M-Mode Echocardiographic Experience in Congenital Heart Disease at NICVD

By

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M-mode echocardiography has added a new dimension to the diagnosis of congenital cardiac malformations. Diagnostic echocardiographic features of various congenital lesions have been well documented. (I-6) The purpose of the present report is to analyse our M-mode echocardiographic experience, qualitative as well as quantiative, with congenital Heart Disease during the year 1980-81 at the NICVD, Karachi.

Material/and/Methods.

Two hundred and ninty one patients with various congenital cardiac malformations were studied by single crystal M-mode echocardiography. The age ranged between 10 Days to 55 years. Echocardiographic examination was done in supine position without sedation in older children and with chloryl hydras sedation in infants. The commercially available Ekoline Echocariograph was used; 2.25,3.0 and 5.0 MHZ transdures were used depending upon the age of the patient. New born babies required 5.0. MHZ transducer, older children and adults required 3.0 and 2.25 MHZ. The transducer was placed at the 3rd/4th intercostal space Para Sternally, however the optimal place on the precordium was searched for the best Echo imaging in each patient. Aortic and or mitral Valve echoes were first obtained and all other structures were searched with reference to these echoes. The pulmonic valve echoes were looked for in each instance and were generally best recorded at one or two intercostal space above where mitral valve was imaged.(3)

The records were obtained on a light sensitive paper at 50mm paper speed or alternately pollariod films were used to photograph the echo images. Continuous Electrocardiographic recording was made during the study. The anteroposterior dimension of the aorta was measured from outer edges of the aortic wall echoes at end systole and the left atrial dimen sion were measured form the posterior wall echo of left the atrium and posterior edge of the posterior aortic wall echoes at end systole Fig. 1.(5) The left ventricular outflow tract was measured as an anteroposterior dimension between the leading edge of the first recognisable closure point of the mitral valve echo below the aortic root and the left ventriculr endocardium of the ventricular septum Fig 2.(5) The end-

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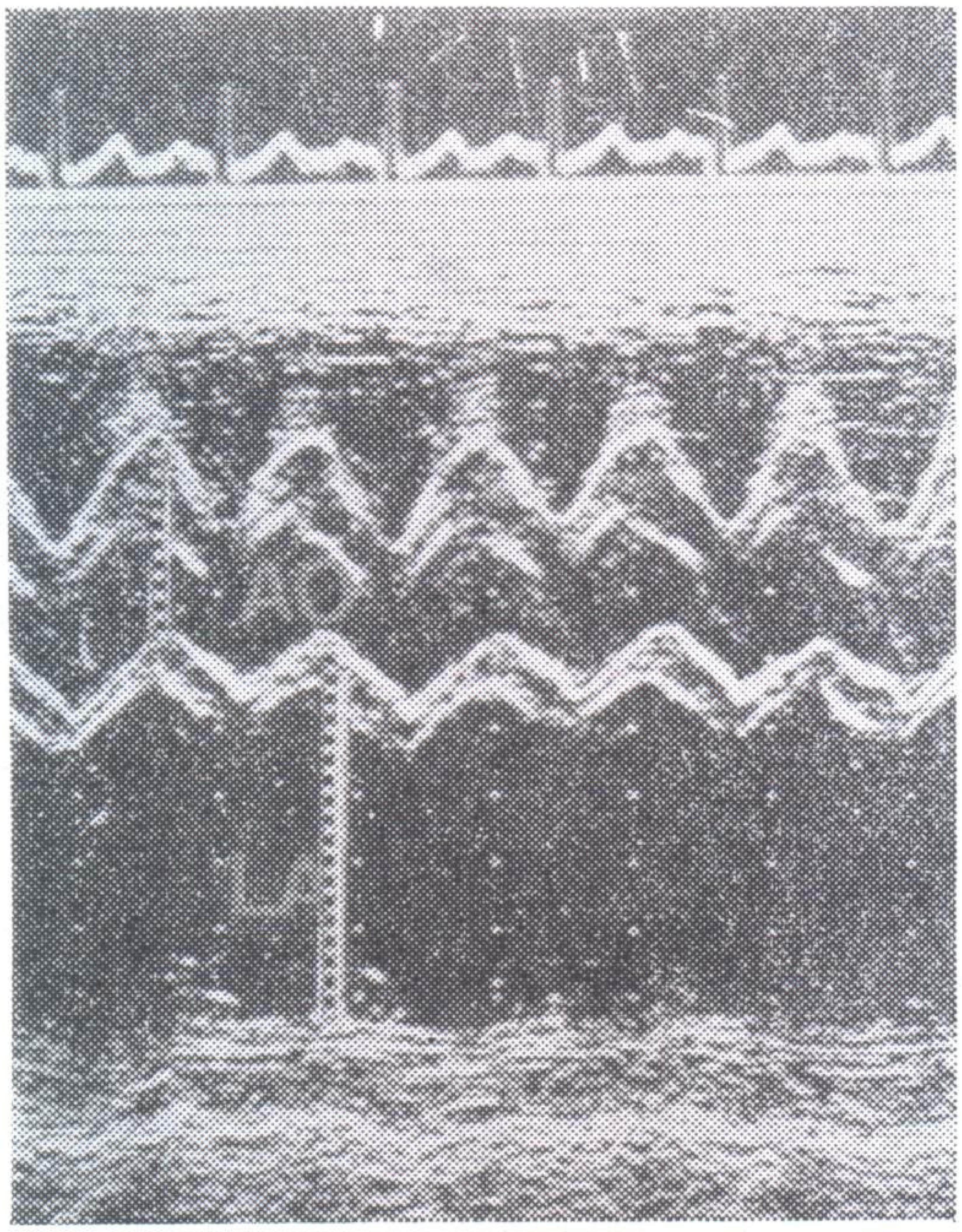
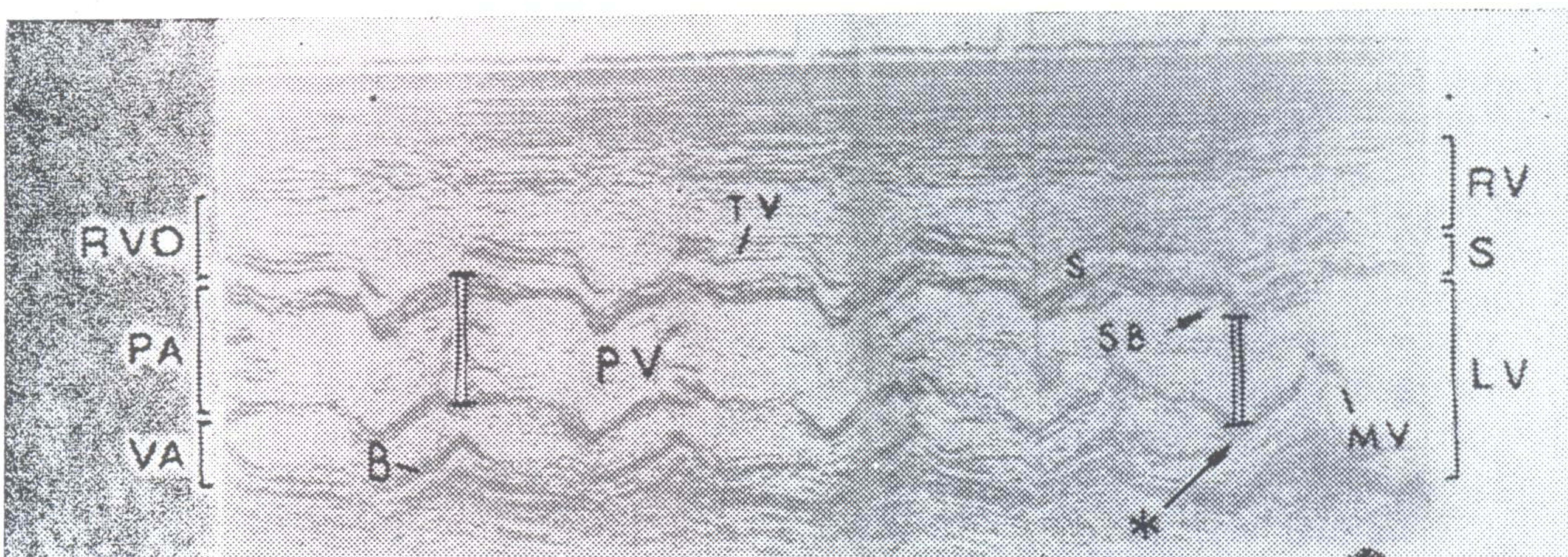


Fig. 1: M-mode echogram at aortic root (Ao), Right ventricular outflow tract lies anterior to aorta and left atrium (LA) behind it. The Antoroposterior dimension of the AO are measured between the outer odges of its anterior and posterior wall echoes in end systole (white bar) while the LA dimension is measured between the outer edge of the posterior Aortic wall echo and the posterior wall of the left atrium (White bar).

diastolic septal thickness was measured between the endocardial surfaces and the posterior wall thickness of the left ventricle was measured form the left ventricular endocardium to the anterior edge the pericardium-epicardium echo complex, at the time of R wave of the Electrocardiogram. The end-diastolic dimension of the left ventricle ventricle was measured between the leading adge of the posterior wall endocardium and inner edge of the septal endocardium at the time of R wave of the Electrocardiogram. End systolic dimension was measured as the smallest dimension. (7) Fig. 3.

