

Echocardiographic identification of aorta and main pulmonary artery in complete transposition¹

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SUMMARY No completely reliable echocardiographic technique has been described for the separate identification of the aorta and main pulmonary artery in complete transposition of the great arteries. A mechanical wide-angle (60°) sector scanner has been applied to this problem in 17 infants and young children, including 8 newborns before angiocardiology. In all patients a longitudinal scan (sagittal section) identified the main pulmonary artery by its directly posterior course immediately beyond the pulmonary valve, and the aorta by its retrosternal course upwards before turning posteriorly above the main pulmonary artery. In addition, a high transverse scan showed the precise spatial relation of the great arteries, and, in 11 of the 17, tilting the scanning plane upwards showed branching of the main pulmonary artery. In 8 infants examined with M-mode echocardiography, an upward sweep from the pulmonary valve showed abrupt termination of the echo from the posterior wall coinciding with the posterior arching of the main pulmonary artery.

The echocardiographic diagnosis of complete transposition of the great arteries has been based largely upon the demonstration of an abnormal relation of the semilunar valves (Dillon *et al.*, 1973; Gramiak *et al.*, 1973) or of the great artery origins (King *et al.*, 1973; Sahn *et al.*, 1974; Henry *et al.*, 1975; Maron *et al.*, 1975). However, the relation of the great arteries can vary considerably in the rarer transposition complexes (Van Praagh *et al.*, 1971) and in other forms of complicated congenital heart disease. Therefore, for an accurate assessment of great artery anatomy it is essential that the aorta and pulmonary artery should be separately identified.

We report on the use of a mechanical 60° sector scanner to identify the aorta and pulmonary artery in infants with complete transposition of the great arteries and, arising from our findings, a preliminary study of M-mode echocardiography in making this distinction.

Methods

Studies were made on 18 infants with normally related great arteries: 9 were less than 10 days old

and 9 were between 1 month and 1 year. Their weights ranged from 2.2 kg to 10.3 kg. All were examined with two-dimensional echocardiography and in all 9 of the newborns and in 6 older infants an M-mode recording was made as a sweep from the anterior mitral leaflet to the aortic valve was continued upwards to follow the ascending aorta as far headwards as possible. In addition, 17 infants and children with complete transposition of the great arteries were studied; the examination was carried out before cardiac catheterisation and angiocardiology in 8 newborn infants less than 14 days old, and after angiocardiology in 9 children between 2 weeks and 20 months old. Their weights ranged from 2.7 kg to 8.7 kg. Examination with M-mode echocardiography was carried out after angiocardiology on 7 of these, whose ages ranged from 8 days to 20 months, and before two-dimensional echocardiography or angiocardiology on one 2-day-old baby.

The real-time two-dimensional scanning equipment was a hand-held mechanical 60° sector scanner fitted with a 5 MHz 6 mm transducer focused for optimum performance in the range 20 to 40 mm (Shaw *et al.*, 1976; Houston *et al.*, 1977b). The oscillating transducer is ultrasonically coupled to the patient through an oil-filled cell which, while separating the patient from the movement of the transducer, maintains ultrasonic contact and avoids

¹Supported in part by a research grant from the Equipment Research Committee of the Chief Scientist's Organisation of the Scottish Home and Health Department.

discomfort. The scanner and interface unit were used in conjunction with a Nuclear Enterprise Diasonograph (NE 4200) fitted with a cardiac module. The M-mode recordings were obtained on a fiberoptic recorder (NE 4105) after stopping the transducer in an appropriate position or with a separate hand-held transducer.

The two-dimensional scanning planes employed were longitudinal and high transverse; the technique for obtaining these has been described elsewhere (Houston *et al.*, 1977b). A longitudinal view was obtained through the left ventricle to include the ventricular septum, the mitral valve, and the semilunar valve continuous with it; the scanner was then tilted or moved superiorly to show the supra-valvar part of the great artery arising from the left ventricle. A high transverse view was then obtained and adjusted to show either the normal crescentic right ventricular outflow and main pulmonary artery crossing the aorta, or the two circular spaces with central cusp echoes in diastole characteristic of the parallel great arteries in complete transposition of the great arteries. In the patients with complete transposition of the great arteries the scanning plane was at this point tilted towards the head in an attempt to show branching of the pulmonary artery (Houston *et al.*, 1977a). The plane was then adjusted to provide a longitudinal view of the supra-valvar aorta. Still frames of the transverse view from patients with complete transposition of the great arteries were used to assess the relation of the great arteries and to compare their diameters at valve level.

