Scanning suprasternal echocardiography

T H GOH, A W VENABLES

From the Department of Cardiology, Royal Children's Hospital, Melbourne, Australia

SUMMARY Scanning suprasternal echocardiography was performed in 280 patients with a variety of cardiac anomalies. By using the special suprasternal transducer on the suprasternal notch, the aortic arch, right pulmonary artery, and left atrium were recorded superoinferiorly. From this reference position various scanning techniques were made to record the main pulmonary artery, pulmonary valve, ascending aorta, aortic valve, and distal aortic arch, wherever possible. These scans made it possible to assess (a) the integrity and size of right pulmonary artery and main pulmonary artery in pulmonary atresia, stenosis of origin of right pulmonary artery, pulmonary artery banding, kinked Waterston anastomosis, and aneurysm of pulmonary artery; (b) relative positions of aortic valve and pulmonary valve in malposition complexes; (c) the position and size of the aortic arch in tetralogy of Fallot and aortic coarctation. Measurements of the left atrium made by suprasternal echocardiography were consistently larger than those made by praecordial echocardiography. Changes in relative sizes of aortic arch, right pulmonary artery, main pulmonary artery, and left atrium were also documented in the various cardiac anomalies. The atrial baffle after Mustard repair for d-transposition of the great arteries and the atrial membrane in cor triatriatum were also demonstrated. The introduction of scanning techniques has thus widened the scope of suprasternal echocardiography.

Since the original description of suprasternal echocardiography,¹ more recent reports have confirmed its usefulness in clinical practice. Petsas *et al.*² reported its use in detecting left atrial myxomas. Allen *et al.*³ assessed the relative size of aortic arch and right pulmonary artery, and left atrial dimensions in various cardiac malformations, and Mortera *et al.*⁴ assessed the use of contrast echocardiography for the diagnosis of transposition of the great arteries. In this paper we report experience of its routine use over the past two years and of a new scanning procedure which appears to enhance the usefulness of the technique.

Subjects and methods

Two hundred and eighty patients, ranging from premature infants to young adults (Table 1) with a variety of congenital and acquired heart lesions had conventional praecordial echocardiograms. Particular attention was paid to the recording of the left atrium, aortic root, and main pulmonary artery. Left atrial dimension (LAp) was measured in end-systole from the anterior aspect of the endocardium of the left atrial posterior wall to the anterior aspect of the posterior aortic wall, aortic root (AR) from the anterior aspect of the posterior aortic wall to

the anterior aspect of the anterior aortic wall, and main pulmonary artery (MPAp) from the anterior

Table 1 Diagnoses of patients studied by suprasternal echocardiography

	No. of patients
Normal	45
Pulmonary valve stenosis	20
Tetralogy of Fallot	20
Pulmonary atresia	18
Ventricular septal defect	
large	17
small	11
with pulmonary artery band	14
Atrial septal defect or persistent ductus arteriosus	6
Pulmonary vascular disease	10
Myocarditis/cardiomyopathy	8
Mitral valve disease	15
Pulmonary artery stenosis	3
Prematurity + PDA	10
Marfan's syndrome	4
Pectus excavatum	7
Truncus arteriosus (type 1)	3
Hypoplastic left heart syndrome	7
Tetralogy of Fallot with absent pulmonary valve	3
Aortic valve stenosis	17
Coarctation of aorta	13
d-transposition	19
l-malposition	9
Cor triatriatum	1
Total	280

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aspect of the posterior pulmonary artery wall to the anterior aspect of the anterior pulmonary artery wall.

Suprasternal echocardiography was performed using the special suprasternal transducer (Aerotech) 2.25 or 5 MHz 6 mm diameter on the suprasternal notch, angled inferiorly and slightly posteriorly to record the aortic arch (AA), right pulmonary artery (RPA), and left atrium (LAss) in its superoinferior axis. Whenever possible left atrial measurements were made immediately posterior to the mitral

annulus. At this point left atrial contraction could be observed following the P wave of the surface electrocardiogram; this recording was possible in most infants and young children, though in older children and adults the mitral annulus often could not be detected and the left atrial inferior wall was recorded as a flat immobile structure.