Fig. 2: Echo scan from pulmonary artery (PA) to left ventricle (LV) in a patient with Complete transposition of the great arteries after Mustard operation. The left ventricular out flow tract was measured between the first recognizable closure point of the Mitral valve (MV) below the pulmonic root (PA) and the septal endocardium (S) (astrisk; Bar). Abbreviations. R.VO=right ventricular out flow tract; VA venous atrium; B—Intra-atrial baffle, PV= pulmonary Valve, TV=tricuspid Valve S= septum, SB=early systolic posterior septal bulging. (arrow). ↓



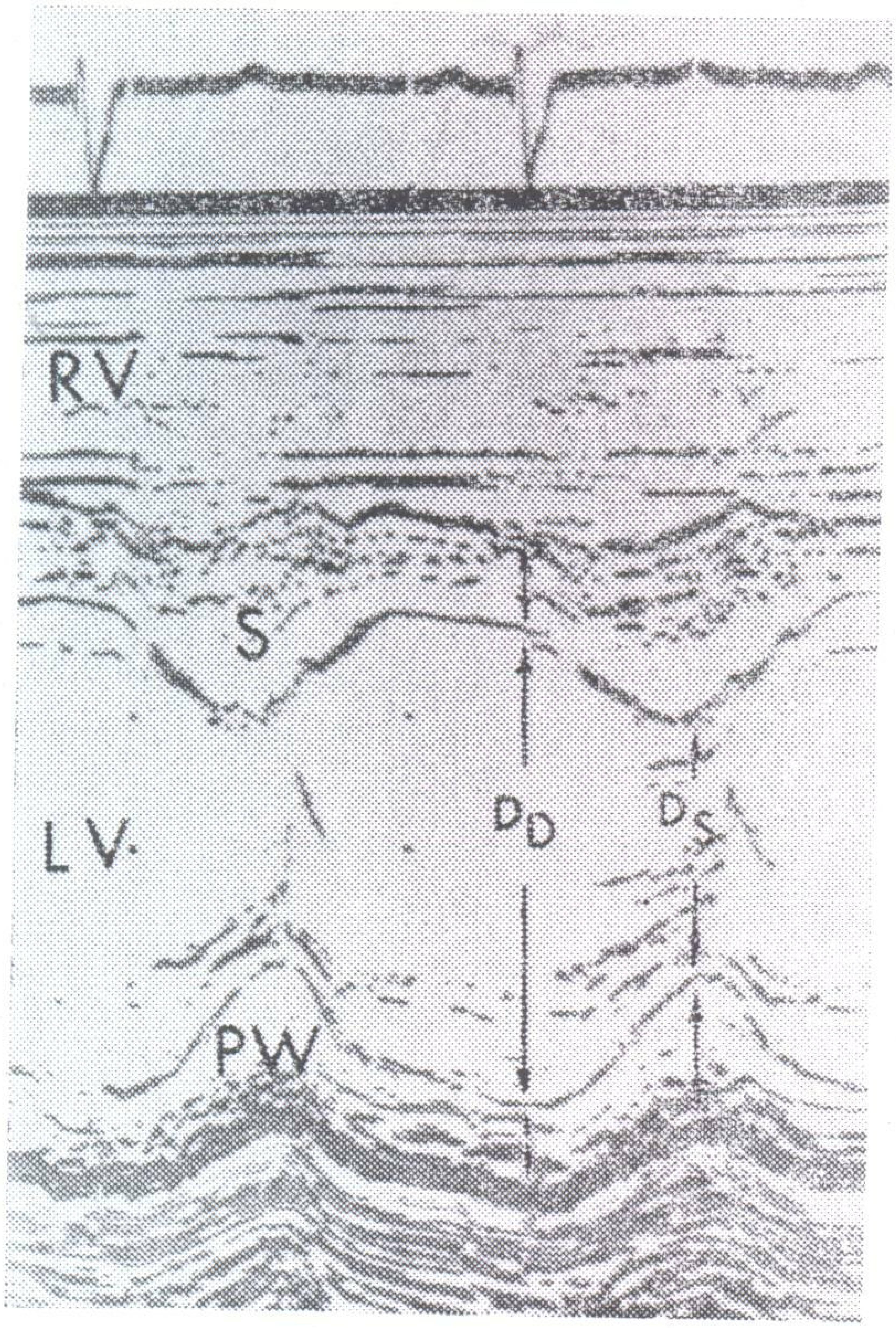


Fig. 3: Left ventricular (LV) echocardiogram obtained at the tip of the mitral valve. Enddiastolic wall thickness of the ventricular septum (S) was measured between the left and right ventricular endocardium at the time of the R wave of the electrocardiogram (arrows) The end-diastolic posterior wall thickness (PW) was measured between the endocardium and inner (leading) edge of epicardium-pericardium echo; The diastolic anteroposterior dimen sion of the left ventricle (DD) was measured between the septal and posterior wall end-ocardium and end systolic dimension (DS) as the smallest dimension during systole. RV= right ventricle. Note normal motion of the ventricular septum. During systole both Septum and posterior wall thicken and move toward each other with Septum moving posteriorly.

The pre ejction period of the pulmonic valve was measured between the Q wave of the Electrocardiogram and the opening point of the pulmonic valve echo. The ejection period was measured between opening to the closure point of the Pulmonic valve echo. The result was expressed as PEP/ET ratio (8) (Fig. 4) Right ventricular end diastolic dimensions were measured at the same time and site as the left ventricle.

