Pulse wave patterns in patent ductus arteriosus

B P W LUNDELL

Department of Paediatrics, Karolinska Hospital, Stockholm, Sweden

SUMMARY  Pulse wave patterns were analysed in 10 term and 10 preterm infants with patent ductus arteriosus (PDA) and in 2 matched control groups. A non-invasive technique was used to record the pulse waves from the axillary artery. The pulsatile ratio was calculated as the quotient between the amplitude of the incisural notch and the peak of the pulse wave above the end diastolic baseline. The pulsatile ratio was considerably lower in preterm and term infants with PDA compared with the ratio after closure of the ductus and the ratio in control infants. A pulsatile ratio less than 0.50 indicates the presence of a large PDA whereas a ratio over 0.55 is normal. The technique may be used to document and evaluate arterial pulse wave patterns and may be a useful diagnostic tool.

Diagnosis of patent ductus arteriosus (PDA) is usually made by a combination of clinical observations and non-invasive examinations. Although different ultrasound techniques are used, it is still the clinical symptoms and findings that initiate further examinations. The most frequent finding second to the murmur is the presence of bounding arterial pulses. A wide pulse pressure indicates that the systemic arteries communicate with a low resistance vascular bed and that an aortopulmonary communication exists. Bounding pulses are easily ascertained by the experienced paediatrician. But although their presence is regarded as a typical and sensitive clinical finding, recording and objective evaluation are not made. We evaluated a non-invasive technique for arterial pulse wave analysis that was performed in preterm and term infants with PDA and in 2 matched control groups.

Patients and methods

Two groups of 10 infants with PDA and 2 matched control groups were studied. The characteristics of the groups are shown in Tables 1 and 2. The infants with PDA were examined before surgery, indomethacin, or anticongestive treatment; after ductal closure; and at follow up approximately 1 week after ductal closure. The control infants were studied once.

Preterm infants with PDA. The preterm infants with PDA were all symptomatic and in need of ventilatory support at diagnosis, which was made on clinical grounds. All had systolic murmurs and increased precordial activity. In most the radial artery pulse could be palpated in spite of the very low birthweight. Surgical closure of the ductus was made in 2 infants, indomethacin was given to induce closure in 2, and spontaneous closure occurred in the remaining 6. Treatment also included fluid restriction, diuretics, and digoxin.

Term infants with PDA. All the term infants in this group had had an uneventful neonatal period. They were referred to the cardiologist because of a heart murmur. Slight tachypnoea and poor weight gain were reported in a few, but otherwise they were considered asymptomatic. All these infants had a typical continuous murmur and the pulses were usually reported as bounding. In 4 infants the

<table>
<thead>
<tr>
<th>Group</th>
<th>Birthweight Median (range) (g)</th>
<th>Gestational age Median (range) (weeks)</th>
<th>Postnatal age at start of study Median (range) (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDA (n=10)</td>
<td>1000 (770-1750)</td>
<td>28 (26-32)</td>
<td>20 (6-36)</td>
</tr>
<tr>
<td>Control (n=10)</td>
<td>1015 (820-1880)</td>
<td>29 (26-34)</td>
<td>23 (8-48)</td>
</tr>
</tbody>
</table>

Table 2 Characteristics of the term infant groups

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Term infants with PDA. All the term infants in this group had had an uneventful neonatal period. They were referred to the cardiologist because of a heart murmur. Slight tachypnoea and poor weight gain were reported in a few, but otherwise they were considered asymptomatic. All these infants had a typical continuous murmur and the pulses were usually reported as bounding. In 4 infants the
diagnosis was confirmed by catheterisation. No drugs were given and all the infants underwent surgical ligation of the ductus. No additional cardiovascular malformation was found at follow up.

Control groups. The control infants were matched with the PDA infants for birthweight, gestational age, and postnatal age at the examination. They had no cardiorespiratory problems and no drugs were used except iron, vitamins, and antibiotics in the preterm controls.

Techniques. Electrocardiogram, arterial pulsations, and blood pressure were recorded simultaneously. The right axillary artery pulse was recorded by a small soft plastic funnel connected to a piezoelectric pulse transducer (Siemens Elema 860) with a time constant of 7 s and a flat frequency response between 0.1 and 100 Hz. The signal was amplified and recorded with an ink jet writer at 100 mm/s paper speed. Only tracings with distinct onset of upstroke, peak, and incisural notch were measured (Fig. 1). A baseline was formed by connecting the end diastolic points. The amplitude of the incisural notch above the baseline was compared with that of the peak of the pulse wave. The pulsatile ratio was averaged from 5 consecutive beats. Systemic blood pressure was measured by cuff and Doppler technique (Roche Arteriosonde 1020).

Statistical analysis. A 2 way classification and analysis of variance and regression were performed. Preplanned comparisons between the groups were made as orthogonal contrasts.

Informed parental consent and approval by the local ethical committee was obtained.

![Fig. 1](image)

**Fig. 1** Electrocardiogram and axillary artery pulse wave.

The pulsatile ratio is calculated as the quotient between the amplitude of the incisural notch (B) and the peak of the pulse wave above the end diastolic baseline (A).

