# Colour Flow And Doppler Assessment Of Ventricular Septal Defect

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## SUMMARY:

**One hundred and eightyfive patients with isolated ventricular septal defect were studied by colour flow Doppler echocardiography and additionally 52 of these patients underwent angiography. The purpose was to evaluate the capability of echocardiography to determine the size and location of ventricular septal defect and to estimate intracardiac pressures. Colour flow Doppler imaging showed that in 11 of 52 patients, (21.1 per cent) the site of ventricular septal defect was incorrectly identified when compared to angiography. Subcristal ventricular septal defects were diagnosed on short axis left parasternal view by nothing a colour flow disturbance close to the tricuspid valve. Using this criterion supracristal ventricular septal defects were misdiagnosed as paramembranous in 7 of 52 (13.5 per cent) patients while 3 posterior ventricular septal defects were wrongly diagnosed as paramembranous. In one patient additional muscular defects were missed. Review of echocardiograms of patients with supracristal defects showed that in short axis left parasternal plane, flow disturbance was present close to tricuspid valve as well as underneath the pulmonary valve with an interposed, tissue which may be the prolapsed aortic valve. The Doppler pressure gradient at ventricular septal defect was inversely linearly related to the peak systolic pulmonary arterial pressure (r = -0.84). It was further noted that end diastolic pulmonary arterial pressure obtained at cardiac catheterization was linearly related to cardiac catheterization derived pulmonary vascular resistance (r = 0.79). Diastolic pulmonary arterial pressure can be measured by Doppler technique, since in patients with pulmonary arterial hypertension, pulmonary arterial regurgitation is often present so that estimates of pulmonary vascular resistance would be possible by Doppler technique.**

**It is concluded that Doppler colour flow echocardiography provides reliable visual imaging of ventricular septal defect and estimation of systolic pulmonary arterial pressure.**

Echocardiography provides imaging of intracardiac structures as well as hemodynamic assessment of intracardiac blood flows[1,2,3]. Qualitative as well as quantitative assessment of normal as well as disturbed blood flows is possible. This capability of detection and quantification of abnormal flows provides a unique opportunity to study intra or extra cardiac structural defects[4,5,6]. Ventricular septal defect can be present in various locations on the interventricular septum. On imaging, these defects appear as interruptions of the ventricular septal surface echoes. Large defects are easily recognizable, however, smaller subcristal defects measuring few milimeter in diameter, and small muscular defects particularly multiple defects at anterior or apical position[2,3,7,8] are difficult to image. Supracristal

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ventricular septal defects need special attention during imaging and multiple planer views need to be employed for their detection[9,10]. Colour flow Doppler technique allows visualization of both right to left and left to right

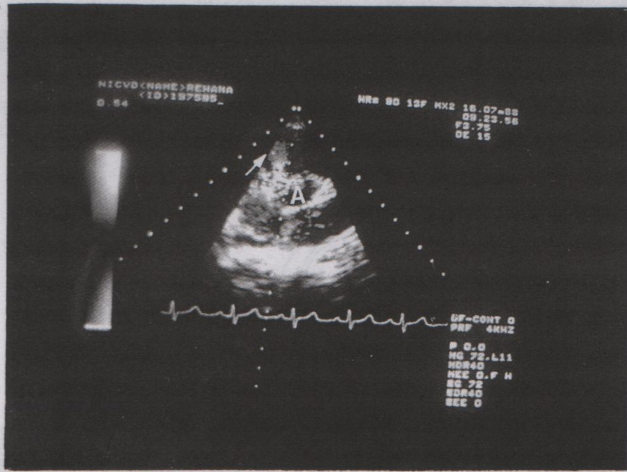

Fig. 1
Colour flow spectrum in short axis left parasternal view in a patient with subcristal ventricular septal defect and pulmonary artery hypertension. A multicolour jet close to the tricuspid valve is seen through the ventricular septal defect (arrow) which soon dissipates into pure red colour (low velocity).

shunts through these defects[11]. Thus it is relatively easy to detect even tiny defects in these odd positions[7]. Small defects have a large pressure gradient across the defect and larger defects have smaller pressure gradient. Thus presence of high velocity jets, visualised as multicolour flow distrubance, are produced by small ventricular septal defects. Large ventricular septl defects with pulmonary arterial hypertension produce a multicolour high velocity jet if left to right shunt is significant while in cases where left to right shunt is not large a low velocity blood flow is seen which appears as pure red. presence of low velocity left to right (pure red) and right to left shunt in the opposite direction (pure blue) suggests a high pulmonary arterial pressure and possibly elevated pulmonary vascular resistance[11]. Absence of high velocity jet due to left to right shunt, implies that elevated right ventricular pressure may not due to increased blood flow. The purpose of our tudy was to assess the diagnostic capability of the colour flow mapping technique in determining the size and location of the ventricular septal defect in a busy echocardiography department and to assessment the pulmonary arterial systolic pressure of ventricular septal defect and relationship of size with pressure gradient across the defect. The relationship of cardiac catheterization derived diastolic pulmonary arterial pressure and pulmonary vascular resistance was determined in patients with isolated ventricular septal defect.

