Two Dimensional Sector Scan Echocardiographic Profile of Tetralogy of Fallot**

By

KALIM U. AZIZ*, M.D., TERESA E. BERRY, M.D. and MILTON H. PAUL, M.D.

The M-mode echocardiographic diagnosis of tetralogy of Fallot is based essentially on demonstration of the aorta overriding the ventricular septum above a ventricular septal defect [1-2]. The pulmonary valve is less often visualized and satisfactory imaging of the hypertrophied infundibulum cannot be obtained. Two-dimensional echocardiographic imaging was recently reported to demonstrate the narrowed right ventricular outflow tract in both short and long axis views [3]. The purpose of the present study is to present the diagnostic two-dimensional sector scan echocardiographic features of tetralogy of Fallot observed in 15 patients with additional correlative angiographic and pathologic data.

Material and Methods:

Fifteen patients aged 10 days— 4.8 years (mean 1.8 years) with tetralogy of Fallot are included in this study (Table I). One or more two-dimensional sector scan echo studies were obtained in each patient, and the echocardiographic diagnosis of tetralogy of Fallot established prior to angiography. The echocardiograms were obtained with an Advanced Technology Laboratories sector scanner using a 3.5 MHz transducer, videotape recording and replay, and stop-frame 35 mm camera photography.

Cardiac catheterization with hemodynamic and angiocardiographic recordings were done in all patients. In 2 patients (Cases 2, 4) indocyanine green was injected via a cardiac catheter positioned in the right ventricle and echocardiographic contrast studies were obtained with the transducer positioned at the sub-xiphoid and suprasternal areas.

The sector scan images were obtained with the patient in the supine position using suprasternal, apical, subxiphoid, and left parasternal transducer positions [4-6]. We also utilized a sector scan image obtained with the transducer positioned at the 2nd-3rd intercostal space and approximately 2-3 cm to the left of the sternum (high left parasternal position). Using this transducer position the sector beam plane was first directed medially and inferiorly so that it obliquely transected the left ventricul ar-aortic long axis (Figs. 1A;). Imaging of the right ventricular infundibulum and the main pulmonary artery was then obtained by superior and leftward tilting of the transducer (Figs. 1B;).

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*Pediatric Cardiologist, NICVD, Karachi.

**From the NICVD, Karachi and the Wills J. Potts Children's Heart Center (Division of Cardiology), The Children's Memorial Hospital, and the Department of Pediatrics, Northwestern University Medical School Chicago, Illinois.

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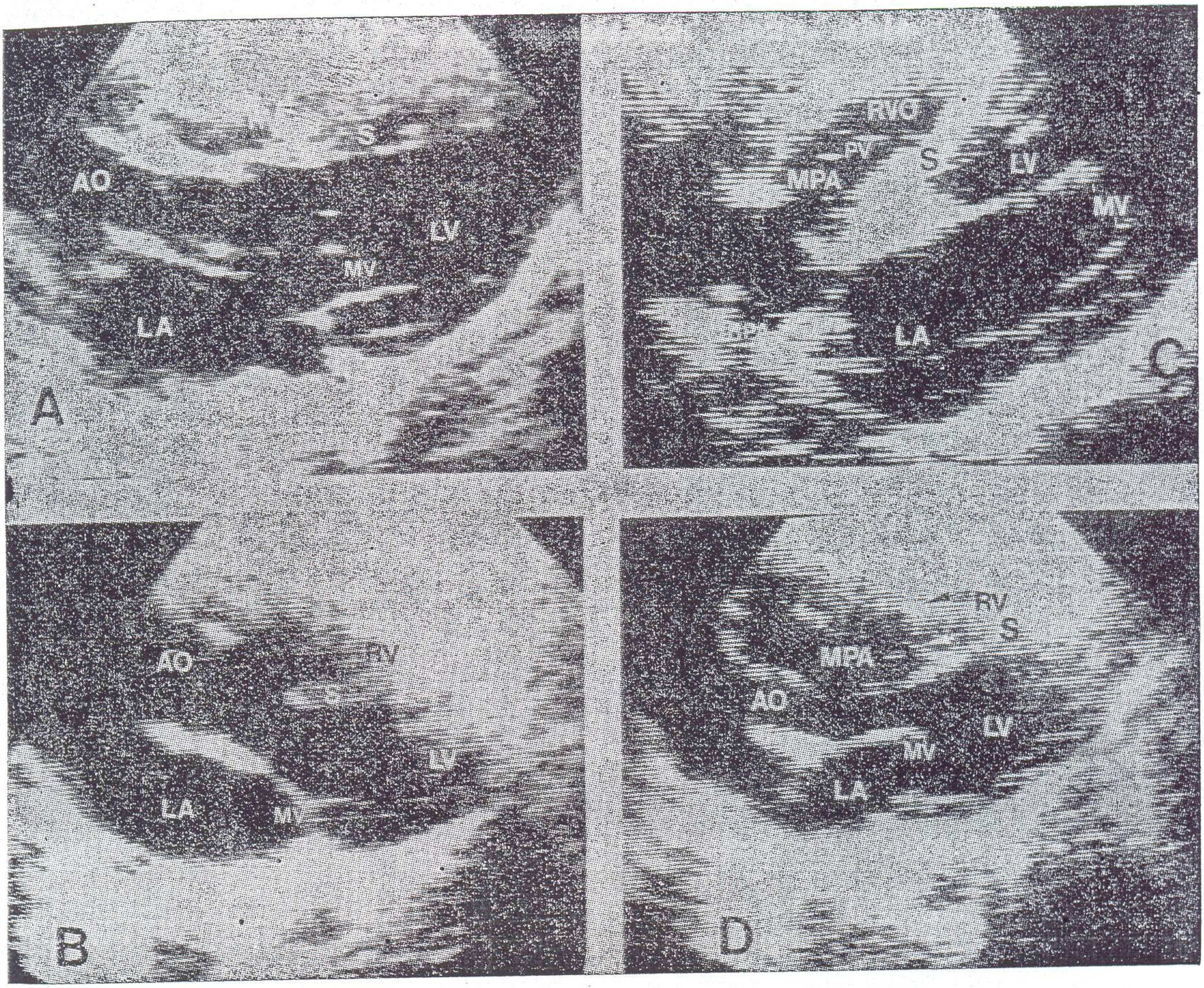

