SOME AUSCULTATORY AND PHONOCARDIOGRAPHIC FINDINGS OBSERVED IN EARLY INFANCY

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[WITH SPECIAL PLATE]

With recent advances in cardiac surgery, early recognition and accurate diagnosis of congenital heart disease is increasingly important. In early infancy, tachycardia, rapid respirations, and crying make auscultation no easy matter. Distinction of the abnormal from the normal is difficult, and evaluation of adjustments between intra- and extra-uterine life provides an additional problem. Auscultation is easier in children and the normal more clearly defined, but the assessment of systolic murmurs remains difficult.

The present study was designed to evaluate the normal cardiac status in infancy, and particularly the incidence and character of murmurs. A series of infants have been examined clinically under optimal conditions both before and after birth. Phonocardiograms were recorded from these infants and from others with known congenital heart disease.

Clinical Material and Methods

Mothers without rubella or unexplained illness during pregnancy and their infants born at the Canadian Red Cross Memorial Hospital, Taplow, were studied. Premature infants, those with any obvious congenital abnormality, and those developing an infection were excluded. The infants with known or suspected congenital heart disease were referred from the paediatric department of the same hospital or from the Royal Berkshire Hospital.

Auscultation

In all, 230 infants were studied each night of their hospital stay after the late evening feed, when they were sleeping, supine, and the nursery was quiet. Observations were made on heart rate, sounds, and the presence

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GRAPH 1

GRAPH 2

GRAPH 3

GRAPH 1.—Mean sleeping heart rate during first 13 days of life. GRAPH 2.—Percentage incidence of audible systolic murmurs in first 8 days of life. GRAPH 3.—Sleeping heart rate of infant who died with congenital heart disease compared with mean rate of 200 infants.

and character of murmurs. If an infant would not sleep the heart rate for that night was omitted. Of these infants, 55 were re-examined between the ages of 6 weeks and 6 months.

Phonocardiograms

Phonocardiograms were obtained from 59 of the main series between the ages of 6 hours and 8 days. Repeat tracings were obtained from 14 of those seen for follow-up between 4 and 6 months of age. Because of the non-portable nature of the machine, recordings could not be taken at birth or from sick infants. The machine used has already been described (Besterman and Harrison, 1953). Tracings were made either soon after or during a feed, and crystal microphones were applied by skin suction. With the use of small microphones, simultaneous records from base and apex could be obtained, together with lead 2 electrocardiogram. Often, however, better results were obtained by using a single larger microphone attached to the flattest portion of the upper left chest or apex. Recordings were made by suppressing frequencies below 75, 150, 300, and 600 cycles per second by selection of the desired filter within the amplifier.

The foetal phonocardiograms most suitable for this study comprised some 64 from non-obese patients within approximately six weeks of term, 27 of whom had repeat post-natal recordings. A microphone was placed on the abdominal wall where the foetal heart was maximal and the uterine souffle minimal; maternal phonocardiogram and lead 2 electrocardiogram were recorded simultaneously.

Results

Heart Rate and Rhythm

Recurrent irregularities in rhythm were noted in six of the 200 infants studied, and persisted for a maximum of seven days; sinus arrhythmia was not clearly demonstrated. For a very short period after birth the usual infantile rapid changes in rate response to crying and external stimuli were less marked. The mean sleeping heart rates in relation to age are given in Table I and plotted in Graph 1. These results show that there was a rise from the second to the eighth day, with the maximum increase between the fourth and eighth days. After this day the number of infants observed fell sharply, but the mean rate continued to increase until

TABLE I.—*Mean Sleeping Heart Rate During First 13 Days of Life*

Day:	1	2	3	4	5	6	7	8	9	10	11	12	13
Mean sleeping heart rate ..	112.8	108.5	110.4	111.5	116.9	119.2	123.4	126.7	126.8	128.5	130.3	130.3	129.5
Number of babies	198	187	187	195	187	187	190	180	141	71	27	17	10

* The standard error of these means did not exceed a value of 0.8 beat per minute.

the eleventh day, after which there was a tendency to levelling off around 130 beats per minute. On the second day the minimum recorded rate was 76 and on the eleventh day 120 beats per minute.