**Material & Methods:**

BOne hundred and eighty five consecutive patients with isolated ventricular septal defect, seen at the National Institute of Cardiovascular Diseases during 1988-1990, were included in the study. All patients with significant right ventricular outflow pressure gradient were excluded. The age ranged between 4 months to 14 years, mean 5.6$\pm$3.7 years. These patients were evaluated by clinical, echocardiographic and angiographic means. The diagnosis of ventricular septal defect was made by echocardiography in all patients. Additionally angiography and cardiac catheterization were undertaken in 52 of 185 (28 percent) patients. angiocardiography was performed within six months of echocardiography Echocardiograms were obtained by utilizing, Toshiba SSH 65A colour flow Doppler, echocardioogram. Imaging of the ventricular septal defect wad done by using multiple planar views however short axis parsternal view and four chamber apical view were most commonly employed. The size of ventricular septal deffect was graded visually by comparing it to the root of aorta, as small moderate and large. samll defects would then be approximately few mm in diameter, moderate greater than approximately 1/2 of aortic diameter and large defects would be greater than 75 per cent of aortic root in diameter The location of ventricular septal defect was considered to be subcri\stal or paramembranous when in short axis parasternal view,

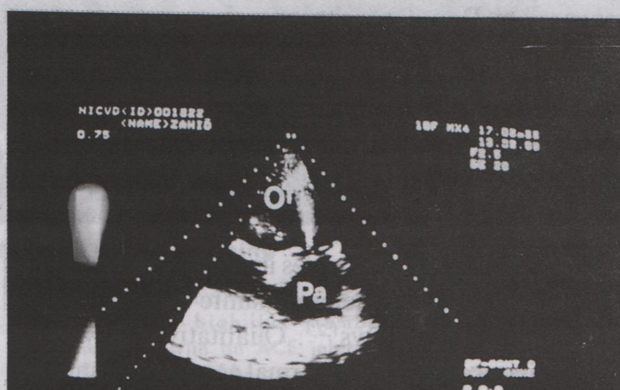


Fig. 2
Short axis left parastrnal view of a colour flow map is a patient with ventricular septl defect and pulmonary artcnal hypertension. At shows a multicolour jet arising trom the pulmonary artery (Pa) and directed into the right ventricle.

the defect was visualised close to the tricuspid leaflet and in subxiphoid sagittal planar view underneath the crista supraventricularis Supracristal ventricular septal defect was suspected when on long axis planar, view there was over riding of a dilated anterior aortic root above the ventricular septum at times anterior aortic leaflet could be seen prolaosing through the defe t into the right ventricular outflow tract[9-10] In subxiphoid view the supracristal ventricular septal defect could be well visualised because anatomically crista supraventricularis is absent to a variable extent and the defect is under neath the pulmonic valve Finally short axis left parastrnal view was often used particularly in older children when subxiphoid imaging was not optimal Doppler velocity at the ventricular septal defect was recorded in long axis and short axis parasternal view and where the jet or directio of the flow was approximately parallel to the echo beam Colour flow patterns were studied in all of the planes. Left to right shunt was either in the form of multi colour jet when Doppler gradient across a small ventricular septal defect was high or in the form of low velocity flow (red colour) when ventricular septal defect was large and pressure gradient was small.