Fig. 1. A, C, Left ventricular echocardiogram in early diastole from high left parasternal location in a normal child, and C, D, in patient with tetralogy of Fallot (Case 11). A, With the sector beam directed inferiorly and medially, the left ventricle (LV) and aorta (A0) are imaged together with a small portion of right ventricular outflow tract (RVO). Mitral valve (MV) is seen in slightly open position. *C*, Leftward and superior tilting of the transducer from the above position images the right ventricular outflow tract (RVO) and main pulmonary artery (MPA) and its continuation into the right pulmonary artery (RPA) above the left atrium (LA). *B*, Left parasternal view with sector beam as in A, shows overriding of the aorta above the ventricular septum (S), and D, slight superior tilting of transducer images hypertrophied infundibular muscle (arrows).

Abbreviations: PV, pulmonary valve; S, septum.

Table I: Quantitative Measurements: Echocardiographic and Angiographic Data on Patients with Tetralogy of Fallot.

Case No.	*Age at Cath & Echo (yrs)*	*Pulmonary Valve Annulus (mm)*		*Right Pulmonary Artery (mm)*	
		Angio	*Echo*	*Angio*	*Echo*
1	3.3	10.0	12.0	10.5	10.0
4	3.3	13.0	15.0	11.0	10.0
5	2.1	12.5	15.0	12.0	12.0
8	0.7	9.0	9.0	4.0	6.0
9	0.4	10.0	9.5	7.0	6.0
10	4.8	16.0	15.0	13.0	15.0
12	0.3	8.5	10.0	5.5	5.0
13	1.3	10.5	12.0	15.0	10.0
15	0.3	12.1	10.0	7.5	6.0
MEAN I		11.3(a)	11.9(a)'	9.5(b)	8.9(b)'
S.D.		2.3	2.5	3.7	3.4

(a) (a)' and (b) (b)': No significant difference by comparing paired data (difference T-test)

The aortic arch was imaged with the transducer positioned at the suprasternal region and rotated counterclockwise so that the plane of the sector echo beam is moved from the coronal (frontal) plane to the saggital plane with optimal imaging occurring when the beam plane becomes parallel to the aortic arch (Fig. 2)[4].

The subxiphoid transducer position was the most useful for imaging the infundibular region. The infundibular imaging search was begun by orienting the sector beam plane in the horizontal plane (so-called "four-chamber" plane). Imaging of both ventricles was obtained from this position, and further superior and rightward tilting of the transducer imaged the aorta overriding the interventricular septum (Fig. 3D.) Clockwise rotation of the transducer sector beam in the sagittal plane transected the right ventricle anteroposteriorly along a superior (pulmonic valve)-inferior (right ventricular sinus) axis. This image plane can be considered an oblique variant of the conventional left ventricular short axis plane [7]. Minor adjustments of the angulation were required to image the right ventricular infundibulum and free wall, pulmonary valve annulus, main pulmonary artery and ventricular septal defect (Fig. 3 B-C) Imaging of the right and left pulmonary arteries was also obtained from this transducer position in younger patients. The short axis view, obtained from left parasternal transducer position at the base of the heart was particularly useful in imaging the pulmonary valve annulus and pulmonary arteries.