M-mode echocardiograms of the supra-valvar portion of the great artery arising from the left ventricle were obtained by continuing a conventional sweep from the mitral to the semilunar valve upwards to follow the great artery as far headwards as possible.

Results

TWO-DIMENSIONAL ECHOCARDIOGRAPHY

Normally related great arteries

In the infants with normally related great arteries, the longitudinal view showed that the aorta followed a long course upwards approximately parallel to the sternum (Fig. 1). The transverse view showed the aorta in cross-section with the right ventricular outflow crossing in front of it and the main pulmonary artery to its left (Fig. 2).

Complete transposition of the great arteries

In all 17 patients with complete transposition of the great arteries the longitudinal view showed the

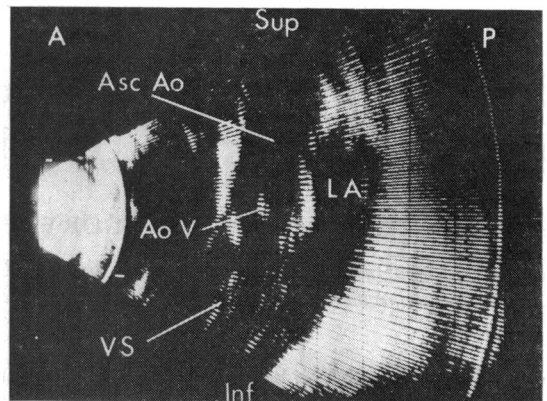


Fig. 1 *Electrocardiogram-triggered diastolic longitudinal view from a 2.8 kg infant with normally related great arteries, showing the ascending aorta. The marker arcs are 5 cm apart. A, anterior; P, posterior; Sup, superior; Inf, inferior; Asc Ao, ascending aorta; LA, left atrium; AoV, aortic valve cusps; VS, ventricular septum.*

artery arising from the left ventricle to turn posteriorly almost immediately beyond the valve (Fig. 3), thus allowing its identification as the main pulmonary artery.

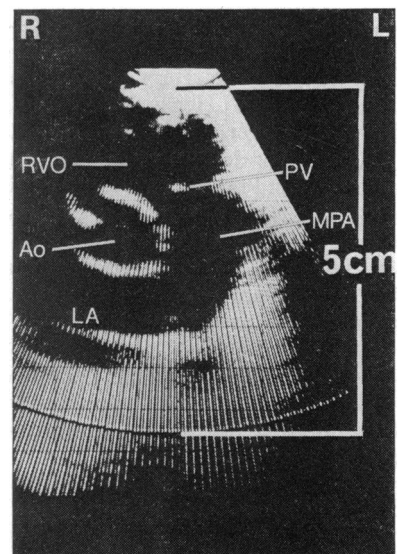


Fig. 2 *Electrocardiogram-triggered diastolic transverse view from the infant in Fig. 1. The right ventricular outflow crosses anteriorly to the aortic root (shown in cross section) and turns posteriorly as the main pulmonary artery. R, right; L, left; RVO, right ventricular outflow; PV, pulmonary valve cusps; MPA, main pulmonary artery; Ao, aorta; LA, left atrium.*

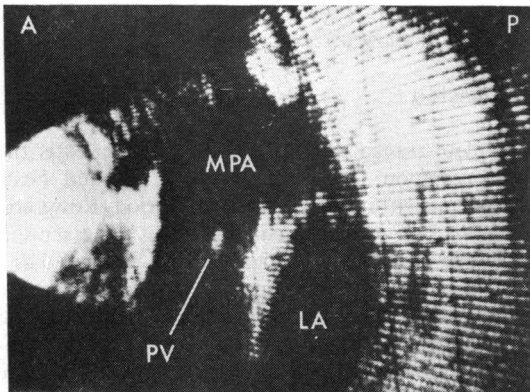


Fig. 3 Video-recorded longitudinal view from 13-day-old infant with complete transposition of the great arteries. The main pulmonary artery rises from the left ventricle and turns posteriorly immediately above the valve cusps. Abbreviations as in Fig. 1 and 2.