Pressure and saturation data were obtained at cardiac catheterization and pulm,onary and systemic blood flows were calucalated as L/min/M² by using an assumed oxygen consumption value of 180ml\ min/M² [9] Pulmonary vascular resistance was calculated by using mean pulmonary arterial pressure mean left arterial

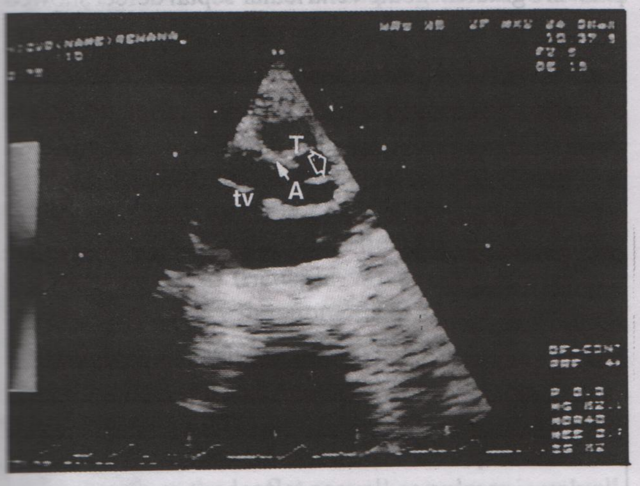


Fig. 3
Colour flow echocardiogram in short axis left parasternal view in a patient with supracristal ventricular septal defect A multicoulr jet is seen closer to the tricuspi9d valve (tv) marked by a close arrow and another multicolour jet is seen (open arrow) closer to the pulmonary valve and the opposite side of a linear echo (T). This tissue (T) may be lower edge of the anterior aoritc sinus or prlapsed artic valve (A).

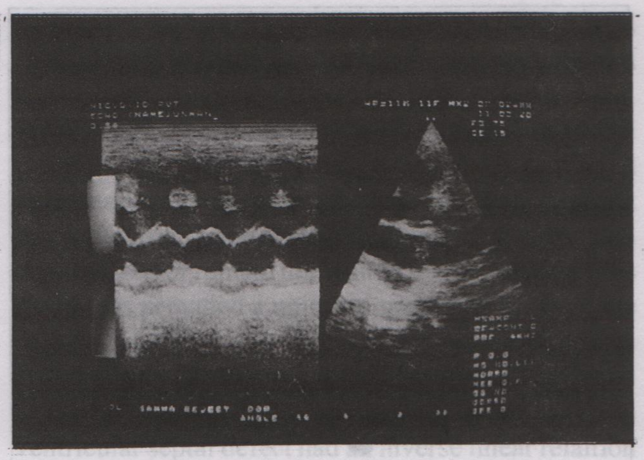

Fig. 4
Colour flow Doppler sector scan and M-mode with Doppler colour flow of a patient with ventricular septal defect and pulmonary arterial hypertension and increased pulmonary vascular resistance, (left panel (A). B (right hand panel) shows a short axis view of the same patient. Bidirectional shunt is seen with a low velocity flow from left ventricular outflow tract into the right ventricle in early systole (red arrow) and a low velocity right ot left shunt (blue arrow) from right ventricle into aorta A = Aorta; LA = Left atrium: S = Septum.

pressure and pul onary blood flow as calculated as L/min /M².

**Results:**

The diagnosis of ventricular septal defect was made on echocardiography alone in 133 of 185 patients (72 per cent) and combined echocardiography and angiography in 52 of 185 patients (28 per cent). The site of the defect was paramembranous in 135. of 185 patients (73 per cent), subpulmonic or supracristal in 23 of 185 patients (12.4 per cent), and muscular in 18 of 185 patients (9.7 per cent). In 9 of 185 patients (4.9 per cent) exact site was not described Multiple ventricular septal degects were noted in 8 of 185 patients (4.3 per cent). Echocardiographic and angiographic correlations could be made in 52 patients (28. 1 per cent) and showed that in 11 of 52 patients (21.1 per cent), the site of ventricular septal defect was incorrectly identifed on echocardography in 7 of these 11 patients (6.4 per cent) ecocardiographic diagnosis was of a paramembranous defect while angiography showed supracristal defect The echocardiographic plane most commonly employed to establish the site of ventricular septal defect was the short axis left parasternal palne so that colour flow disturbance (jet) close to the tricusid valve in this view were interpreted as diagnostic of a subcristal or paramembranous ventricular septal defect, fig. l. Review of these echocardiograms revealed that

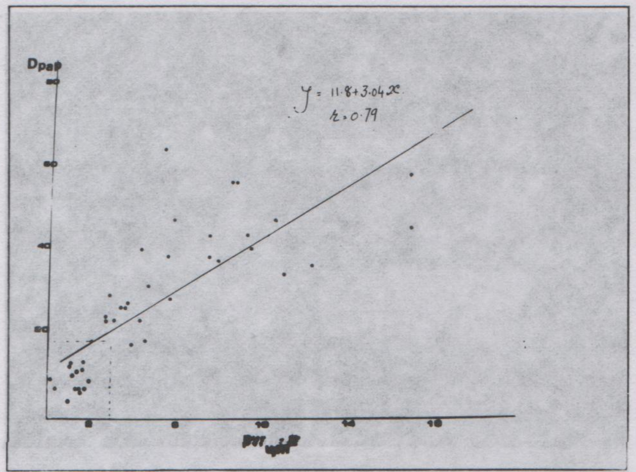

Fig. 5
Pulmonary vacular resistance (pvt U/M²) plot against diastolic pulmonary arterial pressure (D pap). A linear relatioship is present. Note that PVT of less than 3 units is associated with pulmonary arterial diastolic pressure of less than 18mm Hg in most oof the cases.