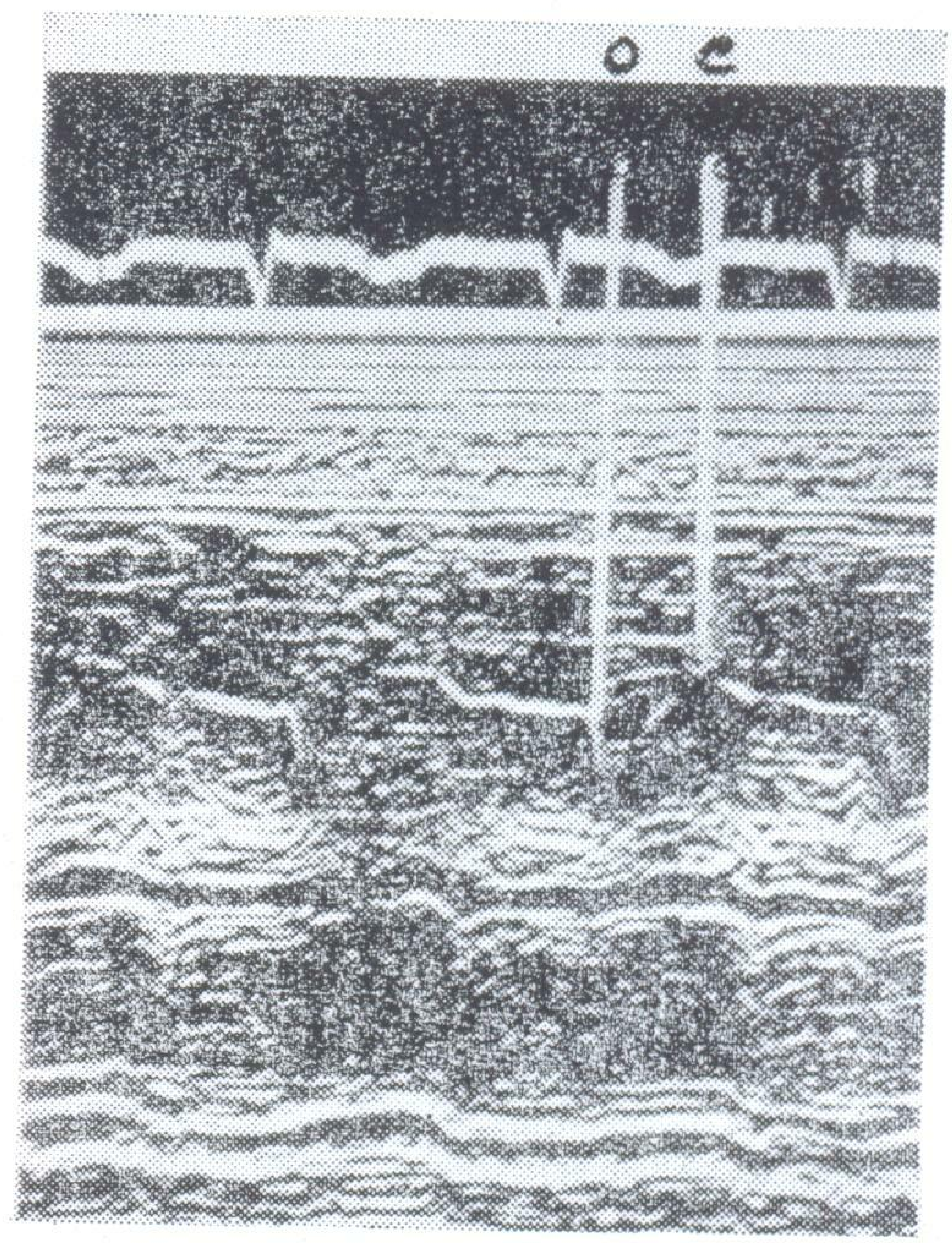


Fig. 4: Pulmonary valve echogram abtained from second left intercostal space with transducer directed anteriorly and left ward (Toward the left shoulder). The preejection period (PEP) was measured between the qwave of the Electocardiogram and the opening point of the pulmonic valve (O.bar.). The ejection time (ET) was measured between the opening and closing point of the pulmonic valve (between 0-c Bar) The result was expressed as PEP/ET ratio.

Result:

One hundred and eighty eight patients had acyanotic lesions (Table I). Largest number of patients (75/188). had ventricular septal defect (VSD). Qualitatative diagnosis of V.S.D. was based on. 1) Increased dimension of the left atrium and left ventricle, and 2) exagg erated motion of the left ventricular posterior and septal walls Fig 5. The magnitude of the left to right shunt was assessed by the LA/AO ratio (9) A ratio greater than 1.2 suggested significant left to right shunt. (Table II). The pulmonary arterial pressure was evaluated by the systolic time intervals of the pulmonic valve (8). The left atrium/aorta .ratio could be measured in 71 patients and was $\geq$ 1.2 (mean 1.36+0.19) in 29/71 indicating a large shunt, and in 42/71 the LA/AO ratio was $\leq$ 1.2 suggesting a small shunt (9). The PEP/RVET ratio was measured in 45 patients and was $\geq$ 0.28 (0.28+0.09) in 13 and $\leq$ 0.28 (mean 0.18+0.04) in 32/45. Patients with PEP/RVET $\geq$ 0.28 had cardiac catheterization and pulmonary arterial hypertension was Confirmed in all. Twelve patients with VSD had associated PS table III. PEP/RVET ratio

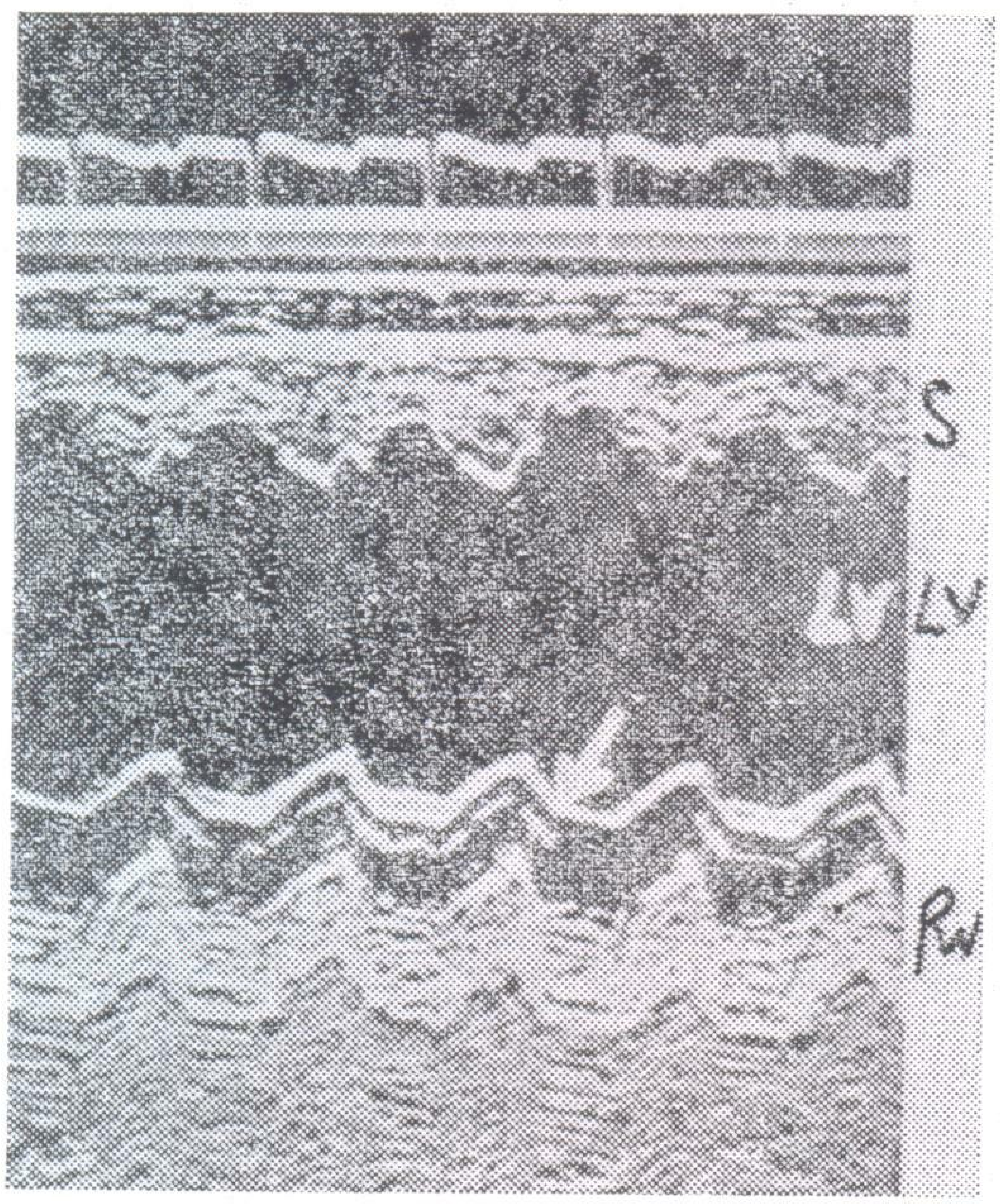


Fig. 5: Left ventricular echogram at the level of the cordae tendinae (arrow). In a patient with large left ventricular Volume overload. Note enlarged left ventricle. (LV) and exagerated motion of the ventricular septum (S) and posterior wall (PW).

Table I. Echocardiographic Study in 188 Acyanotic Children with C.H.D.

Lesions	*Age (year) mean (Range)*	*No.*
V.S.D.	5.6(0.3-18)	75
A.S.D.II°;	13.3(2-55)	48
A.S.D.I°;	5.0(1.5-10)	3
P.D.A.	5.4(0.4-22)	22
A.S.V.	11.2(5-13)	18
P.S.V.	5.3(0.6-9)	10
A.V. Canal	5.0(5-10)	6
Ebstein's anamaly	10 (10-20)	3
L-Transp. with V.S.D.	7.3(2.12)	3
		188

Abbreviations.

V.S.D. —Ventricular septal defect.
ASDII° —Atrial Septal defect, secundum.
A.S.D.I° —Atrial septal defect, Primum.
P.D.A. —Patent ductus Arteriosus
A.S.V. —Aortic stenosis, valve
P.S.V. —Pulmonic stenosis, valve
A-V Canal —Atrio - Ventricular Canal defect.
L-T.GA —Corrected transposition.
CHD —Congenital heart disease.

Table II. Echocardiographic data of 75 Patient with ventricular septal defect.

Age (years)	5.6±4.3	75
RVEDD (cm)	1.4±1.46	75
RVDWT (cm)		
Simple V.S.D.	0.39±0.17	34
with P.A.H.	0.69±0.22	17
LVEDD (cm)	3.6±0.66	71
PEP/RVET		
>0.28	0.38±0.09	13
<0.28	0.18±0.04	32
LA/AO		
>1.2	1.36±0.19	29
<1.2	0.95±0.13	42

Abbreviations.