From this point of reference a routine scan was made by tilting the transducer leftward and anteriorly to obtain a continuous scan from the right pulmonary artery to the main pulmonary artery and valve where feasible; as this was done, the aortic arch progressively gave way to the superiorly placed main pulmonary artery. Alternatively, scans could be made in the reverse direction from the main pulmonary artery to the right pulmonary artery (Fig. 1). Contrast echocardiography was performed to confirm the identification of the structures mentioned, namely right pulmonary artery, aortic arch, left atrium, and main pulmonary artery.

In premature infants with the respiratory distress syndrome it was difficult to obtain a continuous scan from the right pulmonary artery to the main pulmonary artery. The origin of the left pulmonary artery could occasionally be located by scanning from the main pulmonary artery directly posteriorly. An echo-free space was sometimes noted superior to the aortic arch in infants, or superior to the main pulmonary artery in older children and contrast echocardiography confirmed that this space was the innominate vein. The oesophagus could at times be identified inferior and posterior to the left atrium when the patient swallowed saliva

Fig. 1 (a) Diagram of normal heart in anteroposterior and lateral views showing the ultrasound path in routine scan from position 1 to position 2 or vice versa.

Fig. 1 (b) Echocardiographic scan from position 2 to position 1.

Ao arch, aortic arch;
AV, aortic valve;
Inn. v, innominate vein;
LA, left atrium;
LV, left ventricle;
M. ann, mitral annulus;
MPA, main pulmonary artery;
MV, mitral valve;
PV, pulmonary valve;
RPA, right pulmonary artery;
RV, right ventricle.

Fig. 2 Scan from RPA to MPA in child with coarctation. Top arrow indicates innominate vein faintly opacified by contrast saline injected from intravenous line in left upper limb vein. Lower arrow indicates oesophagus lying inferior to left atrium, opacified by microbubbles in swallowed saliva.

containing micro-bubbles (Fig. 2). The aortic valve could occasionally be located inferior and medial to the main pulmonary artery by scanning more medially than usual (Fig. 3). In certain patients the size and position of the distal aortic arch could be

Fig. 3 Scan from child with ventricular septal defect and pulmonary artery band. Arrow indicates pulmonary artery band at origin of right pulmonary artery. The transducer had been tilted more medially than usual to record aortic valve lying medial and inferior to main pulmonary artery and pulmonary valve.

ascertained by scanning posteriorly leftward or rightward from the reference position. Other scanning procedures for malposition complexes will be described in a later section.

Measurements of the aortic arch, right pulmonary artery, left atrium, and main pulmonary artery were made in end-systole, as shown in Fig. 1. Measurements of the aortic arch, right pulmonary artery, left atrium, and main pulmonary artery were also made from cineangiocardigrams by comparison with catheter diameter in 15 patients who underwent cardiac catheterisation, and were compared with echocardiographic measurements made within 48 hours of the catheterisation. Praecordial and suprasternal measurements of the various structures were compared and ratios, regression curves and equations, and correlation coefficients obtained. Serial echocardiographic measurements were made in 20 patients.

Results

MEASUREMENTS OF AORTA, PULMONARY ARTERY, AND LEFT ATRIUM

Echocardiographic (X_1) and angiographic (Y_1) measurements of the great vessels and left atrium showed good correlation ($R=0.85$; $Y_1 = -0.01 + 1.06 X_1$). There was more variation with left atrial measurements than with measurements of aorta and pulmonary artery.

Measurements of the aorta made suprasternally

(X_2) and praecordially (Y_2) were generally similar ($R=0.88$; $Y_2=0.05+0.99 X_2$; $AA/AR=1.03 \pm 0.19$). Patients with significant aortic valve stenosis had a tendency to larger AA/AR ratios resulting from post-stenotic dilatation of the aortic arch and small aortic annulus.

Praecordial measurements of main pulmonary artery (X_3) were generally slightly larger than suprasternal measurements (Y_3) ($MPAss/MPAp=0.93 \pm 0.16$; $R=0.74$; $Y_3=0.59+0.68 X_3$). There was wider scatter and variation in measurements of the main pulmonary artery, which is probably explained by the obliquity of the main pulmonary artery and the difficulty of obtaining accurate praecordial measurements of its diameter; measurement of a portion of the right ventricular outflow tract was usually included. Only in patients with a large main pulmonary artery in whom recording of two pulmonary valve leaflets was obtained was it possible to obtain a more accurate measurement of the true dimension of the main pulmonary artery. Suprasternal measurements of the proximal main pulmonary artery may at times be difficult because of the obliquity of the scan as well as the obliquity of the main pulmonary artery. However, suprasternal measurements of the distal main pulmonary artery may give a more accurate assessment of the size of the vessel at that site.