left to right shunting was indeed present towrd the triuspid valve but well away from the leaflet. A separate jet was also seen below the pulmonic valves with a tissue interposed in between fig. 2. This tisue may be the prolapsed aortic valve or lower edge of right coronary aortic sinus. In 1. of 11patients multiple ventricular septal defects were missed and 3 of 11 patients who were diagnosed by echocardiography as a paramembranous the defects were posterior or basal in location. Correlation of the size of ventricular septal defect on echocardiography and angiography vas available in 36 of 52 (69 per cent) patients. Agreement between the methods was presednt in 22 of 37 patients (59.5 per cent) and in 14 of 36 patients (39 per cent) there was one grade difference One grade difference was most frequent when the defect was graded as moderate on echocardiography so that the defect on angiography was either one grade larger (4 of 7 or one grade smaller (2 of 7), and agreement between the two methods was noted in only one patient. When the defect was considered small on echocardiography it was also samll on angiography in all six cases. A well developed multicolour jet was noted through the defect when Doppler pressure gradient across the ventricular septal defect was large as in small defects. In moderate to large defects with significant left to right shunt a multicolour jet could still be seen, fig 3. When Doppler pressure gradient across the defect was small then the flow was purered colour due to low velocity left to right shunt. Right to left shunt was seen on colour flow mapping as pure blue colour flow in the long axis or parasternal short axis views, fig. 4.

Haemodynamic data. was available in-52. patients who underwent cardiac catheterization procedure Two groups were recognised, normotensive group comprised 12 patients who had normal pulmonary arterial pressure, i.e., less than 35mm Hg systolic (26.8±6.6) and less than 20mm Hg mean (15.5±50mm Hg). The pulmonary vascular resistance was 1.3±0.7 units in 11 of 12 patients and the OP/QS ratio was 1.8±0.54.

Hypertensive group comprised 40 patients who had pulmonary arterial hypertension, i.e., peak systolic pressure greater than 35mm Hg; (71.4±0.17) and mean pulmonary arterial pressure greater than 20mm Hg, (51.5±14.6). The pulmonary vascular resistance was 6.3 units ±4.6 in 34 of 40 (91.9 per cent) patients and the QP/QS ratio was 2.5±1.0 in 36 of 40 (90 per cent) patients. The pulmonary arterial systolic pressure and pulmonary arterial mean pressure showed linear correlations with the pulmonary vascular resistance, r=0.73 and 0.62 respectively. However pulmonary arterial diastolic pressure showed the best linear correlation to the pulmonary vascular resistance in 45 of 52 patients (r=0.79); (Y=11.8+3.04 X), so that higher the diastolic pulmonary arterial pressure, greater was the pulmonary vascular resistance. It was observed that in majority of patients (17 of 20 patients) with pulmonary vascular resistance of less than 3 units the pulmonary arterial diastolic pressure was 18mm Hg or less, fig. 5.

In 18 of 52 patients the echocardiographic Doppler pressure gradient at the ventricular septal defect showed

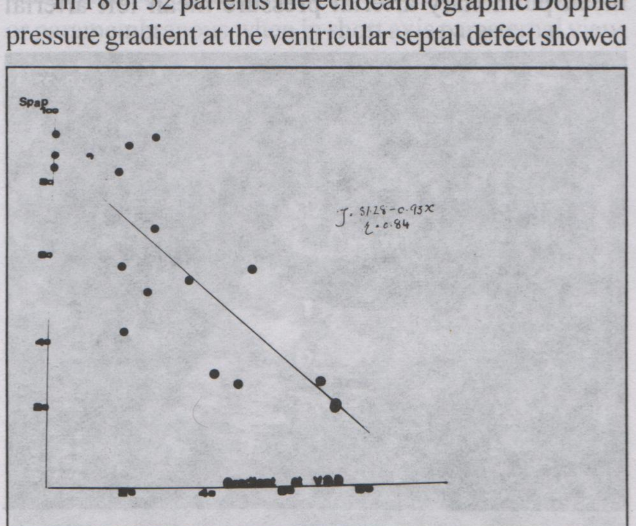

Fig. 6
Doppler pressure gradient between the left and right ventricle acorsss the ventricular septal defect (VS) is plotted against systolic pulmonary arterial pressure (S pap). An inverse linear relatinship is noted so that higher pressure gradient at the VSD is associated with lower pressure in the pulmonary artery.

an inverse linear relationship to the peak systolic pulmonary artery pressure obtained during cardiac catherization (r=-0.84, Y=87.28-0.93) so that larger the pressure gradient across the defect lower was the pulmonary artery systolic pressure, fig. 6.

