Doppler Flow Characteristics in the Main Pulmonary Artery and the LA/Ao Ratio Before and After Ductal Closure in Healthy Newborns

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SUMMARY. Echo-Doppler (ED) techniques were used to estimate the time of closure of the ductus arteriosus in 30 normal neonates. We found that after birth there was a left-to-right (L-R) shunt through the ductus, which disappeared within 14 hours in 50% of the neonates investigated. Furthermore, patency of the ductus was not associated with a murmur. After closure of the ductus there was a significant diminution of the echocardiographically determined left atrium/aortic (LA/Ao) ratio, which was used as a measure of the L-R shunt.

KEY WORDS: Echo-Doppler — Patent ductus arteriosus — Normal neonate

Part 1. Doppler Flow Characteristics

Up to now, determining the exact time of closure of the ductus arteriosus has been very difficult. So far data have been obtained from autopsy [7, 14], heart catheterization [16, 19], dye curve [18], and auscultation [6]. Closure times of the ductus, estimated by these techniques, vary from 10 hours to several weeks after birth. Hence the value of these data as a reference for normal neonates is limited. Using echo-Doppler (ED) techniques a patent ductus arteriosus (PDA) with left-to-right (L-R) shunt can be diagnosed noninvasively by changes in the flow pattern in the main pulmonary artery (MPA) [22]. From the disappearance of these changes in the flow pattern the closure time of the ductus arteriosus in healthy normal newborns can be estimated.

Methods

In the ED investigation a 5-MHz sector echocardiograph was used in combination with a range gated pulsed Doppler system [3, 4] (ATL Mark V). With sector echocardiography, a two-dimensional longitudinal section of the MPA was obtained from a parasternal position so that the pulmonary valve was visible. Within the MPA an area of 2–4 mm, the sample volume (SV), was chosen, in which velocity and direction of the erythrocytes were determined with respect to the transducer position (Figs. 1A and 2D). In a normal flow pattern there is a flow away from the transducer in systole (forward flow) and no flow in diastole. Patency of the ductus arteriosus can cause L-R shunt. If the pressure in the MPA is always lower than in the aorta there is a continuous L-R shunt. In that case a continuous backward flow can be found in the MPA near or in the opening of the ductus arteriosus (Fig. 2A) and further on in the MPA, depending on the position of the sample volume, a pandiastolic backward or forward flow (Figs. 1B, 2B and 2C).

The systolic backward flow is sometimes difficult to find because of pulmonary overlap of the opening of the PDA high in the MPA. In most cases no clear systolic backward flow is found further on in the MPA due to the systolic forward flow from blood going from right ventricle into the MPA. This can lead to systolic turbulence. The diastolic flow pattern is more easily discernible. During diastole there is a blood flow from the aorta through the ductus arteriosus into the MPA (diastolic backward flow), and as the pulmonary valves are closed in diastole this blood must also find a way out through the MPA (diastolic forward flow). This gives the flow pattern as indicated in Figs. 1B, 2B, and 2C. We also found these flow patterns in older children with proven PDA with L-R shunt during heart catheterization.

Because of the difficulty of picking up the systolic backward flow we used a pandiastolic backward and forward flow as a criterion for a PDA with L-R shunt. When a pandiastolic backward flow is found, there is, according to Stevenson [22], a

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Fig. 1A. Longitudinal section of the pulmonary artery and descending aorta with flow directions (arrows). The dot on the line indicates the sample volume. Below, the electrocardiogram and the velocity registration as measured in the SV in the case of a normal flow pattern are schematically given. B. Same section as in A in the case of a patent ductus arteriosus. The arrows indicate the flow directions in diastole. With the SV in position I we expect a diastolic backward flow and in position II a diastolic forward flow, as indicated below.

PDA with L-R shunt and a low pulmonary artery pressure. Another reason to use this criterion is that the measurement of diastolic flow avoids "aliasing (frequency ambiguity)" as described by Peronneau [17] and others. Aliasing is inherent in the pulsed Doppler system and occurs when blood velocity exceeds some maximum value. The maximum velocities that can be recorded by our equipment are 148.2 cm/sec at 3 cm, 98.7 cm/sec at 5 cm and 59.3 cm/sec at 9 cm, where the velocity vector is in line with the beam of ultrasound. When the velocity vector exceeds these limits, aliasing results, and the Doppler signal may appear turbulent or reverse its direction. This is shown in Fig. 3. Aliasing occurs especially in early systole when the blood velocity reaches its maximum. With our instrument adjusted to 5 cm we did not normally have aliasing in systole. By looking only to the diastolic component of the flow pattern we avoided the problem of aliasing as there is normally no blood velocity in diastole. With the ductus open we are not able to detect a R-L shunt by our method, as in this case the flow directions in the MPA are the same as in a normal situation.

Material

In 30 normal healthy neonates with a gestational age of 37–42 weeks (median 39 weeks) and a birth weight of 2710–3880 g (median 3280 g) four ED examinations were carried out. In the same session an echo examination was performed as a routine (see Part 2). The consent of the parents was obtained. The first examination was carried out within 18 hours after birth; the second on the second day, the third on the third day, and the last...