RVEDD —Right ventricular end diastolic dimension.

RVDWT —Right ventricular end diastolic wall thickness.

PAH —Pulmonary arterial hypertension..

LVEDD —Left ventricular end diaslotic dimension.

PEP/RVET — Pre Ejection period / Ejection Time:

LA/AO —Left atrium/Aorta.

in these was <0.28 (0.18+0.04) and the mean LA/AO ratio was 0.95+0.13. The right ventricle was hypertrophied and confirmed the clinical impression of right ventricular outflow (RVO) obstruction. Table III. In two cases Marked Flutter of the pulmonic valve during systole was noted, further coroborating the evidence of RVO abstruction.

Table III. Echocardiographic data on twelve Patients with V.S.D. and Pulmonic stenosis.

LA./AO Ratio	0.95+0.13	12
PEP/RVET Ratio	0.18+0.04	12

Abbreviations.

AS in Table II.

Forty eight patients had Atrial Septal defect (A.S.D.), Table IV. The Echocardiograms showed a small left atrium, and paradoxic motion of the interventricular septum(10) Fig. 6. The right ventricle was enlarged, indicated by increased the RVEDD/

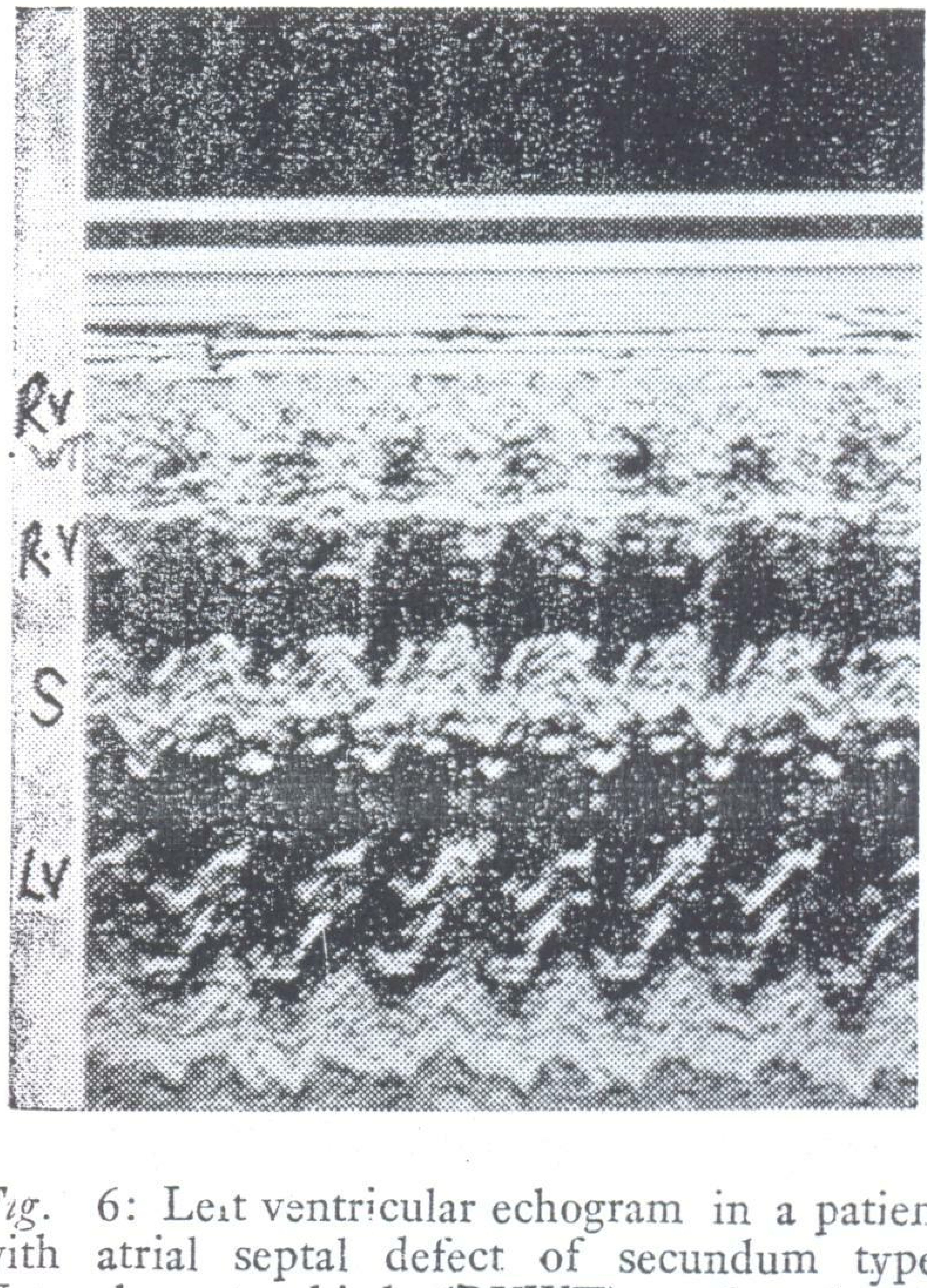


Fig. 6: Left ventricular echogram in a patient with atrial septal defect of secundum type. Note hypertrophied (RVWT) and enlarged right ventricle (RV) due to ventricular Volumeover load. The ventricular septm (S) shows paradoxic motion. i.e the septum thickkens and moves anteriorly during systole.

Table IV. Echocardiographic data of 48 patients with Atrial septal defect (A.S.D.II).

Age (years)	13.3±12.9	48
RVEDD cm	2.5± 0.9	46
RVDWT cm	0.6± 0.3	38
RVEDD/LVEDD	0.73± 0.25	44
<0.3	0.24± 0.04	2
>0.3	0.77± 0.23	42
LA/AO Ratio	0.97± 0.12	31
PEP/RVET		
With PAH >(0.28	0.32± 0.03	4
Without PAH <(0.28	0.15± 0.06)	25

Abbreviations.

A.S.D. II	=Atrial septal defect secundum.
RVEDD	Right venticular end diastolic dimension.
RVDWT	=Right venticular diastolic wall thickness.
LVEDD	=Left ventricular end diastolic dimension.
LA/AO Ratio	=Left atrium/Aorta ratio.
PEP/RVET	=Pre ejection period /Right Ventricular ejection time ratio.
PAH	=Pulmonary artery Hypertension.
±	=One standard Deviation.

LVEDD ratio > 0.3 in 42/48 (mean 0.77±0.25) (10). In 2 patients the RVEDD/LVEDD ratio was < 0.3 suggesting normal size RV and small L-R shunt. Elevated pylmonary arterial pressure was suggested in 4 patients by increased value of PEP/RVET ratio>0.28 (mean 0.32±0.03). These were older patients and were Confirmed to have pulmonary arterial hypertension at Cardiac Catheterization.

Clinical diagnosis of patent ductus arteriosus was made in 22 patients. (Table V). The size of left to right shunt was estimated by LA/AO ratio (16). The shunt was large in II/21 with LA/AO ratio of 1.4±0.08 and small in 10/21; LA/AO ratio 0.9±0.06. Pulmonary artery hypertension was indicated in 5/16 by an elevated PEP/RVET ratio>0.28. The PEP/RVET ratio was<0.28 in 11/16.

Table V. Echocardiographic data of 22. patients with patent ductus arteriosus.

Age (years)	5.4 ±5.6	22
LVEDD (cm)	4.3 ±5.6	22
PEP/RVET Ratio		
<0.28	0.19±0.03	11
>0.28	0.32±0.04	5
LA/AO		
>1.2	1.4 ±0.18	11
<1.2	0.9 ±0.06	10

Abbreviation.
As in Table II.

Semilunar valve stenosis was present in 28 patients, 18 had aortic valve and 10 had pulmonic valve stenosis. (Table VI & VII) The assessment of pulmonary valve stenosis was made by estimating the PEP/RVET ratio which (Table VII) was less than <0.28 in all. The right ventricle was hypertrohied. (RVDWT 0.7+0.04 cm).

Table VI. Echocardiographic data of 18 Patients with Aortic valve stenosis.

Age (years)	11.2±4.8	18
LVEDD (cm)	3.6±0.6	18
LVDWT (cm)	0.94±0.3	18
h/r ratio	0.6 ±0.1	18

Abbreviations.

h/r —Left ventricular posterior and septal Wall diastolic thickness mean/One half LVEDD.

Table VII. Echocardiographic data of 10 Patients with Pulmonary valve stenosis.