Suprasternal measurements of the left atrium (X_4) were consistently larger than praecordial measurements (Y_4) ($LAss/LAp=1.53 \pm 0.29$; $R=0.88$; $Y_4=0.05+0.64 X_4$) though the ratio varied. In only two out of three patients with tetralogy of

Fallot with absent pulmonary valve was the suprasternal left atrial measurement smaller than the praecordial measurement; this resulted from compression of the left atrium superoinferiorly by the aneurysmal rightpulmonary artery (Fig. 4C).

Fig. 4 Miscellaneous suprasternal echocardiograms. (A) Severe mitral regurgitation with large left atrium. (B) Hypoplastic left heart syndrome with small aortic arch, but dilated right pulmonary artery and left atrium. (C) Tetralogy of Fallot with absent pulmonary valve showing aneurysmal right pulmonary artery compressing left atrium superoinferiorly and also dilated aortic arch.

Table 2 Suprasternal echocardiographic measurements

Classification	No. of patients	$\frac{LAss}{LAp}$	AA/RPA	LA/AA	AA/MPA
Normal	45	1.59 ± 0.21	1.46 ± 0.23	1.49 ± 0.26	1.03 ± 0.16
Pulmonary valve stenosis	20	1.45 ± 0.26	1.16 ± 0.22	1.40 ± 0.27	0.89 ± 0.14
Tetralogy of Fallot	20	1.58 ± 0.32	1.75 ± 0.44	1.30 ± 0.29	1.12 ± 0.32
Pulmonary atresia	18	1.50 ± 0.41	2.64 ± 0.93	1.21 ± 0.25	2.00 ± 0.69
VSD large	17	1.68 ± 0.30	1.22 ± 0.19	1.95 ± 0.42	0.77 ± 0.12
small	11	1.54 ± 0.23	1.53 ± 0.32	1.52 ± 0.28	1.01 ± 0.21
with PA band	14	1.61 ± 0.26	1.23 ± 0.34	1.79 ± 0.46	0.78 ± 0.19
ASD or PDA	6	1.48 ± 0.08	1.16 ± 0.15	1.61 ± 0.30	0.75 ± 0.16
Pulmonary vascular disease	10	1.58 ± 0.30	1.26 ± 0.28	1.72 ± 0.62	0.80 ± 0.20
Myocarditis/cardiomyopathy	8	1.44 ± 0.18	1.41 ± 0.31	2.08 ± 0.35	0.99 ± 0.10
Mitral valve disease	15	1.42 ± 0.26	1.34 ± 0.17	2.37 ± 0.57	0.85 ± 0.15
Pulmonary artery stenosis	3	1.93 ± 0.67	1.80 ± 0.38	1.64 ± 0.54	—
Prematurity + PDA	10	1.71 ± 0.23	1.44 ± 0.31	$1.55 \pm 0.27^*$ $1.94 \pm 0.31^\dagger$	—
Marfan's syndrome	4	1.98 ± 0.67	1.81 ± 0.40	1.33 ± 0.49	1.26 ± 0.21
Pectus excavatum	7	2.27 ± 0.50	1.43 ± 0.28	1.71 ± 0.37	0.99 ± 0.16
Hypoplastic left heart syndrome	7	1.53 ± 0.65	0.63 ± 0.39	3.51 ± 1.62	0.46 ± 0.26
Tetralogy of Fallot and absent pulmonary valve	3	0.82 ± 0.38	0.70 ± 0.16	0.79 ± 0.27	—
Aortic valve stenosis	17	1.44 ± 0.32	1.67 ± 0.38	1.39 ± 0.32	1.21 ± 0.31
d-transposition	19	1.80 ± 0.60	0.97 ± 0.12	1.60 ± 0.30	—
Coarctation of aorta	13	1.71 ± 0.37	1.27 ± 0.33	$1.41 \pm 0.11^*$ $1.87 \pm 0.09^\dagger$ 1.23^*	1.03 ± 0.29
Truncus arteriosus with pulmonary artery band	3	1.93 ± 0.52	2.17 ± 0.43	$1.78 \pm 0.07^\dagger$	—

* Without heart failure. † With heart failure.