Quantitative assessment of the pulmonary valve annulus and right pulmonary artery was made in 9 patients who had both catheterization and echocardiographic studies performed within a few days. The right pulmonary artery diameter was measured at a point midway between its origin and the first branch point (Fig. 4). The right pulmonary artery was quantitated

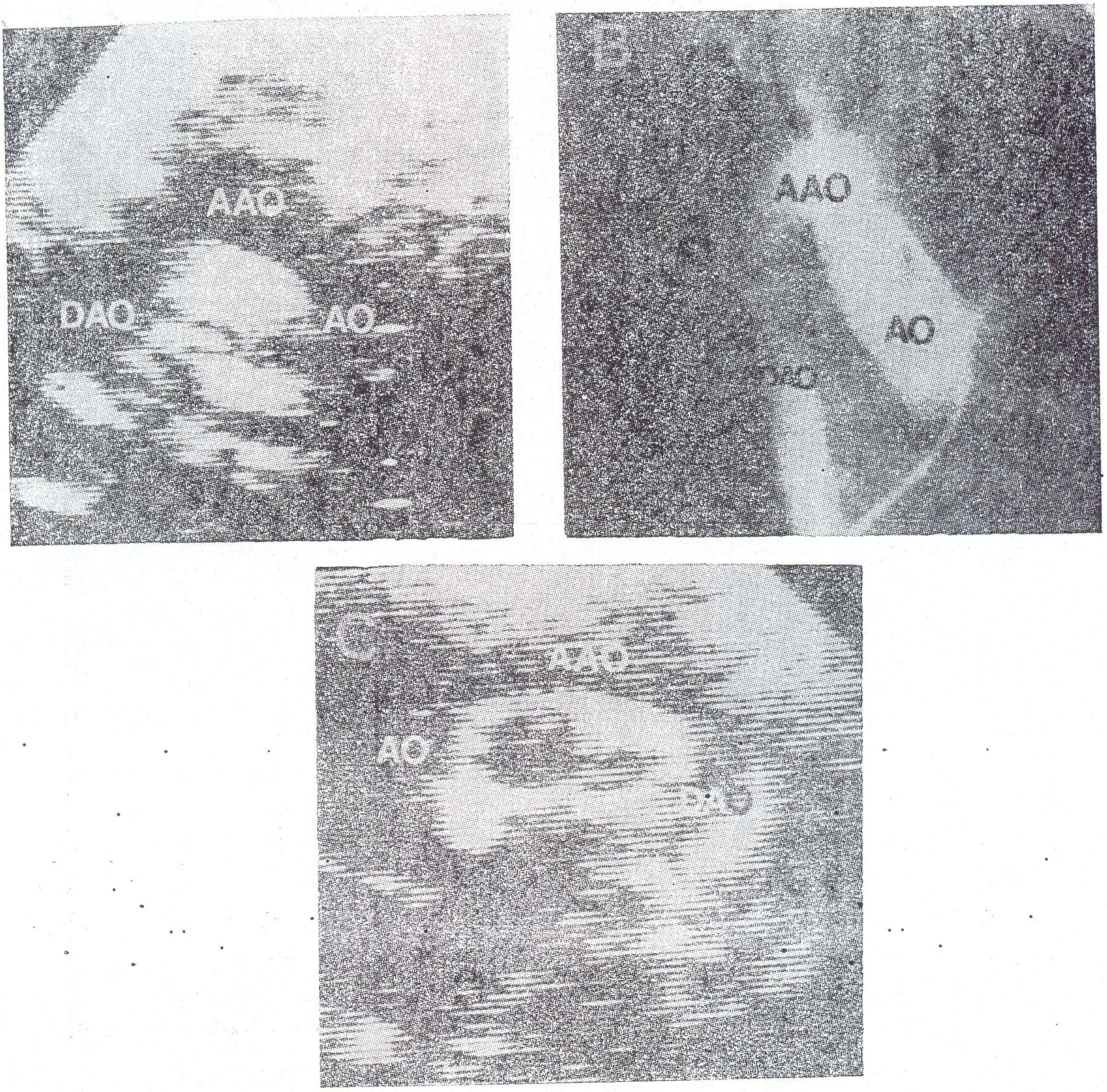

Fig. 2. B, Anteroposterior view aortogram in Case 2, and A, correlative sector scans obtained from suprasternal location with sector beam plane approximately in sagittal body plane. Note imaging of the descending aorta (DAO) which descended on the right with right aortic arch (A,) as opposed to left positioned descending aorta with left aortic arch (C).

Abbreviations: AAO, arch of aorta; AO, ascending aorta; and DAO, thoracic (descending aorta).