### Table 3 Heart rate and blood pressure

<table>
<thead>
<tr>
<th>Group</th>
<th>Heart rate Mean (SD) (beats ± min⁻¹)</th>
<th>Blood pressure Mean (SD) (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm PDA</td>
<td>156 (15)</td>
<td>54 (6)/25 (8)</td>
</tr>
<tr>
<td>Preterm control</td>
<td>138 (19)</td>
<td>60 (11)/39 (12)</td>
</tr>
<tr>
<td>Term PDA</td>
<td>138 (17)</td>
<td>89 (9)/45 (12)</td>
</tr>
<tr>
<td>Term control</td>
<td>112 (12)</td>
<td>87 (8)/59 (7)</td>
</tr>
</tbody>
</table>

### Results

High quality pulse tracings were easy to obtain irrespective of the infants' weight, age, or clinical condition. The axillary pulse recordings were not influenced by breathing, sucking, or minor body movements. Data on heart rate and blood pressure are shown in Table 3. A significantly higher heart rate was recorded in the 2 PDA groups compared with the controls (P < 0.01). Diastolic blood pressure was significantly lower in preterm PDA infants (P < 0.01) and in term PDA infants (P < 0.05) compared with the respective control group. Systolic pressure, however, was similar in the PDA and the matched control groups. Ductal closure reduced heart rate and increased diastolic blood pressure. The percentage increase in pulsatile ratio was significantly higher in the ductus group compared to the control groups (P < 0.05).

![Fig. 2](image)

**Fig. 2** Individual pulsatile ratio values in the control groups and in the patent ductus arteriosus (PDA) groups before and after ductal closure.
The pulsatile ratio

<table>
<thead>
<tr>
<th>Group</th>
<th>Start of study Mean (SD)</th>
<th>After ductal closure Mean (SD)</th>
<th>Follow up Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm PDA</td>
<td>0.45 (0.05)</td>
<td>0.65 (0.06)</td>
<td>0.65 (0.05)</td>
</tr>
<tr>
<td>Preterm control</td>
<td>0.60 (0.05)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Term PDA</td>
<td>0.47 (0.03)</td>
<td>0.64 (0.06)</td>
<td>0.65 (0.06)</td>
</tr>
<tr>
<td>Term control</td>
<td>0.67 (0.04)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

pressure. No significant difference in heart rate or blood pressure persisted after ductal closure in the PDA groups compared with the matched controls.

The pulsatile ratio was significantly lower (P<0.001) in both PDA groups compared with controls (Table 4) but after ductal closure this became normal (Fig. 2). A weak correlation between diastolic blood pressure and pulsatile ratio was present (r=0.74, P<0.01). The pulsatile ratio was not influenced by minor beat to beat heart rate variations. The mean pulsatile ratio variation coefficient for all infants was 7.1%.

Discussion

Symptomatic PDA is not an unusual problem in infants, particularly among infants of very low birthweight. Although various non-invasive techniques have become important diagnostic tools, there are still several pitfalls in its diagnosis.

The finding of bounding pulses has 2 implications—a wide aortapulmonary communication is present and the pulmonary vascular resistance is low. Both are important factors for the development of a large ductal shunt. A high left ventricular output maintains systolic blood pressure in the systemic arteries, whereas the diastolic pressure is low because of ductal steal of systemic blood during diastole. The antegrade blood flow during diastole is reduced and may even be reversed. This has been recorded in different systemic arteries by the Doppler technique. Palpation of bounding pulses, however, yields no information about magnitude or direction of blood flow in the artery. The pulse wave recordings used in the present study reflected only the pulsatile pressure variations and the pulsatile ratio should not be compared with the pulsatile index obtained in studies of blood flow velocity. The signal from a pulse transducer cannot be accurately calibrated to give absolute pressure or a true zero line because the pressure with which the recording funnel is pressed over the artery varies. Therefore, a baseline is constructed and relative changes in the pulse wave amplitude are measured. A low pulsatile ratio implies a collapsing pulse and should correspond to the bounding sensation when the pulse is palpated. The pulsatile ratio is also correlated with the diastolic blood pressure (r=0.74). Non-invasive measurements of diastolic blood pressure are, however, sometimes unreliable and cannot be used as a diagnostic measurement.

In the present study the pulsatile ratio was less than 0.50 in 19 of 20 infants with PDA and increased after ductal closure to more than 0.55 in 19 of 20. In the control groups 18 of 20 infants had a pulsatratio more than 0.55 (Fig. 2). A pulsatile ratio less than 0.50 may indicate a large ductal shunt whereas a ratio over 0.55 may be regarded as normal. The pulsatile ratio was not correlated with gestational age, weight, or postnatal age of the infant.

It is concluded that the present non-invasive technique may be used to document and evaluate the arterial pulse wave. By analysing the pulse wave pattern a qualitative measure was obtained. The pulsatile ratio may be useful in the diagnosis of PDA in very low birthweight preterm infants and in older infants.

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References

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Correspondence to Dr Bo Lundell, Division of Néonatologie, Department of Paediatrics, School of Medicine, Vanderbilt University, Nashville, Tennessee 37232, USA.

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Reprints: B P W Lundell, MD, Department of Paediatrics, Karolinska Hospital, S-104 01 Stockholm, Sweden.

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**Erratum**

Brooke OG. Supplementary vitamin D. *Arch Dis Child* 1983;58:574.

Alphacalcidol should read alfacalcidol.