**Discussion:**

Colour flow mapping technique allows visualization of even the smallest ventricular septal defects[7]. Our data showed that muscular and posterior ventricular septal defects need special care and unless specially searched are liable to be missed[7,11]. Posterior defects are best visualised in the four chamber apical or subxiphoid views and unless these defects are very large they will not extend anteriorly to be imaged in the long or short axis parasternal views. Muscular defects can be imaged from long axis parasternal and short axis sweep from the base of the heart to the apex[1,11]. Each short axis view need to be carefully scaned for possible flow disturbance. Apical muscular defects require special care so that imaging of cardiac apex is made in the apical four chamber view[7]. Our data showed that supracristal or subpulmonic ventricular septal defects were common in Pakistani population, i.e., 12.4 per cent in the persent series. Therefore, proper echocardiographic technique is required for their detection. The determination that a ventricular septal defect is supracristal is of critical importance since most of these defects would need to be surgically corrected since aortic regurgitation, due to prolapsed aortic valve is often present and tends to be progressive. Our data showed that if only short axis echo plane was used to detect supracristal ventricular septal defect then mistakes can be made, because as was shown in our study, a left to right shunting jet close to the tricuspid valve was often present. Since infundibular septum or crista supra ventricularis is absent, the subpulmonic ventricular septal defect generally extends from pulmonic valve to tricuspid valve. Thus the critical manoeuvre to image the supracristal defects in the short axis view, was imaging of a jet or flow disturbance underneath the pulmonic valve. We observed that with careful mapping in the short axis parasternal view one could demonstrate a jet toward the tricuspid valve but well away from the leaflet as well as pulmonic valve[11]. There was often a tissue interposed between these two jets. This tissue may be the lower edge of the prolapsed aortic leaflet or lower edge of the aortic sinus. If one combined the short axis parasternal and short axis subxiphoid views then mistakes in localization of a supracristal ventricular septal defects can be avoided. In our study there were a number of children who had pulmonary arterial hypertension and increased pulmonary vascular resistance. This was due to the fact that in Pakistan large ventricular septal defects remain undiagnosed or remain unrepaired during infancy. This study thus provided a unique opportunity to study the relationship of echo derived parameters with catheterization data in this group of patients. We showed that echo derived pressure gradient across the ventricular septal defect had an inverse linear relaltion to the peak systolic pulmonary arterial pressure so that smaller the pressure gradient at the ventricular septal defect greater was the peak systolic pulmonary arterial pressure and vice versa. This obviously was applicable only when right ventricular outflow obstruction was not present which, incidentally, could be detected by the Doppler technique and should pose no problem[4]. We also showed that pulmonary vascular resistance could be predicted by the cardiac catheterization derived pulmonary arterial diastolic pressure so that a pulmonary arterial diastolic pressure of 18mm Hg or less was associated with pulmonary vascular resistance of less than 3 units. There was however a linear relationship between these variables, so that greater was the diastolic pulmonary artery pressure greater was the likelihood of increased pulmonary vascular resistance. By recording the Doppler velocity spectrum of pulmonary arterial regurgitation[11] it was be possible to determine the diastolic pulmonary arterial pressure with Doppler technique. We observed that a multicolour jet of pulmonary regurgitation was often present in cases where pulmonary vascular resistance was significantly elevated. In normal subjects or those in whom pulmonary arterial pressure was normal blood flow of pulmonary regurgitation was of low velocity.

The peak systolic pulmonary arterial pressure could be determined by measuring the pressure gradient at the ventricular septal defect which was corroborated by Doppler measured pressure gradient at the tricuspid valve even when tricuspid regurgitation was trivial. Thus echocardiographically derived pressure can enable one to estimate the systolic pulmonary arterial pressure.

In conclusion, Doppler colour flow mapping is reliable in detection, size estimation and assessment of pulmonary arterial hypertension in a patient with ventricular septal defect.

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