Systolic blood pressure variation during the first 6 days of life

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Summary
1. Systolic blood pressure was measured by a Doppler ultrasound technique in twenty normal babies on 6 successive days after the day of delivery. In three babies blood pressure was recorded every 15 min for 24 h.
2. Systolic blood pressure during the first 6 days of life was 95 (SEM = 2) mmHg.
3. Systolic blood pressure increased on average by 2 mmHg/day, but increased most between the second and third days of life.
4. Systolic blood pressure was 11 mmHg higher when awake than when the babies were asleep.
5. There was marked within-baby variation in the systolic blood pressure of neonates, which could not be accounted for by age or recognizable changes in level of consciousness.

Key words: heart rate, neonate, wakefulness.

Introduction
The use of Doppler ultrasound allows accurate non-invasive measurements of systolic blood pressure in neonates (Elseed, Shinebourne & Joseph, 1973). In an attempt to assess the value of casual observations of blood pressure in neonates, we have employed this technique to study the variability of blood pressure in the first 6 days of life, and the relation-ship of blood pressure to age, level of consciousness, feeding and heart rate in individual babies.

Subjects and methods
The babies were clinically normal and were of full-term normal delivery after a normal pregnancy. The investigation was approved by the Ethical Committee of Queen Charlotte's Hospital, and the informed consent of mothers was obtained before babies were admitted to the study.

Two groups of babies were studied. The first group (6 day series) consisted of twenty babies. Their right upper limb systolic blood pressure was measured at the same time of day (about 11.00 hours) on 6 successive days after the day of delivery by the Doppler shift technique (Elseed et al., 1973). All measurements in this group were made by only one observer. A 5 cm cuff attached to a conventional sphygmomanometer was placed snugly around the upper limb above the elbow and the ultrasound probe (Parks Electronics Laboratory model no. 802. G.B. Distributors: Instrumentarium, Ltd) was placed over the brachial artery below the cuff, which was inflated to 200 mmHg. It was then deflated no faster than 6 mmHg/s and the cuff pressure at which continuous rhytmical Doppler sounds could be heard was taken as the systolic blood pressure. This technique gives accurate measurements of systolic blood pressure only (Elseed et al., 1973). On each day three measurements of blood pressure were made within 5 min. The time since previous feed and the method of feeding were noted. The

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level of consciousness was graded 1–4 (Prechtl & Beintema, 1964).

A second group (24 h series) of three 6-day-old infants was studied more intensively and continuously for a period of 24 h. Blood pressure was measured by one of two observers, using the techniques described above, except that the conventional sphygmomanometer was replaced by the ‘random zero’ sphygmomanometer (Wright & Dore, 1970). This instrument decreases observer bias since the true value selected for blood pressure is not known until a varying figure for the zero error has been subtracted. Three measurements of blood pressure and one of heart rate were made every 15 min unless the infant was crying or being fed. Heart rate was calculated by measurement of four successive R-R intervals from an electrocardiograph tracing recorded from adhesive chest electrodes.

All results are quoted as mean value ± SEM unless otherwise stated.

Results

We have analysed 102 of the 120 measurements made of upper limb blood pressure in twenty babies (6 day series); eighteen measurements taken while the babies were feeding or crying were discarded because of the extra variability which these factors introduced. The upper limb systolic blood pressure was 95 (SEM = 2) mmHg.

In order to investigate the relationship between blood pressure, baby age and level of consciousness, we performed three successive analyses of variance in which blood pressure (mean of three observations) was related first to individual constants for each baby and then to individual constants and a day constant (age) and finally to individual constants, day constant and an adjustment for level of consciousness.

Baby constant

We obtained a significant reduction in variance (Table 1) by fitting separate constants for each baby. This confirms that there was considerable variation in systolic blood pressure between babies throughout the 6 days of observation. Individual babies’ blood pressure, without correction for age or level of consciousness, when averaged over the 6 day measurement period, varied from 75 to 125 mmHg.

Age

Systolic blood pressure was significantly correlated with age and increased by an average of 2 mmHg/day. However, the relationship was far from linear (Fig. 1). Blood pressure increased most between days 2 and 3, and we achieved a better fit by fitting individual constants for each day (Table 1).

Level of consciousness

The level of consciousness was originally graded 1–4 (Prechtl & Beintema, 1964), the greatest increase in blood pressure being from levels 1 and 2 (asleep with eyes closed) to levels 3 and 4 (awake eyes open, but not crying). As there was little improvement in fit when individual levels of consciousness were used, we categorized babies as ‘awake’ or ‘asleep’. The age-corrected systolic blood pressure of babies when awake was 11 ± 3 mmHg higher than the systolic blood pressure of babies when asleep.

Table 1. Analyses of variance of systolic blood pressure

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of squared deviations</th>
<th>Degrees of freedom</th>
<th>Residual mean square</th>
<th>Reduction in variance (%) of total</th>
<th>F ratio</th>
<th>Significance (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>31313</td>
<td>101</td>
<td>310</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual baby constants</td>
<td>13516</td>
<td>82</td>
<td>165</td>
<td>47</td>
<td>$F_{1,9,82} = 5.7$</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Age (day no.)</td>
<td>11300</td>
<td>77</td>
<td>147</td>
<td>6</td>
<td>$F_{3,77} = 3.2$</td>
<td>$&lt;0.05$</td>
</tr>
<tr>
<td>Level of consciousness</td>
<td>9676</td>
<td>76</td>
<td>127</td>
<td>6</td>
<td>$F_{1,76} = 12.8$</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>
Blood pressure variation in neonates

The reduction in the variance of systolic blood pressure achieved by fitting individual baby constants, day number and level of consciousness is shown in Table 1.