	Mean±SD	*No.*
Age (years)	5.3±3.8	10
RVDWT (cm)	0.7±0.4	8
LA/AO ratio	0.9±0.2	6

Abbreviations.

As in previous Tables.

Aortic valve echoes were not helpful in evaluating the severity of aortic Stenosis. However the h/r ratio i.e. the mean diastolic thickness of left ventricular Posterior and septal wall (h)/one half the L.V. end diasolic dimenion (r), was used to be evaluate the severity of the aortic stenosis Fig. 3. (Table VI). h/r ratio less than 0.4 was considered normal. The left ventricular pressure was estimated using the method of AZIZ et by using regression equation; L.V.P.=312 x h/r (+22.8 mm Hg (II) Moderate to severe left ventricular hypertrophy was noted in II/18 patient with mean h/r ratio of 0.6 (LVP=165±63) and in 3/18 L.V.H. was considered normal by h/r ratio (mean h/r =0.3+0.02). (Table VI). The h/r ratio data was not available 4/18 patients.

Six patients were diagnosed to have Attrio-ventricular canal defect by demonstration of characteristic feature of Common anterior A-V leaflet coursing the ventricular septal defect, enlarged and hypetrophied right ventricle Fig 7. (12). In three patients Ebstein's anomaly was diagnosed. (Table I) The characteristic finding were an enlarged right ventricle, paradoxic ventricular septum and delayed tricuspid valve closure greater than 60 m.s. after the mitral valve closure. Additionally large sail like excusion of the tricuspid valve and leftward shifting of the tricuspid valve were helpful in the diagnosis.(13) L-Transposition of the great arteries with ventricular septal defect was noted in 3 patients. Aorta was anterior and leftward, recognised. by delayed opening of its semilunar valve Compared with the posterior pulmonary valve. Table I.

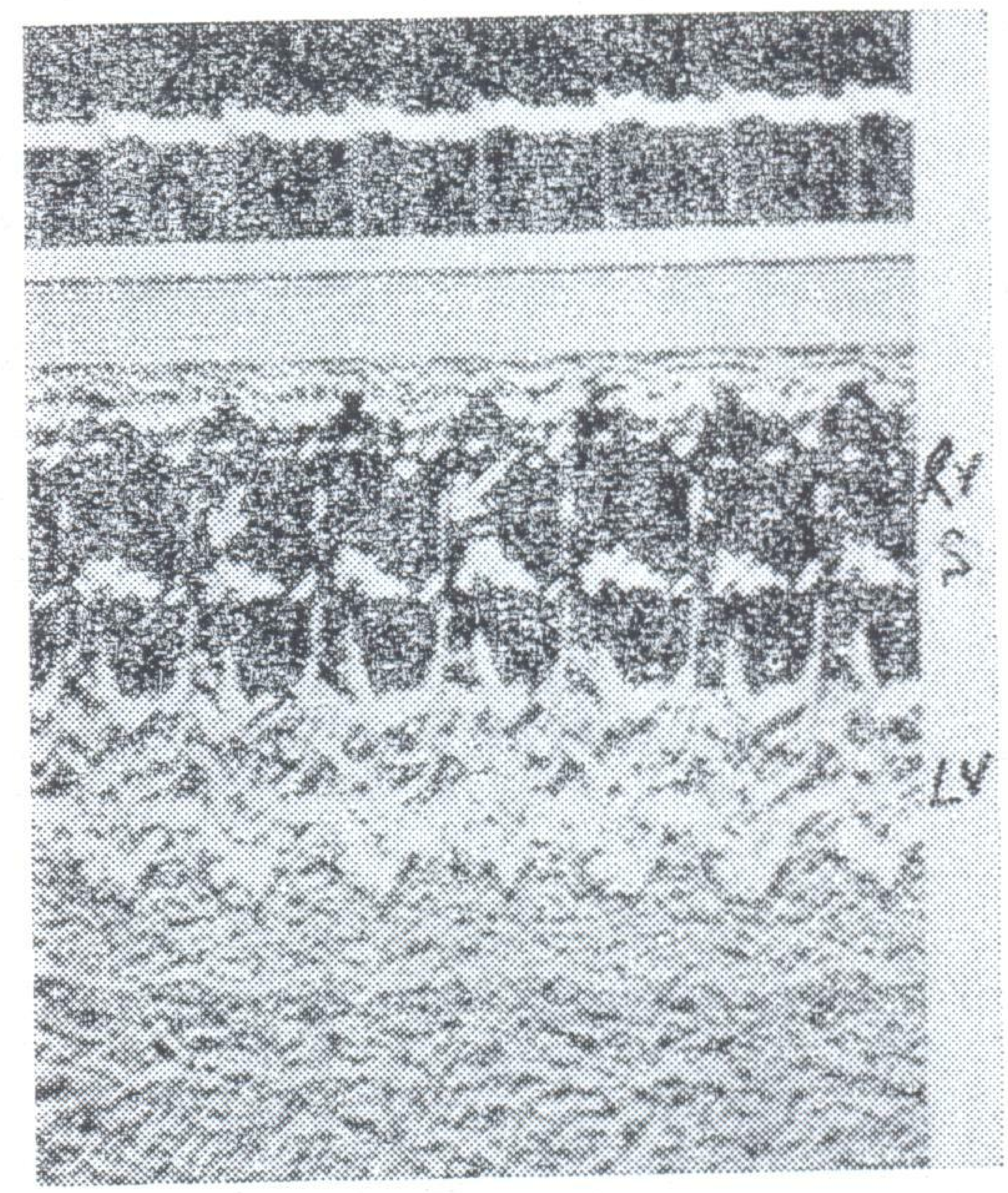


Fig. 7: Left ventricular echogram in a patient with atrio-ventricular canal defect. Note enlarged right ventricle (RV): ventricular septal defect is seen through which the echo of the common anterior leaflet of mitral valve (M.V.) courses from the left ventricle (L:V.) to the right ventricle (arrow).

Cyanotic heart disease was present in 103 patients, 76/103 had Tetralogy of Fallot (TOF) Table VIII. The characteristic features of TOF

Table VIII. Echocardiographic Study in 103 patients with Cyanotic C.H.D.

Lesion	*Age (Yrs) mean (Range)*	*No.*
T.O.F.	5.1 (0.0.1-18)	76
Truncus Type I	0.3	1
TGA with V.S.D.+ LVOTS	5.6 (0.3-15)	15
T.G.A. with V.S.D.	0.35(0.3-0.4)	2
Single Ventricle	0.7 (0.4-0.9)	5
D.O.R.V.	0.75(0.5-1.5)	3
Mitral Atresia	10(days)	1
		103

Abbreviations.
T.O.F. —Tetralogyaf Fallot.
TGA —Complete transposition of great arteries.
DORV —Double outlet right ventricle.
L VOTS —Left ventricular outflow Tract stenosis.

were overriding of the aorta across the ventricular septum above the ventricular septal defect, small left atrium and markedly hypertrophied right ventricle (0.73 0.2 cm) Fig 8 (14) Pulmonic valve was imaged occasionally and in 2 instances marked systolic flutter of the pulmonic valve was noted suggesting infudibular stenosis (Table IX). Truncus arteriosus commumis was diagnosed in one infant by

Table IX. Echocardiographic data of Patients with Tetralogy of Fallot

Age (years)	5.1 ±4.9	76
RVDWT (cm)	0.73±0.27	55
LVEDD (cm)	2.9 ±0.12	64
AO (cm)	2.3 ±0.6	65

Abbreviations.
As in previous Tables.