A few of these infants were observed during and immediately after birth. The majority showed an immediate slowing followed by a sudden tachycardia after the first cry and a slow fall over the next 24 hours. The bradycardia appeared to bear a relationship to the degree of asphyxia, and a rate of 28 beats per minute was recorded in one asphyxiated infant. In some infants, however, the rate changed little immediately after birth, but fell slowly over the next 24 hours.

Heart Sounds

Both heart sounds were clearly heard all over the praecordium, in the epigastrium, and posteriorly; they were generally maximal towards the lower left sternal edge or between there and the apex. Splitting of first and second sounds was clearly audible from the time of birth, and for the first day or two there was commonly some accentuation of the pulmonary component of the second sound. Neither third nor auricular sounds were heard in any infant.

Phonocardiograms of the newborn infants clearly showed the components of the first and second sounds. The average time interval between the two major components of the second sound was 0.024 second. The minimum recorded was 0.01 second and the maximum 0.05 second, with individual variations up to 0.02 second. There was no obvious correlation between this split and the respiratory phase. The pulmonary component of the second sound was often well shown at the apex as well as at the pulmonary area (Special Plate, Fig. 2*b*) in contrast to its appearance in later childhood (Special Plate, Fig. 5).

The foetal tracings showed well-marked low-frequency ejection sounds, and most of the neonatal tracings also showed these sounds. In one infant a mid-systolic click was heard.

Irregular diastolic disturbances were shown in many of the low-frequency-range foetal recordings (Special Plate, Fig. 1*a*). The majority of neonatal phonocardiograms showed somewhat less well amplified disturbances with a constantly occurring deflection in each cycle (Special Plate, Fig. 3*b*). The average timing was 0.095 second after the first major component of the second sound; the individual minimum was 0.07 second and the maximum 0.12 second. These deflections were more impressive in some of the follow-up tracings, and possibly represent the third sound often audible in normal children, and registering as a sharper, somewhat higher-frequency sound (Special Plate, Fig. 5).

Variable low-frequency disturbances preceded the first heart sound in many tracings and were thought to represent auricular sounds.

Murmurs

All murmurs heard were systolic in timing, and their incidence in relation to age is shown in Table II and Graph 2. It will be seen that the incidence rose with each day of life. By the eighth day the incidence was

TABLE II.—*Percentage Incidence of Audible Systolic Murmurs During First 8 Days of Life*

Day:	1	2	3	4	5	6	7	8
Incidence % of systolic murmurs ..	33.5	43.0	48.3	55.6	58.3	63.5	70.4	77.4
Number of babies ..	230	230	230	230	230	230	230	230

77.4%. Systolic murmurs were heard in 48 of the 55 infants followed up. Phonocardiograms taken on an approximate quarter of the series confirmed this incidence.

In a small number of infants transient murmurs were heard soon after birth and persisting for minutes, hours, or a few days; they were noticed more frequently in infants anoxic at birth and in two babies with a severe respiratory infection. They were mostly long and high-pitched in character and localized around the pulmonary area. In one infant the murmur was thought to be continuous into diastole. No phonocardiograms of such murmurs were obtained.