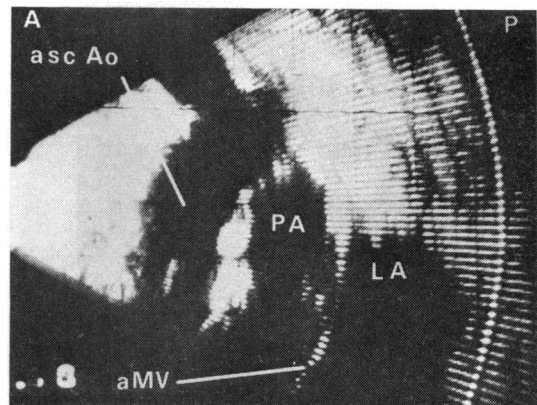


Fig. 4 Video-recorded longitudinal view from a 10-day-old infant with complete transposition of the great arteries. The anterior aorta turns posteriorly above the main pulmonary artery which is sectioned obliquely. The relations of the great arterial roots are shown in Fig. 5a. PA, main pulmonary artery; aMV, anterior mitral valve leaflet; other abbreviations as in Fig. 1.

The other great artery, arising from the right ventricle, was seen to have a longer upward course confirming that this was the aorta (Fig. 4). Both great arteries could be clearly shown in a single longitudinal view only in those patients with anterior-posterior great arteries. Transverse views in all patients showed the origins of the great arteries as two circles with central cusp echoes in diastole. The relation of the arteries determined from this view corresponded with that found at angiocardio-graphy; in 13 the aorta was anterior and to the right

of the main pulmonary artery (Fig. 5a), in 3 directly anterior (Fig. 5b), and in 1 side-by-side to the right (Fig. 5c). In 11 patients branching of the main pulmonary artery (Fig. 6) was shown by tilting or edging the scanning plane upwards. Comparison of the diameters of the arteries at valve level showed that in 4 the great arteries were of the same size, that in 9 the pulmonary artery was larger than the aorta, and that in 4 it was smaller.

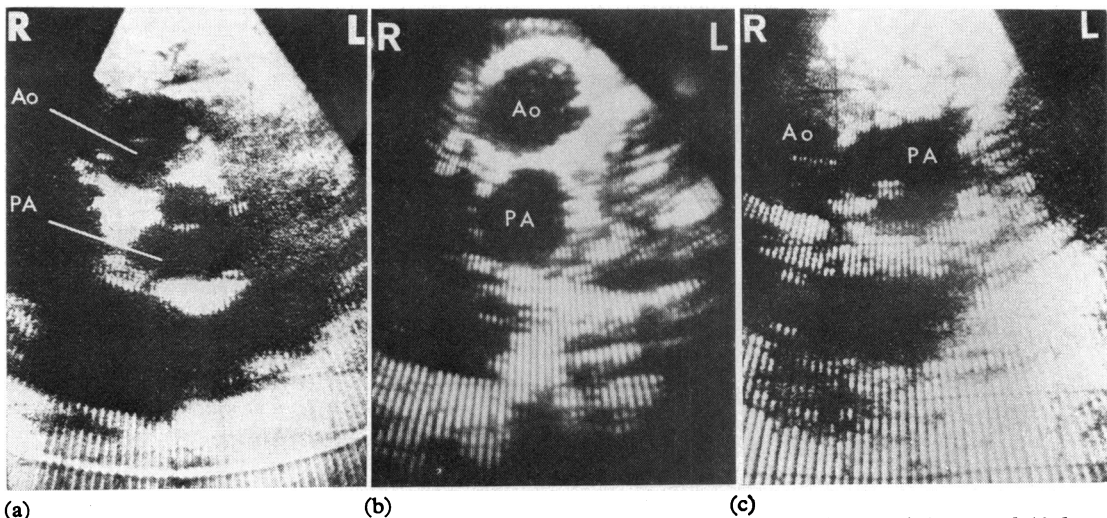


Fig. 5 Video-recorded high transverse views in complete transposition of the great arteries from infants aged 10 days, 11 months, and 13 days, respectively. (a) The aorta lies anterior and to the right of the main pulmonary artery; (b) the aorta lies directly anterior to the main pulmonary artery; and (c) the great arteries lie side by side. Abbreviations as in Fig. 2 and 4.