Other factors

Blood pressure was not related to time since previous feed, method of feeding (breast/bottle) or limb size.

Within-occasion variance

The mean of three measurements of blood pressure was taken on each of the 102 occasions that were subsequently analysed. The within-occasion variance was 15. The SD of repeated measurements of blood pressure on the same occasion was therefore 3.9 mmHg.

24 h series

The mean of the three measurements of blood pressure on each occasion was taken and the results in one baby are shown in Fig. 2.

The between-occasion variances for the babies were 53, 85 and 106, with a mean value of 81.

There was no significant relationship between blood pressure and heart rate.

The within-occasion variance in blood pressure for each observer of the three babies varied from 14 to 29, with a mean of 20.5. There was no systematic difference in within-occasion variance between the two observers, nor was there any significant difference in mean blood pressure recorded by the two observers.

Discussion

Previous estimates of blood pressure in neonates have either been made from intra-arterial readings

![Graph: Blood pressure variation in neonates](image)

Fig. 1. Change in mean values of systolic blood pressure (±SEM) for the first 6 days of life, corrected for between-baby variation and level of consciousness with the day constants from equation 1.

![Graph: Systolic blood pressure of a 4-day-old baby recorded every 15 min except when feeding or crying](image)

Fig. 2. Systolic blood pressure of a 4-day-old baby recorded every 15 min except when feeding or crying. ○, Measurements taken when the baby's eyes were open (awake); ●, measurements made when the baby's eyes were closed (asleep). Note the considerable variability in blood pressure.
Hamilton, Kitterman, Phibbs & Tooley, 1969; Mondanlou, Yeh, Siassi & Hon, 1974; Woodbury, Robinow & Hamilton, 1938; Moss, Duffie & Emmanoulides, 1963) or from indirect techniques such as oscillometry (Gupta & Scopes, 1965; Contis & Lind, 1963; Nelson, 1968), conventional sphygmomanometry (Long, Dunlop & Holland, 1971), palpation (Holland & Young, 1956; Woodbury et al., 1938), impedance plethysmography (Schaffer, 1955) or the flush technique (Moss, Liebling & Adams, 1958).

We found that the mean systolic blood pressure during the first 6 days of life was 95 mmHg, 10–15 mmHg higher than has previously been reported in the majority of the above-mentioned studies. The difference between our values and those obtained from intra-arterial studies probably arises from the different experimental conditions. The accuracy of the Doppler technique has been assessed in our department by comparison with simultaneous intra-arterial measurements (Elseed et al., 1973). The mean difference of 1.5 mmHg between intra-arterial and Doppler measurements was not significantly greater than zero. It would therefore appear that the values obtained by other indirect techniques were either too low, or that the babies’ levels of consciousness were different.

We found that the mean systolic blood pressure of babies asleep (eyes closed) was 11 mmHg lower than that of babies awake (eyes open). This effect has been noted previously in continuous oscillometric recordings of blood pressure (Gupta & Scopes, 1965). However, Long et al. (1971) did not believe there was any relationship between emotional state and blood pressure. This was partly because the majority of their infants were ‘placid’ but also because they did not find any correlation between blood pressure and heart rate. We also failed to find any relationship between blood pressure and heart rate, and suggest that the effect of emotion is independent of heart rate in the neonatal period.

We found a mean rise in blood pressure of 2 mmHg/day during the first 6 days of life. Similar increases in blood pressure have been observed between days 2 and 7 by Contis & Lind (1963). However, these workers did not find the sharp increase in blood pressure between days 2 and 3 which we noted. We do not know why blood pressure increased most at this time. It does not appear to result from the babies being awake for longer as they grow older, since it occurred independently of any changes in the level of consciousness.

In an attempt to partition the considerable variance in systolic blood pressure that we observed, we have estimated the reduction in variability achieved by fitting constants for each individual baby for day number, and for the level of consciousness (see Table 1). We were not able to analyse all the data in a single analysis of variance, because the experiment did not have a balanced design. Measurements were not available for each baby on every day of the study because measurements originally made while the babies were feeding were discarded. Furthermore, we measured the blood pressure at only one level of consciousness on each day. The variance of the 102 measurements of blood pressure was reduced by 47% by fitting individual baby constants. A further reduction in variance of 6% was achieved by fitting the day number, and another 6% by the level of consciousness. After fitting individual constants and day number, the residual variance of repeated measurements of the blood pressure on the same day in the same baby was approximately 12 mmHg. This was confirmed in the 24 h series, where the mean between-occasion variance was 81 (so = 9) mmHg.

The random-zero sphygmomanometer reduces observer bias and disguises the effect of terminal digit preference. Reduction of observer bias in this way only increased within-occasion variance in blood pressure from 15 in the 6 day series in which a conventional sphygmomanometer was used, to 20 in the 24 h series in which the random-zero sphygmomanometer was used. This increase is small compared with the residual variance in the 6 day series. Observer bias thus appears to cause a small effect, when compared with the high overall variability. It is possible that different observers may cause different levels of arousal during blood pressure measurements. If this did occur in our study it did not affect the measured blood pressure since there was no significant difference in mean blood pressures recorded by the two observers in the 24 h series.

In a comparable study in adults, Armitage & Rose (1966) found a residual variance of 18 of systolic blood pressure and a within-occasion variance of 4. These variances are much less than we found, suggesting that the systolic blood pressure of neonates is more variable than that of adults. Even though it was possible to reduce within-baby variance by allowing for the level of consciousness and for the baby’s age, the so of repeated measure-
Blood pressure variation in neonates

Measurements of blood pressure on the same day was still between 9 and 12 mmHg.

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References