AA/RPA RATIO (Table 2)

In 35 normal subjects the ratio was 1.46 ± 0.23 . It was significantly increased in patients with pulmonary atresia, tetralogy of Fallot, pulmonary artery stenosis, Marfan's syndrome, and slightly increased in aortic valve stenosis. This was the result of enlargement of the aortic arch and small right pulmonary artery in the first three conditions mentioned, and enlargement of the aortic arch in the other two. The ratio was significantly smaller in patients with hypoplastic left heart syndrome (Fig. 4B), significant left-to-right shunt, pulmonary hypertension from a variety of causes, tetralogy of Fallot with absent pulmonary valve, pulmonary valve stenosis, and d-transposition of the great arteries. In hypoplastic left heart syndrome this was the result of the hypoplastic aortic arch and dilatation of the right pulmonary artery. In the other conditions the change was the result of enlargement of the right pulmonary artery from a variety of causes. In patients with ventricular septal defect there was a difference between patients with small defects and those with larger defects or who had required pulmonary artery banding. In one patient with a ventriculoatrial shunt for hydrocephalus, a significantly smaller AA/RPA ratio suggested pulmonary hypertension and prompted further investigation of the patient who subsequently underwent revision of his shunt.

AA/MPASS RATIO (Table 2)

In normal patients the ratio was 1.03 ± 0.16 . In the various cardiac malformations the changes were generally similar to those observed for AA/RPA ratio.

LASS/AA RATIO (Table 2)

In normal patients the ratio was 1.49 ± 0.26 . The ratio was significantly increased in patients with mitral valve disease (Fig. 4A), cardiac failure resulting from truncus, coarctation, myocarditis, or cardiomyopathy, large ventricular septal defect, and persistent ductus arteriosus. This was related to enlargement of the left atrium. The ratio was also increased in patients with pectus excavatum as a result of anteroposterior compression of the left atrium, and in patients with the hypoplastic left heart syndrome as a result of the small aortic arch and enlargement of the left atrium. The ratio was decreased in patients with pulmonary atresia, tetralogy of Fallot, and Marfan's syndrome mainly as a result of enlargement of the aortic arch. The ratio was also decreased in tetralogy of Fallot with absent pulmonary valve, as a result of enlargement of the aortic arch and compression of the left atrium by the aneurysmal right pulmonary artery.

OTHER OBSERVATIONS

The pulmonary, aortic, and mitral valves were commonly detected in infants. In older children the pulmonary valve was more easily detected in pulmonary valve stenosis and pulmonary hypertension, the aortic valve in aortic valve stenosis and in pulmonary atresia, and the mitral valve in atrio-ventricular canal. This may supplement information on the valves obtained by praecordial echocardiography.

Structures within the atrial cavity were also detected. The atrial baffle was detected in five children after Mustard's operation for d-transposition of the great arteries. A rightward transverse scan from the systemic venous atrium often showed the superior and inferior aspects of the baffle which divided the cavity into three chambers. Contrast echocardiography confirmed the superior cavity as the superior vena caval inflow, the middle cavity as the pulmonary venous atrium, and the inferior cavity as the inferior vena caval inflow. It was often difficult to get a good view of the inferior vena caval inflow (Fig. 5a, b). In a patient with cor triatriatum, the membrane was seen as a single or double linear shadow across the atrial cavity. In the latter instance the superior and inferior aspects of the bulging membrane had been caught by the transducer beam; these linear shadows disappeared after successful operation (Fig. 5c).

SCANNING TECHNIQUES IN ABNORMALITIES OF PULMONARY ARTERY AND AORTA

Routine scans from the right pulmonary artery to the main pulmonary artery (MPA) made it possible to assess the size and integrity of both vessels.

In 18 patients with pulmonary atresia, the hypoplastic right pulmonary artery could be identified but in 11 it was not possible to detect continuity with a hypoplastic main pulmonary artery (Fig. 6a). These observations were in close agreement with angiocardiographic and surgical findings. The method thus appears to be a specific and sensitive technique to assess the presence or absence of the main pulmonary artery.