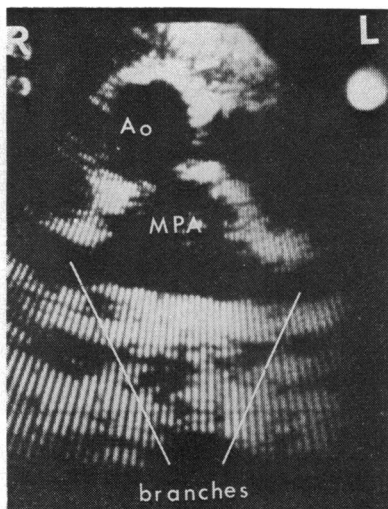


Fig. 6 Video-recorded high transverse view from the infant in Fig. 5b, with the scanning plane tilted upwards from position in Fig. 5b to show branching of the pulmonary artery. Abbreviations as in Fig. 2.

M-MODE ECHOCARDIOGRAPHY

The M-mode sweep upwards from the aortic valve in the 15 normal subjects showed the upwards continuation of both the anterior and the posterior walls of the aorta. In the 8 patients with complete transposition of the great arteries in whom an M-mode recording was made, just above the point at which the pulmonary valve cusp echoes disappeared, the linear echo from the posterior wall abruptly termi-

nated as it became the posteroinferior wall when the main pulmonary artery turned backwards (Fig. 7).

Discussion

Complete transposition of the great arteries is the most common form of cyanotic congenital heart disease presenting in the neonatal period (Rowe and Mehrizi, 1968) and immediate diagnosis is essential. In recent years echocardiography has been used as a noninvasive technique for the assessment of the cyanotic newborn infant (Godman *et al.*, 1974) and criteria for the echocardiographic diagnosis of complete transposition of the great arteries have emerged. These have been based largely on the demonstration of an abnormal relation of the semi-lunar valves with M-mode echocardiography (Dillon *et al.*, 1973; Gramiak *et al.*, 1973) or of the origins of the great arteries with electrocardiogram gated B-scanning (King *et al.*, 1973) or real-time two-dimensional systems (Sahn *et al.*, 1974; Henry *et al.*, 1975; Maron *et al.*, 1975). These techniques do not identify the great arteries individually but distinguish the aorta (or its valve) by its anterior right position relative to the pulmonary artery. But in 21 per cent of cases of complete transposition of the great arteries this relation does not hold (Nadas and Fyler, 1972). Attempts have been made to distinguish the great arteries with M-mode echocardiography by comparing systolic time intervals (Solinger *et al.*, 1974; Fouron *et al.*, 1976) or the outside diameters of the great artery roots (Solinger *et al.*, 1974) or, most recently, by using contrast echocardiography (Mortera *et al.*, 1977). Measurement

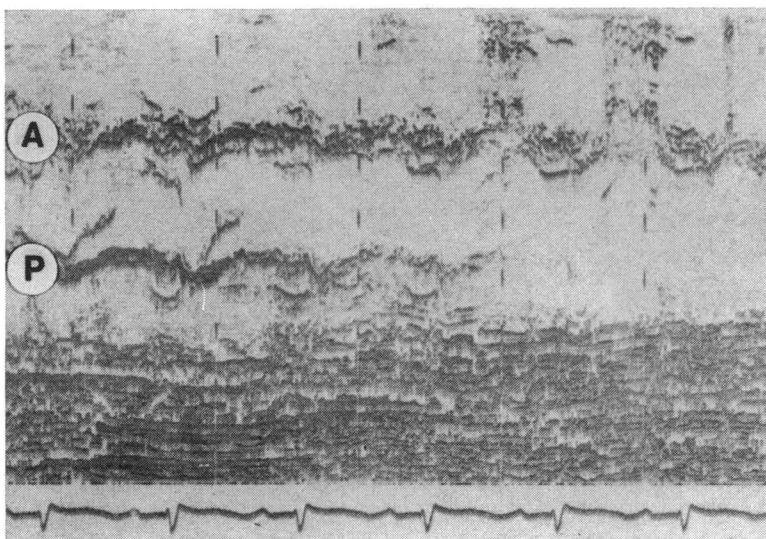


Fig. 7 M-mode sweep upwards from the pulmonary valve in a 5-month-old infant. The upward continuation of the anterior wall (A) is seen but the posterior wall (P) terminates abruptly at the level at which it turns posteriorly.