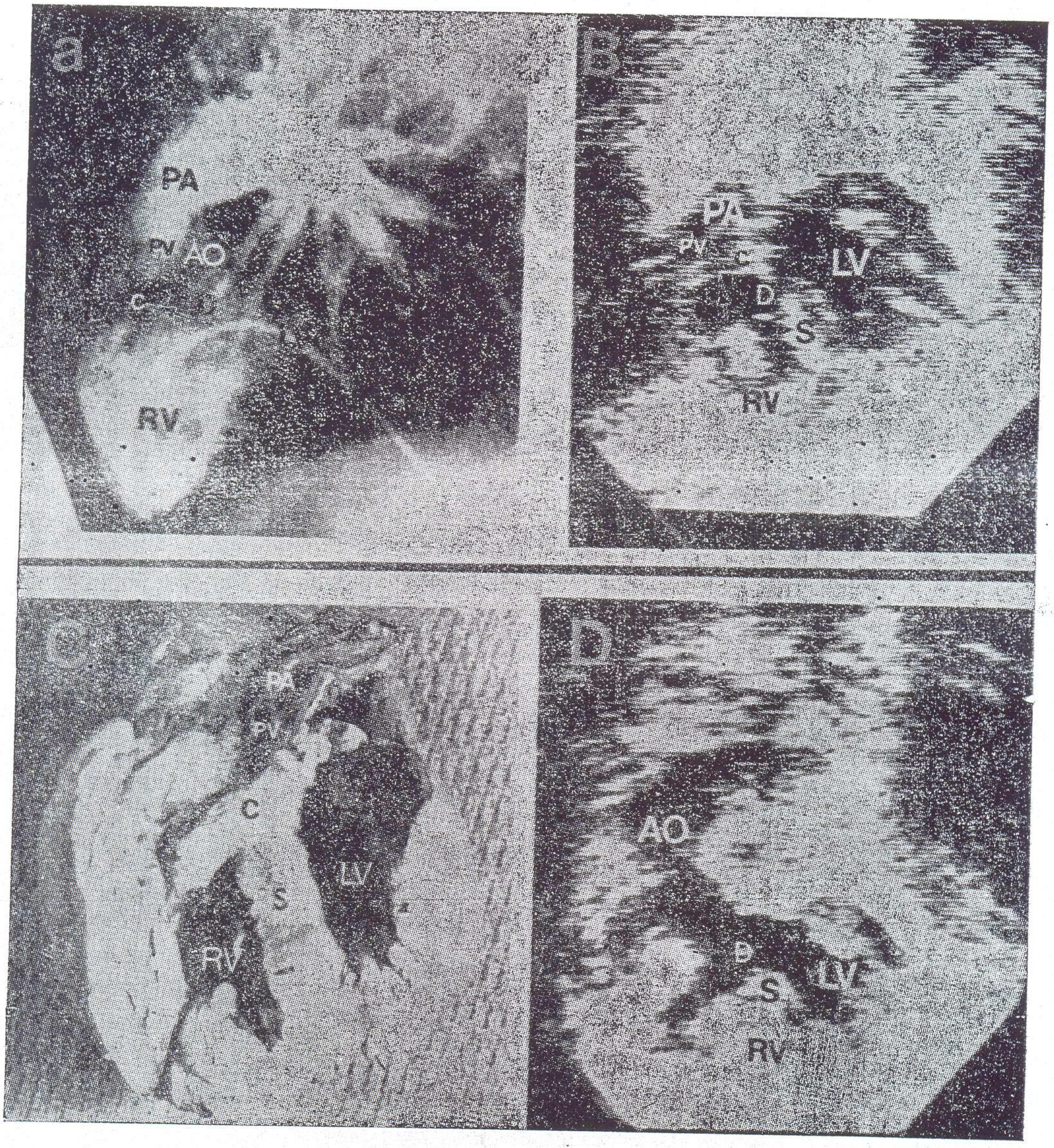

Fig. 3. A, Lateral view (sagittal plane) cineangiogram, *B*, saggital plane (left ventricular short-axis plane) sector scan obtained from subxiphoid position in Case 1, and *C*, a correlative post-mortem heart specimen sectioned in saggital plane. Sector scan shows the position of the hypertrophied infundibular muscle as a thick transverse echo mass (arrow), constituted medially by crista supraventricularis (C), and laterally by right ventricular free wall. Note anterior deviation of the crista supraventricularis vis-a-vis the axis of the interventricular septum (S). Ventricular septal defect (D) is seen below the crista supraventricularis. Postmortem heart specimen shows a close structural correlation to the images obtained by the sector scan and angiogram. *D*, Long axis sector scan view obtained from subxiphoid location showing over Riding Aorta (AO) above the ventricular septal defect D.

Abbreviations: LV, left ventricle; PA, pulmonary artery; PV, pulmonic valve; and RV, right ventricle.