Certain characteristics of the majority of murmurs may be defined. They were all short, of low or medium pitch, and mostly very soft or soft—Grade 1 or 2 of Levine's (1933) classification, and best heard with a bell stethoscope using light skin pressure. They were loudest in the first few quiet cycles following crying or other exercise, and became diminished or disappeared during deep inspiration or forced breath-holding, as did the heart sounds (modified Valsalva manoeuvre). The majority were maximal at the lower left sternal edge or at some point between there and the apex, with varying propagation within this area; it was not unusual to hear these murmurs posteriorly or up in the neck. Others were maximal at the pulmonary area, with varying propagation towards the apex. Six infants had easily audible murmurs of a low-pitched, rasping character, maximal internal to the apex and widely propagated over the left praecordium. At follow-up the characteristics of these murmurs appeared to be identical with that found during the first week, though the six referred to above were all softer and less widely propagated. Phonocardiograms showed the murmurs to have a slightly delayed onset and to finish well before the second sound, the peak being in early or mid-systole. Characteristic murmurs are shown in Special Plate, Figs. 1, 3*b*, and 4, 7, and 8*a*. One of the six loud rasping murmurs is shown in Special Plate, Fig. 3*b*, but is not obviously distinguishable from the more common type of low-frequency murmur (Special Plate, Fig. 2*b*). Follow-up phonocardiograms in the same infants are shown in Special Plate, Figs. 3*c*, 4*b*, and 7*b*, and confirm the clinical impression of the unchanged character of the murmurs.

Comparison of Antenatal and Postnatal Murmurs

Systolic murmurs were shown in most of the better antenatal tracings. Characteristic murmurs are shown in Special Plate, Figs. 1*a*, 2*a*, and 3*a*, with postnatal tracings from the same infants in Figs. 1*b*, 2*b*, and 3*b*, respectively. The majority of prenatal murmurs had a late systolic component not seen in postnatal life, but such a murmur as that shown in Special Plate, Fig. 1*a*

appears to be similar to that shown after birth (Special Plate, Fig. 1b).

Two infants had murmurs picked up by the midwifery department with foetal stethoscope, thus raising the question of congenital heart disease. The characteristics of both murmurs were identical (Special Plate, Fig. 2a). In the first a low-pitched mid-systolic murmur became audible immediately after birth (Special Plate, Fig. 2b); the second had no murmur within minutes of birth and none at follow-up (Special Plate, Fig. 6). Both these infants had normal electrocardiograms and radiographs. Often no murmurs were audible at the time of birth, but sometimes either transient or definitive murmurs were noted at that time. However, listening conditions were not good.

Congenital Heart Disease

Satisfactory phonocardiograms were eventually obtained in most of the infants referred with known or suspected congenital heart disease. In many cases information on heart sounds and murmurs additional to that determined on clinical auscultation was obtained. Comparison with the normal series of phonocardiograms might show abnormalities in the second sound, such as abnormally wide splitting or accentuation, reduction, or absence of the pulmonary component. Abnormally intense third heart sounds, high-frequency ejection sounds (Special Plate, Fig. 12), diastolic murmurs, and the varying character of the systolic murmurs could also be demonstrated. In most cases the character of the systolic murmurs was different from any demonstrated in the normal series. A few, however, demonstrated a murmur not dissimilar to those seen in the normal series, and in the absence of any obvious abnormality of the heart sounds auscultation and phonocardiography were of no diagnostic aid in such infants.

Special Plate Figs. 9a and 9b show the phonocardiogram of a 10-day-old infant who had subsequent post-mortem findings of infantile coarctation of the aorta, ventricular septal defect, and patent ductus arteriosus. He was in cardiac failure at 6 days and was diagnosed as having coarctation of the aorta on account of absent femoral pulsations and raised blood-pressure in the arms; at that time no abnormal auscultatory signs were detected. Phonocardiograms show an early systolic murmur in the anterior tracing and a late systolic murmur in the intrascapular area; there is some accentuation of the pulmonary component of the second sound and a diastolic murmur following the third sound, internal to the apex.

Special Plate Fig. 10 is the phonocardiogram of a 5-weeks-old infant who was found to have a medium-sized ductus arteriosus at the time of operation at 7 months. She was breathless on feeding at 3 days, and clinical findings and ancillary investigations suggested the diagnosis of patent ductus arteriosus. At that time the auscultatory findings were of a loud, long, high-pitched systolic murmur at the pulmonary area. The phonocardiogram shows an intense high-frequency murmur at this area, spilling over a somewhat accentuated second sound; there is also a short diminuendo diastolic element.