Four patients with a pulmonary artery band (PAB) had both preoperative and postoperative suprasternal echocardiography. The site and efficacy of the banding could be assessed by reference to the constricted lumen of the main pulmonary artery at the site of the band (Fig. 6b). Echocardiographic (X) and angiographic (Y) measurements of the banded pulmonary artery in 12 patients showed good correlation ($Y = 0.24 + 0.54X$; $R = 0.86$). Two patients who had tight pulmonary artery bands required surgical revision; subsequent echocardi-

Fig. 5 (a) Superior vena caval angiogram after Mustard procedure for d-transposition (anteroposterior view). Arrows point to atrial baffle. IVC, inferior vena cava; PVA, pulmonary venous atrium; SVA, systemic venous atrium; SVC, superior vena cava.

Fig. 5 (b) Transverse and rightward echocardiographic scan from SVA to PVA. The atrial baffle has divided the chamber into three portions; superior SVC inflow, middle PVA, inferior IVC inflow.

graphic assessment showed larger dimensions. Three other patients had serial echocardiographic measurements over a period of six months showing constancy of pulmonary artery band size. Two other patients had distal migration of the band to

Fig. 5 (c) Suprasternal echocardiogram in child with cor triatriatum. (left) Preoperative, showing dilated left atrium with two linear shadows (shown by arrows) lying within the cavity, and dilated right pulmonary artery. (right) Postoperative, showing disappearance of linear shadows within the normal-sized left atrium; right pulmonary artery has also diminished in size.

the bifurcation of the main pulmonary artery, with partial occlusion of the origin of the right pulmonary artery (Fig. 3). One other patient had a loose band. Banding was thought to be effective if the ratio PAB/MPA was between 0.35 and 0.6, tight if PAB/MPA ratio was less than 0.35, and loose if the ratio was greater than 0.6.

In three out of six patients with tetralogy of Fallot who required a Waterston anastomosis, echocardiography showed a right pulmonary artery stenosis at the anastomotic site. Stenosis of the right pulmonary artery at its origin was shown in four patients (Fig. 6c) and supra-valvar pulmonary

artery stenosis in one patient with tetralogy of Fallot. Aneurysmal dilatation of the main pulmonary artery after correction of Fallot's tetralogy with outflow patch was documented in three patients.

In one hydrocephalic patient with a broken ventriculoatrial shunt, the metal tip of which was lodged in the distal right pulmonary artery, it was possible by appropriate scanning to follow the proximal radiolucent tubing from the right pulmonary artery to the main pulmonary artery and thence to the left pulmonary artery.

Scans from proximal to distal aortic arch were made in patients with tetralogy of Fallot, pulmonary atresia, aortic valve stenosis, complex cyanotic heart disease, and coarctation of the aorta. The distal aortic arch was usually of the same size as or slightly smaller than the proximal aortic arch. Out of 14 patients with coarctation of the aorta, distal isthmic

a

b

Fig. 6 Scans from right pulmonary artery to main pulmonary artery. (a) Pulmonary atresia with absent main pulmonary artery: dilated aortic arch and hypoplastic right pulmonary artery; no main pulmonary artery is seen (arrow). (b) Effective pulmonary artery band (PAB) lying away from origin of right pulmonary artery and in distal half of main pulmonary artery. (c) Right pulmonary artery stenosis at bifurcation in tetralogy of Fallot.

hypoplasia was documented in five patients. This was in close agreement with angiographic findings (Fig. 7a). Six patients with tetralogy of Fallot had

a

b

a right-sided aortic arch suggested by echocardiography and confirmed on angiography. The course of an 1-malposed aorta crossing the mediastinum and descending as a right-sided arch was correctly predicted before cardiac catheterisation in a neonate with single ventricle and pulmonary atresia. Recently in three patients with persistent ductus arteriosus (two with transposition of the great arteries) the pulmonary aspect of the persistent ductus was visualised as an echo-free space inferior to the distal aortic arch and separated from the left pulmonary artery (Fig. 7b, c). This space disappeared after ligation of the ductus in two patients and spontaneous closure in one. An alternative way of detecting the ductus was by scanning from the main pulmonary artery directly posterior to the distal aortic arch and showing continuity between the main pulmonary artery and the echo-free space beneath the distal arch; it appears that this method is only possible when a ductus is long and tubular with distinct demarcation from the left pulmonary artery.

c

Fig. 7 Scans from proximal to distal aortic arch. (a) Coarctation of aorta with isthmus hypoplasia (shown by arrow) in a neonate. (b) Persistent ductus arteriosus (arrow) shown as echo-free space beneath aortic arch in neonate with *d*-transposition of the great arteries. (c) Aortogram in same neonate showing persistent ductus arteriosus (arrows) lying between aortic arch superiorly and left pulmonary artery inferiorly.