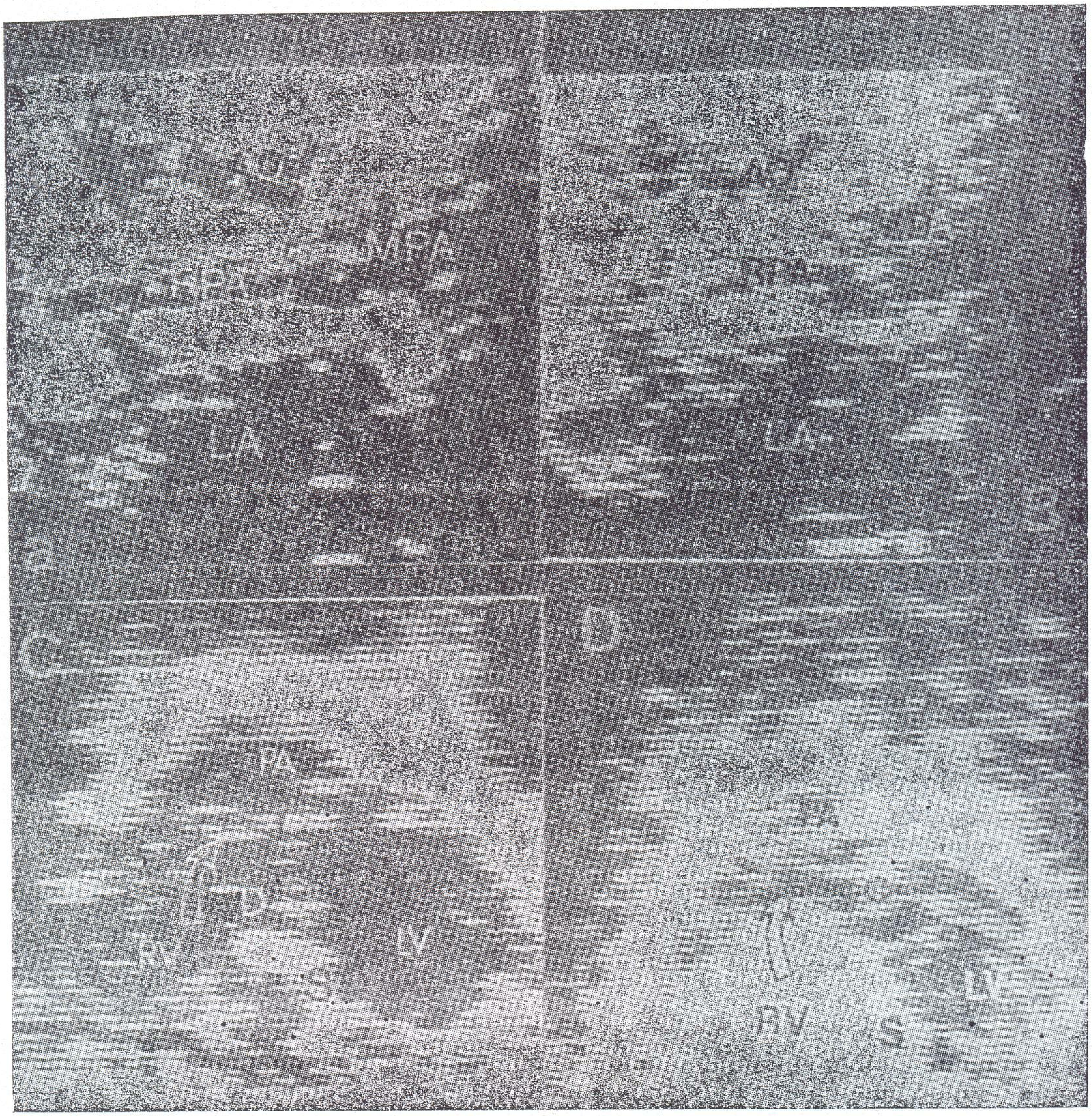

Fig. 4. A, B, Sector scan from suprasternal location with echo beam in coronal body plane, and C, D, saggital plane subxiphoid sector scans in Case 4. A, C, Images are before and B, D, images are after the injection of indocyanine green at cardiac catheterization. A, Note imaging of right pulmonary artery from the lung hilum to its origin and *B*, its opacification after echo contrast material was injected in the right ventricle. *D*, echo opacification of the right ventricle (RV) by the indocyanine green bolus and delay of the bolus by the hypertrophied infundibular muscle indicated by the negative contrast (open arrows). Spill-over of contrast material (black arrow) into the left ventricle (LV) at the subcristal region (C) identifies the position of the ventricular septal defect. *B*, shows the measurement of the right pulmonary artery dimension midway between its origin and 1st branching (Barr).