The third illustration is that of the infant studied daily in the main series, who died at 6 weeks. Nothing abnormal was noted during early postnatal life. He subsequently became blue on feeding and was readmitted deeply cyanosed. Necropsy showed complete mitral atresia with interatrial communication, patent ductus

arteriosus, and pulmonary artery and anteriorly placed aorta arising from the single functioning ventricle. Retrospectively, this infant had an unusually long murmur and a sleeping heart rate well above the mean for the series (see Graph 3). On the sixth to eighth day he had the highest recorded individual rate. Phonocardiogram at 3 days (Special Plate, Fig. 11a) shows the unusually long systolic murmur, which had changed by 5 weeks (Special Plate, Fig. 11b) to one of more usual characteristics. No obvious abnormality was detected in the first sound despite the absence of mitral valve. Phonocardiography proved to be helpful in this case.

Discussion

It is outside the scope of this study to consider possible explanations of the variations in heart rate occurring immediately after birth and in the ensuing days, or the increasing incidence of systolic murmurs with age. Mechanical and chemical factors at birth, control by the autonomic nervous system, adjustments between foetal and adult circulations, and changes in basal metabolism must all be considered.

The incidence of systolic murmurs in the newborn in most previously described series has ranged between 0.5% and 5%. Siemsen (1938), however, found a 37% incidence after multiple examinations. The high percentage in the present series is probably attributable to multiple examinations, very good listening conditions, and the inclusion of very soft murmurs.

There would seem to be three possible explanations for the occurrence of systolic murmurs in this age group—congenital heart disease, persistence of blood flow through foetal channels either in the same or reverse direction, and physiological causes similar to those operating in older children.

MacMahon *et al.* (1953) gave the incidence of congenital heart disease as approximately 3 per 1,000 live births. Since the infants studied were to some extent selected, and since one is known to have congenital heart disease, it seems unlikely that any of the other murmurs are due to this cause. Some observers (Richards *et al.*, 1955; Taylor, 1953) have noted that the majority of murmurs heard in early neonatal life disappear during later infancy. Others (Keith *et al.*, 1958) have noted some persisting into early childhood and then disappearing with no evidence of cardiac abnormality. Transient murmurs were heard soon after birth in some of the infants studied, and these may have been due to the blood-flow through foetal channels. A small number of the persistent neonatal murmurs were softer at follow-up, and these may disappear later as those described above. However, it was the impression that the majority persisted unchanged at follow-up until 6 months of age.

Most of the persistent murmurs heard during the first week of life and at follow-up were not dissimilar from those described by Harris (1955) and others in normal children. Comparison of Special Plate, Fig. 8 with Fig. 8b, and Fig. 4a with Fig. 5, shows the similarity of murmurs in the two age groups. The high incidence of this type of murmur in infancy compares with that of over 90% found in normal children by McKee (1938) and Lessof and Brigden (1957). The probability is, therefore, that most of the neonatal murmurs heard persist into childhood and are functional in nature.

Because of the high incidence of systolic murmurs in normal newborn infants it is evident that the

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FIG. 1a

FIG. 2a.—Phonocardiogram showing maternal and foetal heart sounds. Late systolic murmur demonstrated in foetal tracing.

FIG. 2b.—Phonocardiogram of same infant aged 4 days, recorded simultaneously at base and apex, showing well-amplified pulmonary component of second sound at apex and low-frequency mid-systolic murmur, clinically maximal just internal to apex.

[L.S.E.=left sternal edge; P.A.=pulmonary area; I.S.=intrascapular; L.F., M.F., H.F.=low, medium, and high frequency.]

