidence and timing of apnoea in babies with bradyarrhythmias. The provision of routine neonatal ECG screening, however, together with 24-hour tape recording and analysis, gave our neonatal department a sizeable additional work load and also generated some maternal anxiety. Until there is more information concerning the natural history of neonatal ECG abnormalities and their relationship to sudden unexpected death in infancy, it is premature to recommend the general adoption of neonatal ECG screening.

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