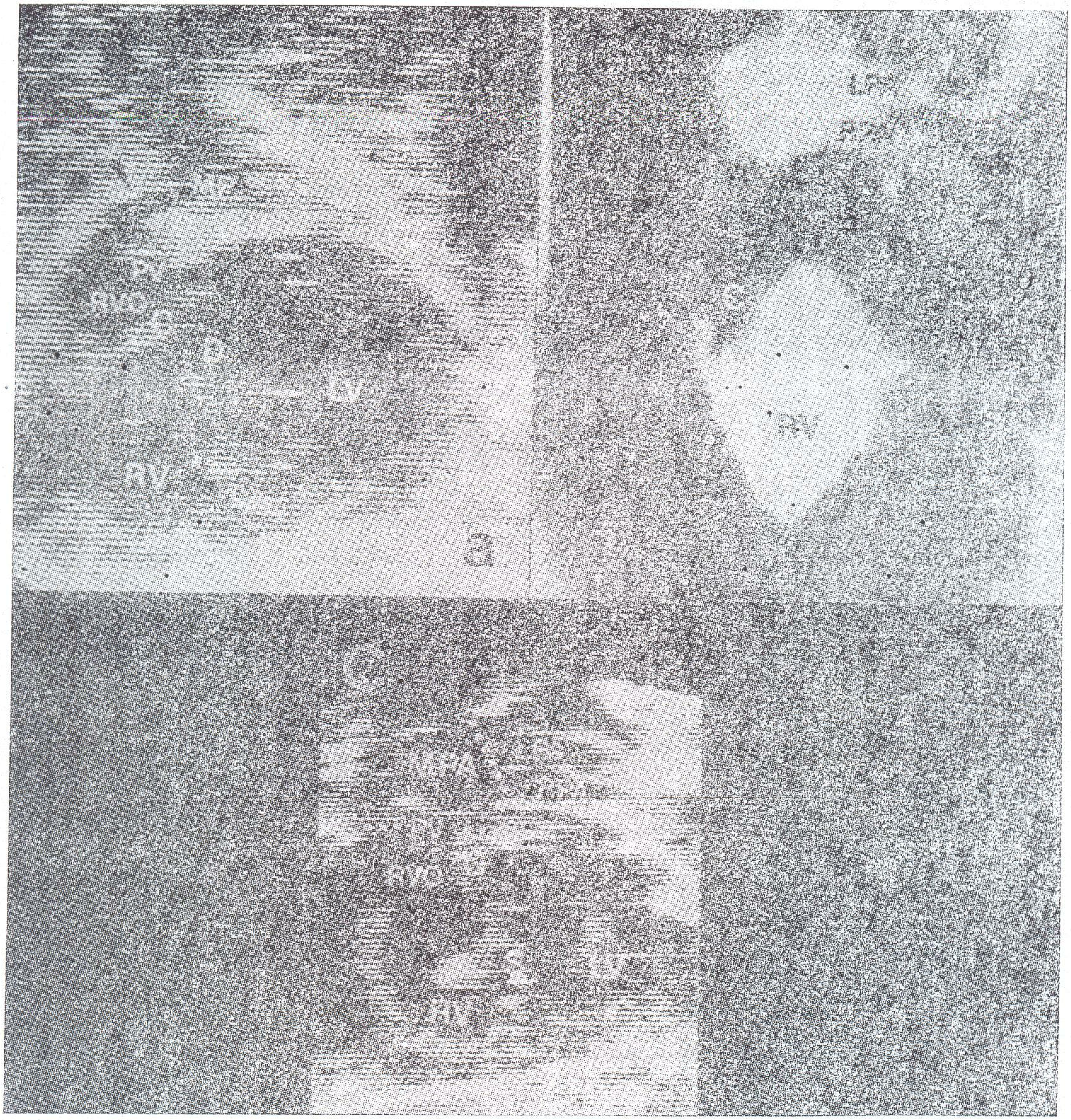

Fig. 5. *A*, *B*, Lateral view right ventricular angiogram in Case 5 *B*, and corresponding sagittal plane sector scan obtained from subcostal position. *C*, sagittal plane subxiphoid sector scan from a patient with pulmonary valve stenosis and intact ventricular septum (not included in our study). Note moderate narrowing of the supravalvar region of the main pulmonary artery (arrows in A and B), compared to patient with isolated pulmonary valve stenosis, C, where the supravalvar region of the main pulmonary artery is not obstructed. Quantitation of the main pulmonary artery is shown. The main pulmonary artery and pulmonic valve annulus dimensions were measured in this view ([illegible]).