FIG. 1b

FIG. 1a.—Phonocardiogram showing maternal and foetal heart sounds, high- and low-frequency tracings. Mid-systolic murmur is demonstrated in foetal tracing.

FIG. 1b.—Phonocardiogram of same infant aged 5 days, showing similar type of murmur, filling sounds, and auricular sound.

[Time marker 0.01-second divisions throughout.]

FIG. 2a

FIG. 2b

FIG. 3a.—Phonocardiogram showing maternal and foetal heart sounds. Plateau mid- and late systolic murmur shown.

FIG. 3b.—Phonocardiogram of same infant aged 2 days, showing mid-systolic murmur which was clearly audible when first listened to two hours after birth.

FIG. 3c.—Phonocardiogram of same infant aged 5 months, showing similar type of murmur, clear third heart sound, and well-marked auricular sound.

FIG. 3a

FIG. 3b

FIG. 3c

FIG. 4a

FIG. 4b

FIG. 4a.—Phonocardiogram of infant aged 4 days who had localized short high-pitched basal systolic murmur.

FIG. 4b.—Phonocardiogram of same infant aged 5 months, showing similar character of murmur.

FIG. 5.—Phonocardiogram of normal 6-year-old boy with simultaneous recordings at base and apex. This shows pulmonary component of second sound, best at base, a clear third heart sound, and a systolic murmur comparable in character to Figs. 4a and 4b.

FIG. 5

FIG. 6

FIG. 6.—Phonocardiogram of infant aged 2 days. No murmur audible or demonstrable on phonocardiogram. Clearly audible split of first and second sounds shown. Audible systolic murmur *in utero* with phonocardiogram showing murmur of type seen in Fig. 2a.

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FIG. 7a

FIG. 7b

FIG. 7a.—Phonocardiogram showing characteristic "early" type of third heart sound—small and irregular in form, but occurring 0.09 second after second sound in each cycle (infant 4 days old).

FIG. 7b.—Phonocardiogram of same infant aged 5 months, showing better defined (though still inaudible) third heart sound 0.09 second after second sound.

FIG. 10

FIG. 11a

FIG. 11b

FIG. 8a

FIG. 8b

FIG. 8a.—Phonocardiogram of infant 6 hours old, showing mid-systolic murmur.

FIG. 8b.—Phonocardiogram of normal boy aged 11 years, showing systolic murmur comparable in character to that shown in FIG. 8a.

FIG. 9a

FIG. 9b

FIG. 9a.—Phonocardiogram taken at intrascapular area in infant aged 2 weeks, showing crescendo systolic murmur and presystolic murmur.

FIG. 9b.—Phonocardiogram of same infant recorded at third left intercostal space. Shows systolic murmur and mid- and late diastolic murmur. Infant had coarctation of aorta with interventricular septal defect and patent ductus arteriosus.

FIG. 10.—Phonocardiogram of infant aged 5 weeks recorded at pulmonary area. It shows pansystolic murmur and short diminuendo diastolic murmur. This baby had a patent ductus arteriosus tied successfully at 7 months.

FIG. 12

FIG. 11a.—Phonocardiogram of infant aged 2 days, who died at 5½ weeks. It shows apparently normal first and second sounds, no obvious third heart sound, and a long-plateau systolic murmur.

FIG. 11b.—Phonocardiogram of same infant aged 5 weeks, now cyanosed and in heart failure. Systolic murmur is now mid-systolic in character. Post-mortem findings were of complete mitral atresia.

FIG. 12.—Phonocardiogram of a 14-month-old infant in congestive cardiac failure; the precise defect has not yet been determined. The tracing shows an ejection sound (X) and abnormally intense third heart sound. The character of the systolic murmur shown confirmed the clinical impression that it was not dissimilar to those heard in many normal infants. The same murmur was heard and recorded at the left sternal edge.

character of this murmur, that of the heart sounds, and the presence or absence of a diastolic murmur are important in deciding whether or not the heart is normal. From the present findings the characteristics of presumed functional systolic murmurs may be defined, but a murmur with apparently similar characteristics may occur in congenital heart disease or none may be audible. It is worth noting that no very loud, long, or high-pitched systolic murmurs were heard or recorded in the normal infants studied, nor any diastolic murmurs.