SCANNING TECHNIQUES IN MALPOSITION COMPLEXES

From the reference position scans were made by tilting the transducer anteriorly and leftward, centrally, or rightward to document the following: (a) continuity of the aortic arch with the ascending aorta and aortic valve where possible; (b) continuity of the right pulmonary artery with the main pulmonary artery where possible; and (c) the relative positions of the ascending aorta and the main pulmonary artery and, where possible, of the aortic valve and the pulmonary valve. Occasionally, when only one vessel could be detected superior to the left atrium, from the reference position it was necessary to scan transversely to locate the other vessel, usually the aortic arch; this was observed in patients with l-malposition in whom the aortic arch usually lay superior and to the left of the right pulmonary artery (Fig. 8). Occasionally in patients with right-sided aortic arch, the arch lay more to the right than usual. This transverse scan was also of value in the detection of the right pulmonary artery in patients with pulmonary atresia. In scanning anteriorly, it was often necessary to place the transducer more anteriorly and superficially on the sternal notch to obtain a good continuous scan.

In normal patients scans from the right pulmonary artery to the main pulmonary artery were obtained as described above. Some difficulty was experienced with premature infants with respiratory distress syndrome. The detection of a semilunar valve just inferior to the main pulmonary artery taken in conjunction with the praecordial echocardiographic findings confirmed normal orientation of the vessels. Scanning from the aortic arch to the ascending aorta and aortic valve was not possible in normal subjects.

In d-transposition of the great arteries the aortic arch and right pulmonary artery were normally related. However, routine scanning anteriorly and leftward from the right pulmonary artery failed to record continuity with the main pulmonary artery when the aortic arch was no longer seen on the scan. This was a good indication of the diagnosis. The main pulmonary artery could only be recorded in a more medial, inferior, and posterior position at the point on the scan when the aortic arch was still lying superior to it (Fig. 9a). Aortic arch to ascending aorta continuity could be shown by scanning anteriorly, centrally, or rightward. This was possible (though difficult) in all infants with d-transposition but was much more difficult in older patients. The anteriorly and superiorly placed aortic valve was located in two patients and an

aortic valve to pulmonary valve scan was successfully accomplished in these two patients.

In l-malposition complexes, the aortic arch was usually superior to the left pulmonary artery and

Fig. 8 (a) Angiocardiogram in child with l-malposition, single ventricle, and pulmonary stenosis, showing leftward position of aortic arch relative to right pulmonary artery.

Fig. 8 (b) Suprasternal echocardiogram in another child with l-malposition. Transverse and leftward scan locates aortic arch.

therefore to the left of the right pulmonary artery. Aortic arch to ascending aorta continuity could be shown in seven patients by scanning anteriorly and leftward. The anterior, superior, and leftward aortic valve was located in two neonates (Fig. 9b). The main pulmonary artery was recorded as in d-transposition in a medial, inferior, and posterior position, but in these patients the aortic arch was not recorded superiorly at the same time. The pulmonary valve was located in two patients.

Discussion

Suprasternal echocardiography as described previously has a useful though limited role, but the introduction of the scanning techniques described above has broadened its application. New information is available regarding structures like the right pulmonary artery, proximal and distal aortic arch, and main pulmonary artery. Scans from the right pulmonary artery to the main pulmonary artery make it possible to assess the size and integrity of both vessels. This has been shown in cases of pulmonary atresia, tetralogy of Fallot, right pulmonary artery stenosis, Waterston anastomosis, pulmonary artery banding, supra-valvar pulmonary stenosis, and pulmonary artery aneurysm. The information provided is of importance for planning surgical treatment in patients with pulmonary atresia as well as in patients with a Waterston anastomosis. The effectiveness of pulmonary artery banding has been assessed by direct visualisation of the site and size of the lumen of the band. Scans from the proximal to the distal aortic arch make it possible to assess integrity, size, and position of the whole aortic arch. Isthmic hypoplasia and persistent ductus arteriosus have been shown, and right and left aortic arch distinguished.