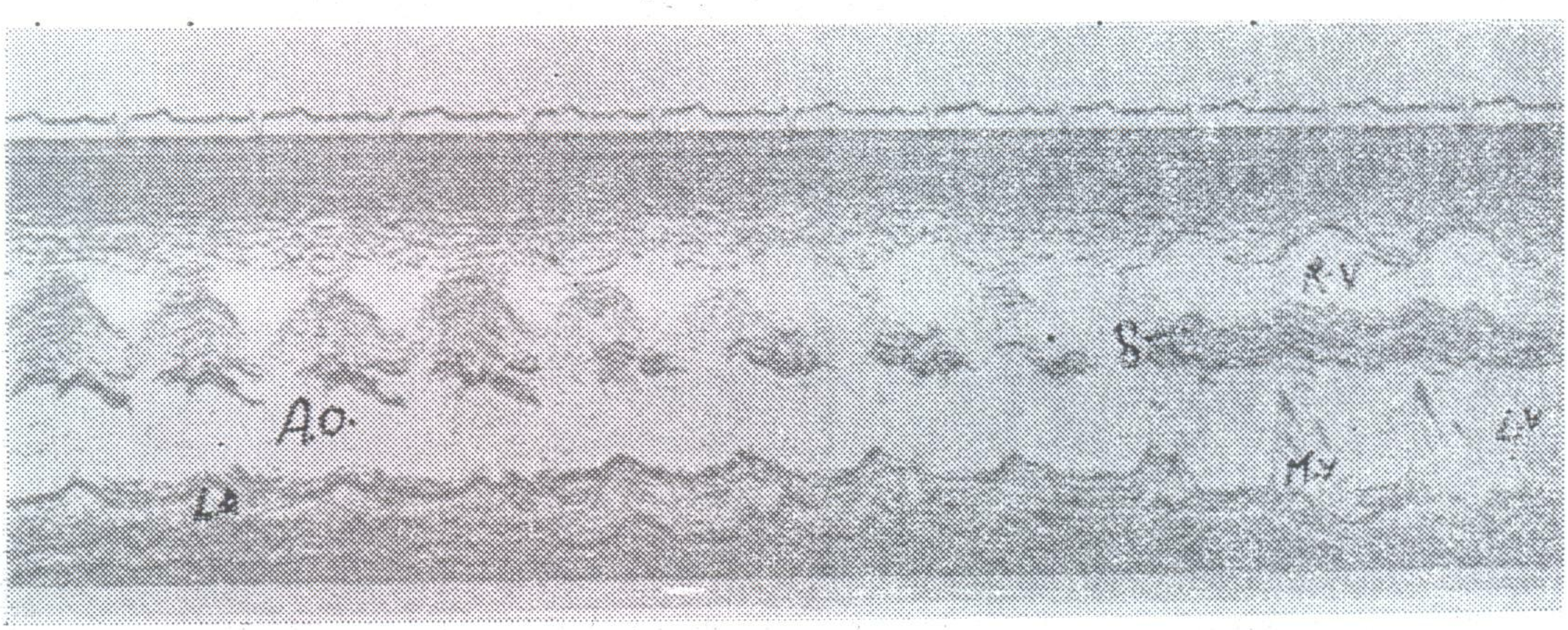


Fig. 8: Echo sweep from aorta (AO) to left ventricle (LV) in a patient with Tetralogy of Fallot. The left atrium (LA) is small and aorta is large. Inerrupted septal echoes are seen below the aortic root representing ventricular septal defect. AO is over riding the ventricular septum (S) above the ventricular septal defect. Right ventricle (RV) is markedly hypertophied.

demonstrating an overriding Aorta, large left atrium and combined ventricular hypertrophy. Complete Transposition of the great arteries was diagnosed in 17 patients Table VIII. The diagnosis of transposed great arteries could be made by imaging an anterior aorta to the right of the posterior pulmonary artery. Normally pulmonary artery is anterior and is imaged to the left of posterior aorta (3). Delayed opening of the anterior semilular valve (Aorta) compared to the opening of the post semilunar valve (PA) confirmed an anteriorily located aorta in all instances (15) Fig. 9. In addition to transposed arteries Ventricular septal

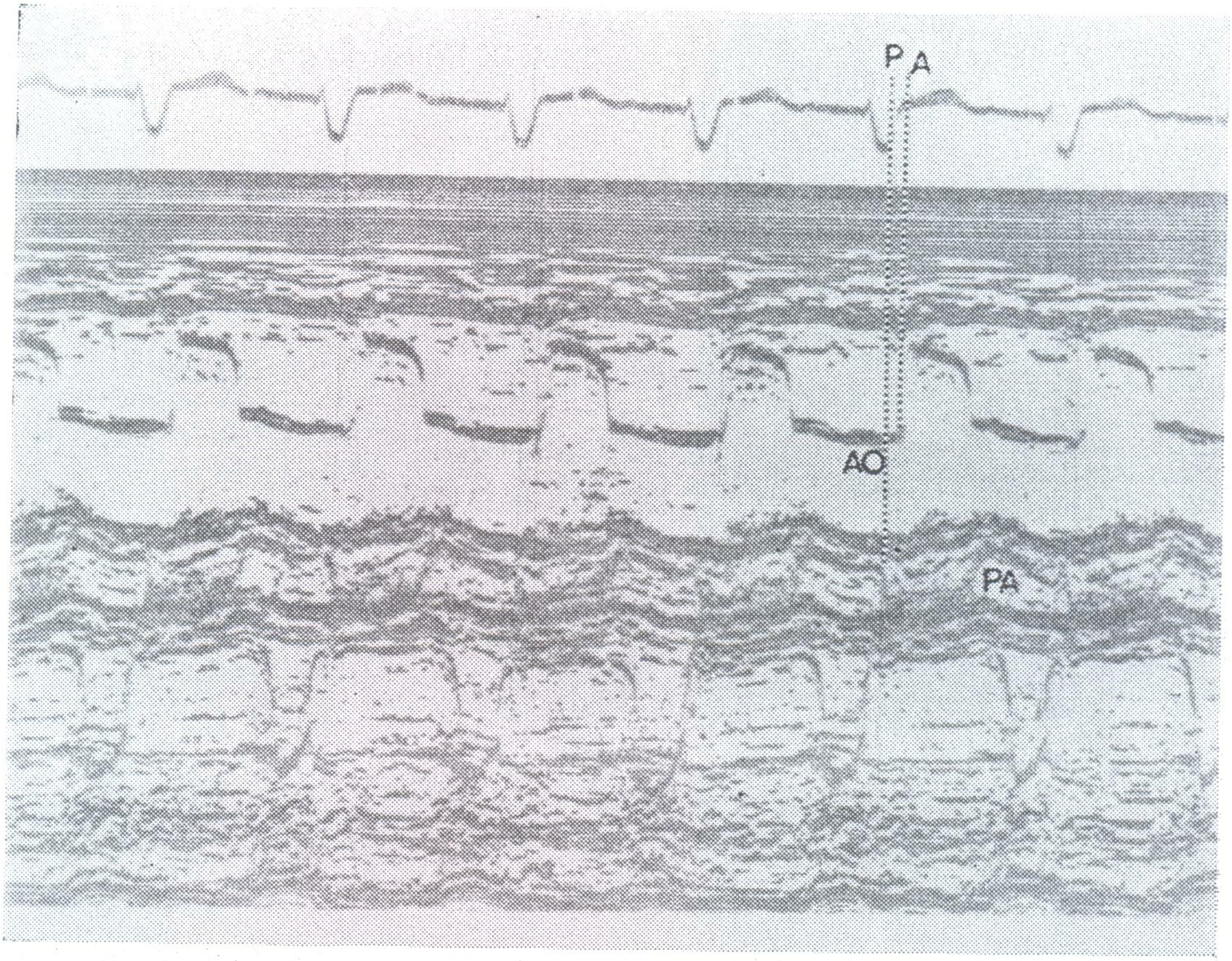


Fig. 9: Echocardiogram in a patient with Complete transposition of the great arteries. Both great vessels are imaged with a large anterior aorta (AO) recognised by delayed opening of its Semilunar valves (Line A) compared to posterior pulmonary artery (PA) with early opening of its Semilunar valve (Line P) Note the interval between the openings of the two semi lunar valves is shown by the black lines. (Line P is drawn at the opening of the posterior pulmonary artery valve which opens earlier than Aortic valve. A-line is drawn at the opening point of the anterior aortic valve, which opens later than the pulmonic valve).

defect and left ventricular outflow tract obstruction was imaged in 15 patients Fig 10. The left ventricular outflow tract (LVOT) was significantly narrowed suggesting a fixed type obstruction of (L.V.O.T.). ventricular Septal defect could at times be seen as interrupted were imaged relative to an anterior right ventricle. Mitral valve atresia was diagnosed in one 10 day old infant. by demonstrating a linear echo of the mitral valve instead of a normal mitral Valve, and hypoplastic left ventricle.