of electromechanical systole, ventricular ejection times, and pre-ejection periods allows the great arteries to be differentiated, but only when the pulmonary vascular resistance is low (Solinger *et al.*, 1974; Fouron *et al.*, 1976). Though the outside diameter of the pulmonary artery root has been reported to be larger than that of the aortic root in normal infants (Solinger *et al.*, 1973; Hagan *et al.*, 1973), this observation is likely to be of little practical value in differentiating the great arteries in complete transposition of the great arteries, where in those with no ventricular septal defect or pulmonary stenosis Shaher (1973) found them to be equal in 54 per cent. Mortera *et al.* (1977) used contrast echocardiography with injection into a systemic vein and a suprasternal approach to show both great arteries simultaneously with M-mode echocardiography. With this approach the artery nearer the probe is the aorta and in patients with an intact ventricular septum and complete transposition of the great arteries this was shown to opacify more intensely, suggesting that it arose from the right ventricle. This technique was considered to be ineffective when there was a large ventricular septal defect.

Two-dimensional echocardiography, with a transverse scan, can show the parallel great arteries characteristic of the transposition complexes. Furthermore, Sahn *et al.* (1974) suggested that in a longitudinal scan the long retrosternal course of the aorta might allow it to be recognised, but the pulmonary artery was not positively identified. In some cases the pulmonary artery can be identified by its branching (Houston *et al.*, 1977a) but in almost one-third of our cases this could not be convincingly shown for the purpose of precise diagnosis, and a more universally applicable finding was still required. Using a mechanical sector scanner we have been able to differentiate the aorta from the main pulmonary artery in longitudinal scans in all 17 patients with complete transposition of the great arteries. In accord with the suggestion of Sahn *et al.* (1974), the long retrosternal course of the aorta has been shown, but this course is subject to variation. To prove that this artery is the aorta it should be shown to turn posteriorly at a level above the main pulmonary artery, which we can now independently identify by its posterior course immediately beyond the pulmonary valve. Thus two-dimensional echocardiography provides a reliable visual recognition of the great arteries in complete transposition of the great arteries. Though this study has included only patients with complete transposition of the great arteries, we believe the method to be applicable to the identification of the great arteries in other complex forms of congenital heart disease. In the new-

born infants with complete transposition of the great arteries examined before cardiac catheterisation and angiography, the diagnosis was reached and the anatomy of the proximal great arteries correctly determined by echocardiography. Demonstration of the posterior course of the main pulmonary artery arising from the left ventricle can allow the diagnosis to be made in less than 2 minutes.

The results of the study with two-dimensional echocardiography suggested that it might be possible to recognise the posterior sweep of the main pulmonary artery with M-mode echocardiography. In the 8 patients upward angulation of the transducer from the pulmonary valve did indeed show apparent widening of the vessel, corresponding to the posteriorly directed course of the main pulmonary artery (Fig. 7); this allowed the diagnosis to be reached with M-mode echocardiography in the one newborn infant examined before two-dimensional echocardiography or angiography. We have been unable to elicit a similar appearance by following the aorta upwards in infants with normally related great arteries. We, therefore, suspect that this feature on M-mode echocardiography may allow the identification of the main pulmonary artery arising from the left ventricle, though variations in the course of the artery will be more readily appreciated with two-dimensional echocardiography.

We have found that two-dimensional echocardiography provides a fast and reliable method of distinguishing the aorta from the main pulmonary artery and thus of providing a rapid diagnosis of complete transposition of the great arteries.

We thank Mr J. S. Paton, B.Sc., who designed the scanning head, Mr A. Shaw, B.Sc., who directed the development of the scanning equipment, and Mr D. J. Wheatley, F.R.C.S., who initiated its clinical application. We acknowledge the help we have received from Dr E. M. Sweet, Dr M. M. Mair, and Miss J. L. McLardy of the Radiology Department of the Royal Hospital for Sick Children, Glasgow.

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