Foetal murmurs have been previously recorded on infants subsequently found to have congenital heart disease (Smith and Hervert, 1940; Smith, 1941; Menzies and Scott, 1955). The present findings show that murmurs may be recorded in the majority of foetuses near term, and may be audible by foetal stethoscope without a congenital defect being present.

Summary and Conclusions

A series of 230 full-term infants were examined daily from birth for a minimum of eight days, and observations made on sleeping heart rate, sounds, and murmurs. A quarter of this number were re-examined between the ages of 6 weeks and 6 months. Phonocardiograms were taken on an approximate quarter of the series both before and after birth, and also on a number of infants with known congenital heart disease. From these observations some normal auscultatory data in early infancy could be obtained.

The mean sleeping heart rate was tabulated, and showed a significant rise from the second to the eleventh day. All murmurs heard were systolic in timing, and their incidence increased with age, reaching 77% by the eighth day and nearly 90% at follow-up examination. The characteristics of these murmurs could be broadly defined, both clinically and phonocardiographically. It is suggested that the majority probably persist into childhood and are functional in nature.

Deviations from the expected normal may be detected clinically, but, because of the difficulties of auscultation, phonocardiography may be a particularly useful diagnostic aid in this age group.

The demonstration of systolic murmurs in the majority of foetal tracings implies that the chance observation of an intrauterine murmur does not necessarily imply that the infant has congenital heart disease.

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INCIDENCE OF LEUKAEMIA IN SINGAPORE, AND RARITY OF CHRONIC LYMPHOCYTIC LEUKAEMIA IN CHINESE

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The aetiology of human leukaemia is still largely obscure, and therefore variations in the incidence of leukaemia in different population groups are especially interesting because of their potential aetiological significance. The only Asian population for which reliable leukaemia mortality figures have previously been available is that of Japan, where the mortality from leukaemia in both sexes and in all age-groups is much less than that of countries in Europe and North America (World Health Organization, 1955). Several authors have also mentioned the clinical impression that chronic lymphocytic leukaemia is particularly uncommon in the tropics generally (Strong, 1944), in India (Majumdar and Chatterjee, 1953), in Japan and the indigenous population of North and South Africa (Witts, 1957), and in Singapore (Wells, 1958). The predominantly Chinese population of Singapore has had comprehensive and effective medical care since the end of the Japanese occupation, and we have analysed the incidence of leukaemia here during the ten-year period 1949–58.

Data and Material

We have examined all the Singapore death certificates and post-mortem reports for the 1949–58 period in which leukaemia or lymphosarcoma are mentioned as a diagnosis or cause of death. Over 95% of these certificates and reports refer to patients investigated at the Singapore General Hospital, in the University departments of medicine and clinical medicine, or in the paediatric unit. We have re-examined the diagnostic criteria of 129 patients with leukaemia attending the department of medicine in the 1949–58 period, many of whom were treated by one or other of us, and have also obtained additional clinical data on some of the patients who attended the paediatric unit. After correlation of all these data and elimination of duplicate and doubtful records, we have records of 253 cases of leukaemia and 23 of lymphosarcoma from the 1949–58 period.

Population figures have been obtained by extrapolation from the 1947 and 1957 Singapore Census reports and the Annual Reports of Singapore Births and Deaths.

Crude Leukaemia Mortality Rates

The number of deaths from leukaemia in Singapore in each of the 10 years 1949–58, together with the crude mortality rates, are given in Fig. 1. The figures for Chinese are given separately.

During the ten years under investigation there has been expansion of the Singapore Medical Services, with improved laboratory and diagnostic facilities, and at the same time the Chinese and other Asians in Singapore