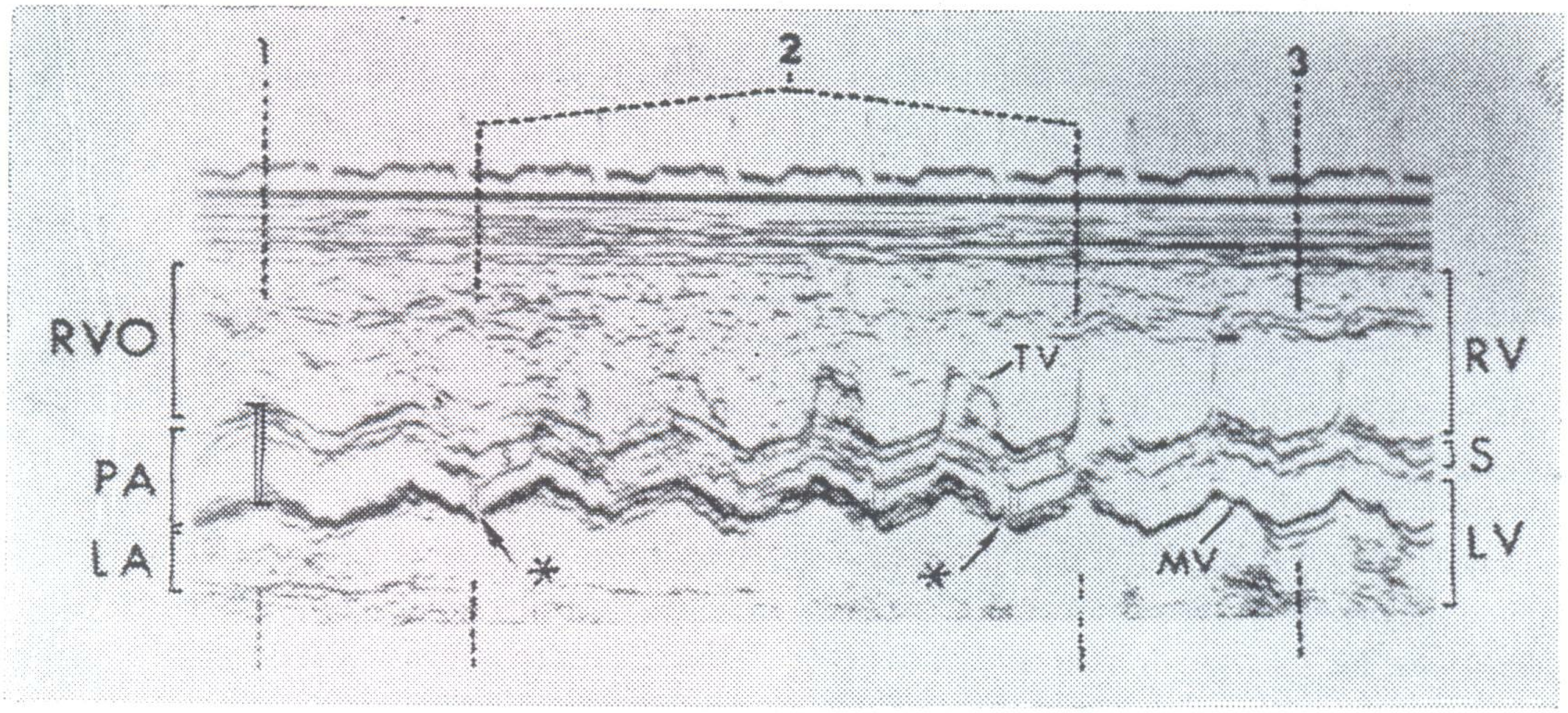


Fig. 10: Pulmonary artery (PA) artery (1) to left ventricular (LV) (3) echo scan in a patient with transposition of the great arteries. Note the left ventricular out flow tract (2) dimension (astrisk, arrow) is markedly narrowed compared to the pulmonary artery dimension (white Bar). R.V.O—Right ventricular out flow tract, LA—left atrium, S—septum. T.V.—Tricuspid Valve, RV—right Ventricle.

septal Echoes (5). The pulmonary arterial pressure was levated in patients who, additionally, had V.S.D. and no LVOT stenosis, (PEP/RVET) ratio was $\geq$ 0.28. Five patients had single ventricle with or without Pulmonic stenesis. Here no ventricular septum could be imaged and both A.V. valves were located within a large ventricle (Table VIII) Fig 11. Double outlet right Ventricle was diagnosed in 3 patients. Posterior vessel to mitral valve discontinuity was present and both great vessels

Discussion:

Qualitative as well as quantitative M-mode echocardiography has truely revolutionized the capability to diagnose congenital cardiac malformations. In acyanotic lesions, imaging of the atrial OR ventricular septal defect or patent ductus arteriosus is not possible using single crystal M-mode method. However the site of shunt can be detected. For instance in atrial septal defect, the left atrial dimension

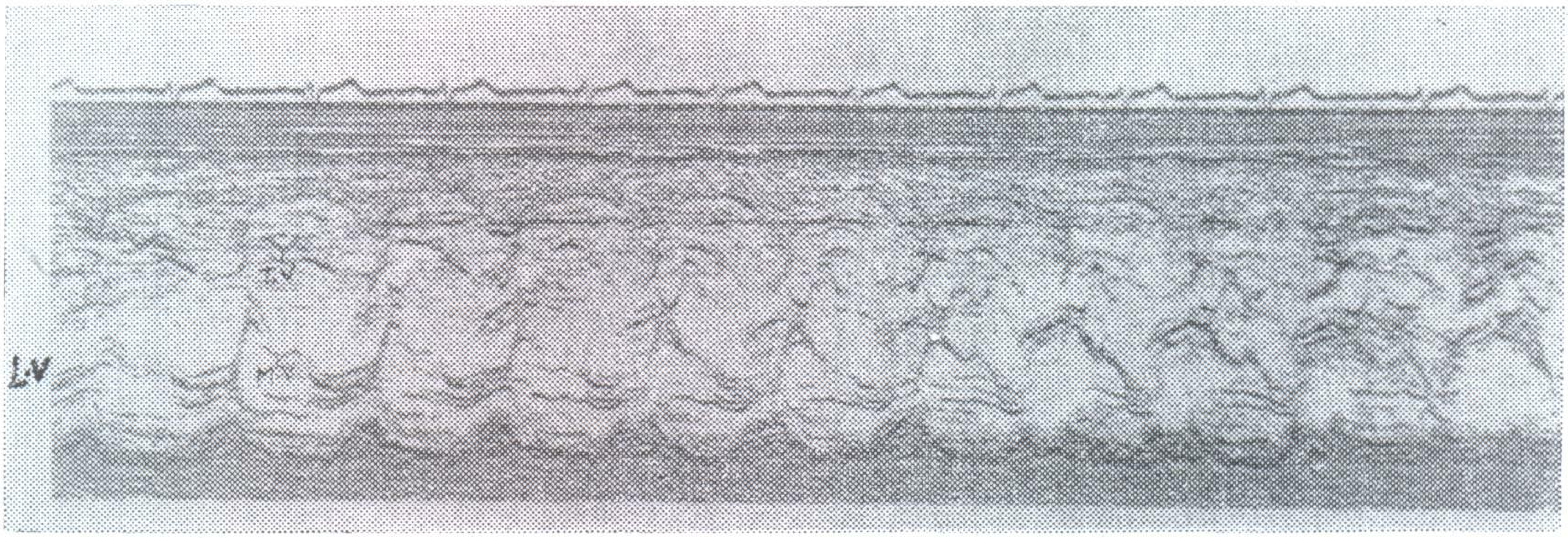


Fig. 11: Ventricular echogram in a patient with single ventricle. Note ventricular septum is not present and both tricuspid (T.V.) and Mitral valve (M.V.) are located within one ventricle without an intervening septum.

is Smaller than normal i.e LA/AO ratio <1.0, ventricular volume overload is present i.e enlarged right ventricle and paradoxic motion of the Ventricular Septum (10). Atrial Septal defect of Primum type Shows systolic thickening of mitral valve echoes and diastolic narrowing of the left ventricular outflow tract Fig. 12. Thus atrial septal defect of secundum and primum type can be accurately differentiated. One must however remember that the right ventricular volume overload can also occur in other lesions such as tricuspid regurgitation, Ebstein's anomaly and pulmonic regurgitation. Therefore, a sound clinical assessment of the patient is mendatory otherwise the echo diagnosis will be imprecise. Left to right shunt at ventricular or ductal level cannot be differentialed with Certainity. However axclusive left ventricular enlargement with elevated LA/AO ratio strongly suggests P.D.A. The clinicaldiagonsis of patent ductus arteriosus is a simple matter, M-mode echo is used to confirm the normality of cardiac Connections and assessment of the degree of L-R shunt by estimation of LA/AO ratio. Normaly aorta is of the same dimension as the left atrium thus LA/AO ratio is 1.0 and ratio 71.25 suggests significant L-R shunt (16). The imaging of ventricular and atrial septal defect can be performed using 2 dimensional secter scan echocardiography. The site of defects and their size can now be accurately measured by this newer modality. M-mode echocardiography is essentially used to evaluate the size of the shunt and presence of pulmonary arterial hypertension. The hypertrophy of the right ventricle and elevated PEP/RVET ratio >0.28 are echo parameters most helpful in this determination (8).