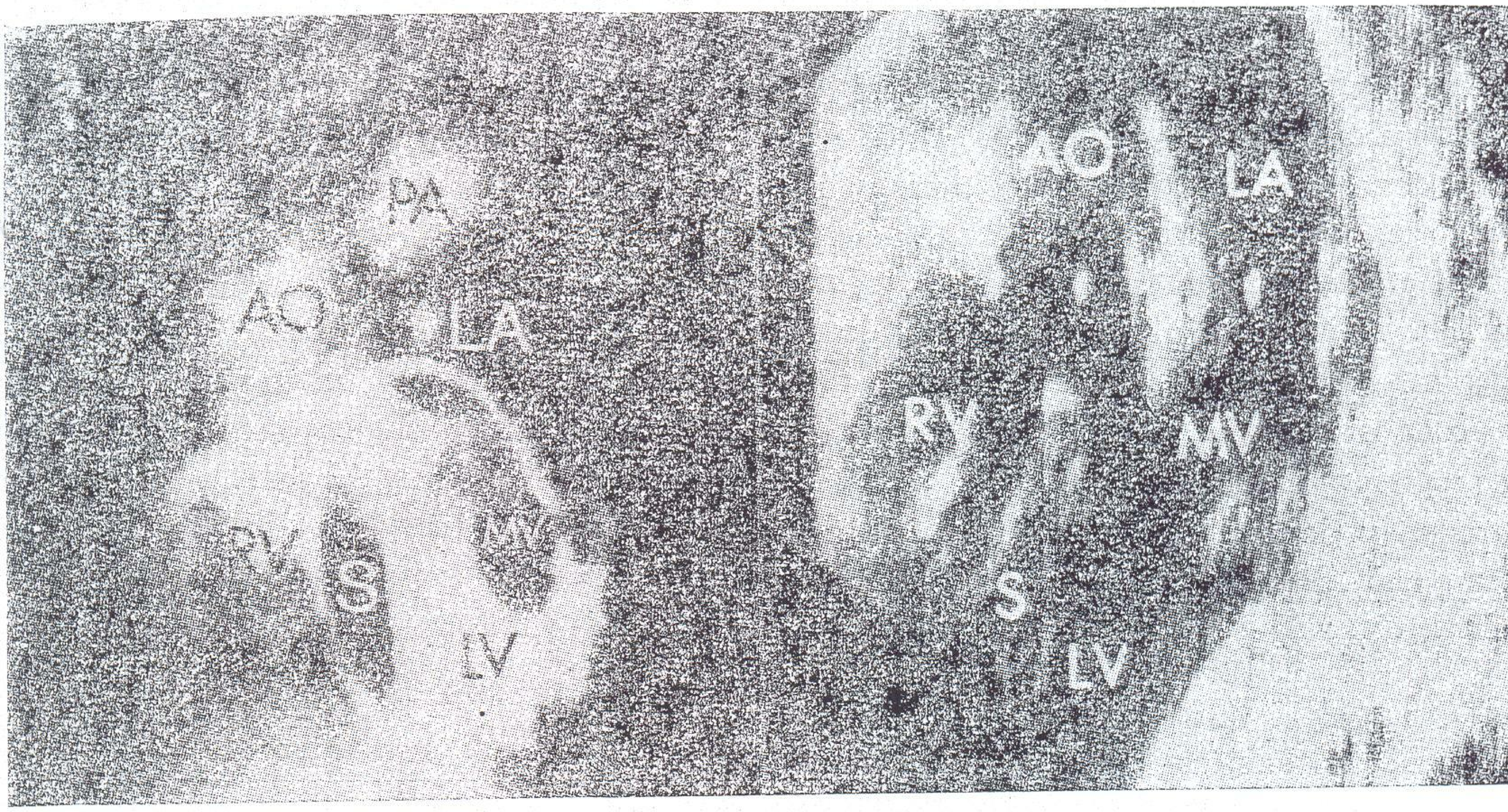

Fig. 6. A, left ventricular (LV) cineangiogram (left anterior oblique view) in Case 2. Note overriding of aorta (AO) above the ventricular septum (S). *B*, correlative left ventricular long axis sector scan from parasternal transducer position demonstrates the features of overriding aorta.

from images obtained from the suprasternal transducer position and the pulmonary valve annulus diameter was measured from sector images obtained from the subxiphoid transducer position (Fig. 5). All measurements were made in peak systole. Angiographic measurements for comparison were obtained from right ventricular anteroposterior angiocardiograms.