In transposition and malposition complexes, suprasternal scanning procedures, in conjunction with praecordial echocardiography, have made possible proper identification of semilunar valves and roots of great arteries. Usually the aortic arch is superior to the right pulmonary artery and is continuous with the ascending aorta and aortic valve on appropriate scans. In the neonate, care must be taken, however, to differentiate the innominate vein which is occasionally detected above the aortic arch. In most patients with l-malposition the aortic arch lies above and to the left of the right pulmonary. In some patients with right aortic arch the arch may lie much more to the right than in others.

The right pulmonary artery lies inferior to the aortic arch and is continuous with the main pulmonary artery and pulmonary valve on appro-

priate scans. Comparison of the relative positions of the roots of the great arteries on suprasternal and praecordial echocardiograms make it possible to identify the arteries and semilunar valves. This non-invasive method of diagnosis of malposition complexes has proved to be useful and could also help in the diagnosis of the rare s-d-l transposition (atrial situs solitus, d-ventricular loop, l-articular loop) and posterior transposition complexes. This method is superior to the contrast suprasternal technique described by Mortera *et al.*⁴ because it is non-invasive and is suitable for all cases of mal-

Fig. 9 (a) *d-transposition of great arteries. Echocardiographic scan from main pulmonary artery to right pulmonary artery shows that main pulmonary artery lies inferior to aortic arch and is posteriorly and medially placed.*

Fig. 9 (b) *Neonate with l-malposition. Echocardiographic scan shows continuity of aortic arch with ascending aorta and aortic valve.*

position, whereas the latter method requires invasive contrast studies and is of limited use for patients with d-transposition of the great arteries with ventricular septal defect or single ventricle, and those patients with persistence of fetal circulation with gross right-to-left atrial shunting.

Angiocardiographic and echocardiographic measurements of great arteries show good correlation. There is more variation with left atrial measurements apparently because angiocardiographic and echocardiographic techniques measure different diameters of a three-dimensional structure. The introduction of scanning procedures may perhaps enable some standardisation of the technique for obtaining left atrial measurements. The largest left atrial diameter is just behind the mitral annulus and measurements should be made here when possible. Consistent values are obtained when serial measurements are made.

Biaxial measurements of left atrial dimension in this study show a consistently larger suprasternal measurement than reported by Allen *et al.*³ These differences were greater in patients with antero-posterior compression of the left atrium from pectus excavatum and in premature infants with sternal retraction associated with the respiratory distress syndrome or persistent ductus. In only two patients, with tetralogy of Fallot with absent pulmonary valve and aneurysmal dilatation of the right pulmonary artery was the suprasternal left atrial measurement smaller than the praecordial. These results are what would be expected from the ellipsoidal shape of the left atrium on lateral view angiocardiograms. On the other hand, Allen *et al.*³ reported equal suprasternal and praecordial echocardiographic dimensions.

Biaxial visualisation of left atrial myxomas has been described². This technique has also been used to locate the atrial baffle after the Mustard operation for d-transposition of the great arteries. The incorporation of a transverse scan makes it possible

to assess the superior vena caval and perhaps inferior vena caval inflow into the systemic venous atrium. The atrial membrane of cor triatriatum was also identified in this manner in one patient.

In conclusion, the introduction of scanning procedures has been shown to enhance significantly the usefulness of suprasternal echocardiography. Scanning suprasternal echocardiography should, therefore, form a part of the routine echocardiographic assessment of the child with heart disease.

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Requests for reprints to Dr T H Goh, Department of Cardiology, Royal Children's Hospital, Flemington Road, Parkville, Melbourne, Victoria 3052, Australia.

Addendum. Since the submission of this paper for publication, we have studied three patients with complete aortic arch interruption. In all three patients we have failed to demonstrate an aortic arch using the scanning procedures described. In one of these patients, a neonate, suprasternal echocardiography appeared to show an echo-free space superior to the right pulmonary artery, but scanning showed this to result from a grossly dilated main pulmonary trunk.