The h/r ratio is helpful, in the assessment of the severity of aortic valve stensis. In absence of L.V. failure and marked aortic regurgitation, h/r ratio has been shown to predict left ventricular systolic pressure accurately enough for clinical decisions.(7). Both end-diastolic (7) and end systolic (17) parameters of cavity dimensions and wall thickeness have been used. We have exclusively used the

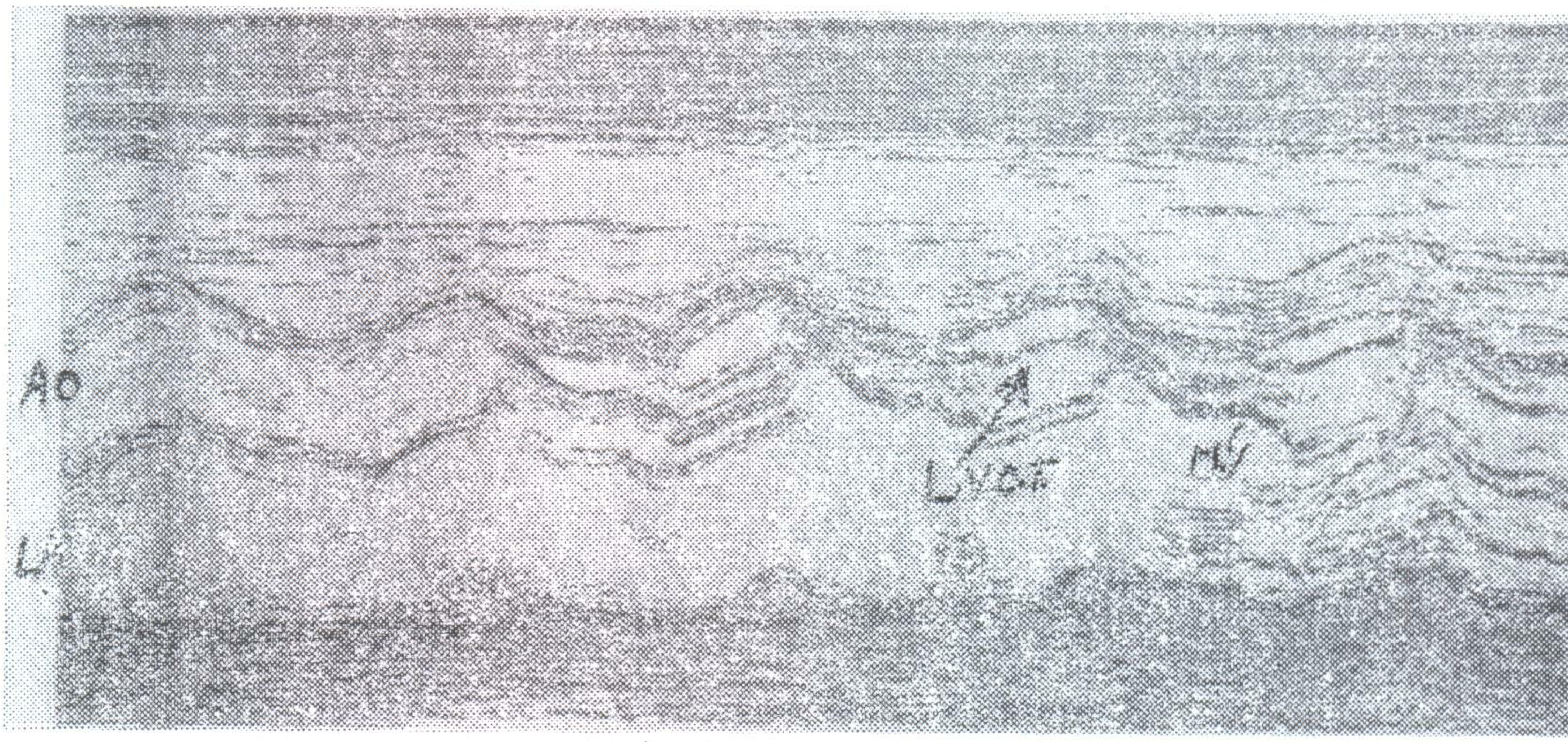


Fig. 12: Aorta (AO) to left ventricle (L.V.) echo Sweep in a patient with Osteum primum atrial septal defect. Note narrowed left ventricular out flow tract (L.V.O.T.) due to diastolic narrowing caused by the mitral valve (M.V.) which is seen touching the ventricular septum (S) during distole. LA—left atrium.

enddiastolic parameters since theoretically these are superior to the systolic parameters.(7)

M-mode echocardiography is helpful in the anatomic diagnosis of cyantoic cardiac lesions.(4) Tetralogy of Fallot can be diagnosed by demonstrating the narrowed right ventricular outflow tract, markedly hypertrophied right ventricle and over riding aorta. (14) The pulmonic valve can less often be visualised however when imaged characteristic fine Systolic flutter oi its leaflets may suggest infundibular stenosis. All four Cardiac valves and both great gessels and four Cardiac chambers can be imaged by M-mode echo. Therefore any structural abnormality of these can be detected. Single ventricle, double outlet right ventricle, A-V canal defect and anomalous pulmonary venous drainage (18-19) can be diagnosed with accuracy. The characteristic features of these lesions have been reported. In conclusion our study demonstrates that M-mode echocardiography is valuable in the diagnosis and management of both cyanotic and acyanotic forms of congenital cardiac malformations.

REFERENCES

1. Solinger R, Elbi F, Minhas K: Deductive echocardiographic Analysis in infant with Congenital heart disease, circulation 50: 1072, 1974.

2. Meyer RA, and Kaplan S: Non invasive techniqes in Pediatric Cardiovascular diseases. Progs. Cardiovasc. Dis. 15:341, 1973.

3. Gramiak R, Nanda NC and shah P.M: echocardiograpnic detection of the Pulmonary valve. Radiol 102-153, 1972.

4. Goodman MJ, Tham P, Kidd BSL: Echocardiography in evaluation of the cyanotic New born infant. Brit. Heart J: 154-166, 1974.

5. Aziz KU, Paul MH, Muster AJ: Echocardiographic assesment of left ventricular out flow tract in transposition of the great arteries,: Am J cardiol 41:543, 1978.

6. Hagan AD: echocardiographic criteria for normal Newborn infants. circulation 48: 1221, 1973.

7. AZIZ KU, Van Grondelle A, Paul MH, Muster AJ: Echocardiographic assesment of the relation between left ventricular wall and cavity dimension and peak systolic prasure in children with Aortic stenosis. Am.J Cardiol 40:775, 1977.

8. HirschFeld S, Meyer RA, schwatz D.G, Korfhagen J, and Kaplan S: The echocardiographic assessent of pulmonary artery pressure and pulmonary vascular resistence, circulation: 52: 642, 1975.

9. Lewis AB, Takahashi M: Echocardiographic assesment of left to right shunt in children with ventricular Septal defect. circulation 54.78, 1976.

10. Tajik AJ, Gan GT, Ritter DG and Schattenburg TT: Echocardiographic pattern of right Ventricular volume over load in children. Circulation 46: 36, 1972.

11. Berry TE, AZIZ KU, Paul M.H: Echocardiographic assesment of discrete subortic stenosis in childhood Amer. J. Cardiol. 43: 957, 1976.

12. Williams RG and Rudd M: Echocardiographic features of endocardial cushion defects. circulation 49: 418, 1974.

13. Lundstrom NR: Echocardiography in the diagnosis of Ebstein's anomaly of Tricuspid Valve, Circulation 47: 597, 1973.

14. Chung KJ, Nanda NC, Manning JA, Cramiak R: Echocardiographic findings in tetralogy of fallot. Amer J cardiol. 31: 126, 1973.

15. Gramiak R, Chung KJ, Nanda NC, Manning J: echocardiographic diagnosis of the transposition of the great vessels, Radiology 106: 187, 1973.

16. Silverman N.H, Lewis AB, Heyman MA and Rudolph AM: Echocardiographic assesment of ductus arteriosus shunt in pramature infants Circulation 50: 821. 1974

17. Bennett DH, Evens DW, Raj MV: Echocardiographic left ventricular demensions in presure and volume over load. Brit, Heart J. 37: 971, 1975.

18. AZIZ KU, Paul MH, Bharati S, Lev M, shannon K: Echocardiographic features of Total Anomalous Pulmonary drainage into Coronary sinus. Am. J. Cardiol. 42:108: 1978.

19. Paquet M, and Gutgessell H: Echocardiographic features of Total anomalous pulmonary venous connection. circulation 51: 599, 1975.

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