Results:

The two major anatomic features of tetralogy of Fallot are, overriding of the aorta above a ventricular septal defect and the ventricular septum, and a hypertrophied and obstructing infundibulum. The position and size of the ventricular septal defect and overriding aorta could be seen in all patients in the long axis, subxiphoid and high left parasternal [illegible]-nsional echocardiographic views (Figs. 1,3,6). The extent of aortic overriding, the size of the ventricular septal defect and the size of both ventricles could be assessed in these views. From the subxiphoid position a sagittal plane view imaged the right ventricle extending from the sinus to the pulmonary artery as a crescent anterior to a circular left ventricle. The obstructing hypertrophied infundibular muscle (crista supraventricularis medially and right ventricular wall laterally) was seen as a thick transverse echo mass with the infundibular chamber above and ventricular septal defect below (Fig. 3,5). Anterior deviation of the crista supraventricularis could also be appreciated on this view (Fig 5a). The pulmonic valve motion and annulus could be viewed through systole and diastole and the size and morphology of the pulmonary valve and main pulmonary artery could also be assessed.

Echo contrast studies in 2 patients confirmed the identity of these structures as viewed from the subxiphoid transducer position (Fig. 4). With injection of indocyanine green in the right ventricle there was opacification of the right ventricular chamber anterior to a circular left ventricle. The position of the ventricular septal defect was indicated by systolic spilling of the echo contrast material into the left ventricle. The progress of the contrast bolus from the right ventricle was delayed at the evel of the infundibulum and the hypertrophied infundibular bands were viewed as negative contrast (Fig. 4D).

From a high, left parasternal position the image in normal subjects showed the left ventricular apex pointing to the left and aorta superiorly and rightward (Fig. 1A). In patients with tetralogy of Fallot, the aorta was seen to override the ventricular septum above the ventricular septal defect (Fig. 1B). With superior and leftward tilting of the echo beam in normal subjects, the right ventricular outflow portion, pulmonary valve annulus and right pulmonary artery superior to the left atrium could be visualized (Fig. 1C). In patients with tetralogy of Fallot, with superior and leftward transducer tilting the hypertrophied infundibular muscle could be seen (Fig. 1D) in the right ventricular outflow tract.

The right pulmonary artery, extending from its origin to first branching point, was imaged in all patients using the suprasternal transducer position with the sector echo beam oriented in the coronal plane. In the two patients with right aortic arch (Cases 7 & 12), the aortic arch was correctly identified prospectively from the suprasternal imaging (Fig. 2). A slight clockwise rotation from the coronal plane imaged the arch descending over the right side as contrasted to a greater counterclockwise rotation of the transducer required to obtain imaging of the left aortic arch. The left pulmonary artery could be imaged at times anterior to the descending aorta from the suprasternal transducer position with a leftward and anterior tilting of the sector beam plane. The left pulmonary artery was more often visualized using a short axis view from the parasternal transducer position. Quantitation of the left pulmonary artery was not attempted since the images were obtained with an excessively oblique beam angulation.

The echo measurements of the right pulmonary artery diameter and the pulmonic valve annulus diameter showed relatively close correlation with the angiographically obtained measurements. The echocardiographic mean peak systolic echo diameter of the right pulmonary artery was 8.9±3.4 mm and angiographic mean diameter was 9.5±3.6 mm. The mean echo measurement of the pulmonary valve annulus diameters was 11.9±2.5 mm and the mean angiographic diameter was 11.3±2.3 mm (Table I). Additionally, in Cases 5 and 10 significant supravalvar stenosis of the main pulmonary artery was prospectively diagnosed from the echocardiograms (Fig. 5A).

Discussion:

Our study showed that two-dimensional echocardiography can accurately diagnose the important anatomic features of tetralogy of Fallot. Identification of echocardiographically obtained images was confirmed by echo contrast studies, angiographic and pathologic correlations. Overriding aorta and ventricular septal defect was always evident. The infundibular stenosis was seen as a thick transversely oriented echo mass constituted medially by crista supraventricularis and laterally by the right ventricular free wall. The size of the infundibular chamber was appreciated as the distance between the crista supraventricularis and the pulmonary valve annulus. Hypoplasia of the right ventricular outflow tract associated with anterior deviation of the crista supraventricularis could be assessed. The plane of the pulmonary valve annulus was displaced anteriorly in contrast to the normal heart where the pulmonary valve annulus plane has a minor angulation with the right ventricular outflow tract axis (Fig. 5C). Pulmonary valve stenosis was suggested by doming of the valve and continuous intraluminal visualization of the valve leaflets during systole. Correlative diameter measurements from the echo images and angiography of the pulmonary valve annulus and right pulmonary artery showed that echocardiography provided a reliable assessment of these structures. Such measurements are of importance in preoperative assessment and planning. The left pulmonary artery was considerably more difficult to evaluate although it could be visualized often from the short axis view with a left parasternal transducer position and at times from the suprasternal transducer position. Supravalvar narrowing or stenosis of the main pulmonary artery was well visualized from the subxiphoid as well as the parasternal short axis transducer positions.

Our study showed that two-dimensional echocardiography in addition to providing an accurate diagnosis of the anatomic features of tetralogy of Fallot can provide useful qualitative and quantitative assessment of the pathology.

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