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DETECTION OF INTRACARDIAC LEFT - TO - RIGHT SHUNTS IN CHILDREN BY CONTRAST ECHOCARDIOGRAPHY AND THE RADIONUCLIDE TECHNIQUE*

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This study was carried out in the Departments of Pediatrics and Nuclear Medicine at Hacettepe University Faculty of Medicine between April 1986 and March 1988 with the aim of detecting left-to-right shunts in 70 patients with isolated ventricular septal (VSD) defect, isolated atrial septal defect (ASD) and patent ductus arteriosus, by using the radionuclide technique together with contrast echocardiography. In some patients, the results were confirmed by both cardiac catheterization and angiocardiography. Most of the data were confirmed during surgery. A good correlation was found between the results of contrast echocardiography and radionuclide angiography. The difference between the QP/QS value and the grade of positive contrast effect was tested statistically and "p" was found to be less than 0.001. Therefore, we conclude that these methods could be applied together to determine the indication for surgery in cases with ASD or VSD. *Key words: intracardiac left-to-right shunts, contrast echocardiography, radionuclide technique.*

The radionuclide technique is used for rapid and safe detection, and quantitation of intracardiac shunts in pediatric patients. It is a noninvasive procedure which delivers low radiation so that it can be repeated, if necessary. Recent studies using this technique have shown a good correlation when estimating letf-to-right shunting according to the Fick method[1].

Another noninvasive method is echocardiography which has found a wide field of application in medicine during the last 20 years. This method is preferred over the others since it is non-traumatic, easy, inexpensive and can be repeated as frequently as necessary[2-4]. Furthermore its reliability has been proven by angiographic and pathologic studies[5]. When compared to oximetry, peripheral vein contrast echocardiography is a much more specific method in demonstrating shunts at septal defects[6,7]. Contrast studies using two-dimensional echocardiography have detected a right-to-left (positive) shunt or a left-to-right (negative) shunt at the atrial level in patients with atrial septal defect and at the ventricular level in patients with ventricular septal defect[8-10].

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In this study, two-dimensional echocardiography and the radionuclide technique were used together to detect and evaluate intracardiac shunts. In some patients, the results of both studies were confirmed by cardiac catheterization and angiocardiography. In addition, most of the data were substantiated surgically.

Material and Methods

The aim of this study carried out between April 1986-March 1988, in the Departments of Pediatrics and Nuclear Medicine at the Hacettepe University Faculty of Medicine was to detect left-to-right shunts in 70 patients with isolated ventricular septal defect (VSD), isolated atrial septal defect (ASD) and patent ductus arteriosus (PDA) using cardioechography, cardiac catheterization and the radionuclide technique in combination. Since the radionuclide method proved to be unsuccessful in 12 patients, the remaining 58 patients formed the study group. A control group of 10 children (with no heart disease) were compared with the study group.

The cases were divided into three groups according to the methods used. The control group comprised 10 subjects in which only radionuclide angiography was performed. Group A comprised 45 subjects in which both contrast two-dimensional echocardiography and radionuclide angiography were carried out. Group B comprised 13 subjects in which contrast two-dimensional echocardiography, radionuclide angiography and cardiac catheterization were used. There were 43 males and 37 females, and their ages ranged between one and 17 years (Table I).

TABLE I: Distribution of 68 Cases According to Age and Sex

	Control	Group A	Group B
Girl	3	21	9
Boy	7	24	4
Total	**10**	**45**	**13**
Age (yrs)	3-7	1-15	4-16
Mean (yrs)	9.72 ± 0.63	8.47 ± 0.51	9.76 ± 0.89

The patients with left-to-right shunts did not have any valvular insufficiency or findings of congestive heart failure.

Two-dimensional echo studies were performed using a Toshiba SSH-60A echocardiograph equipped with 3.75 and 5 mHz transducers. The images were recorded on video tape for further evaluation. The contrast material consisted of 2-10 cc of 3% saline or 5% dextrose injected intravenously into a peripheral vein in patients with either atrial septal defect or ventricular septal defect. The injection was repeated at least three times in each case. The passing of the

contrast material from the right atrium into the left atrium or from the right ventricle into the left ventricle was evaluated as a "positive contrast" while non-contrast blood passing from the left atrium to the right atrium or from the left ventricle to the right ventricle was termed a "negative contrast". A positive contrast was quantitated in four grades while a significant negative contrast effect was graded as three negative or four negative[8-10]. Grade three positive and grade four positive contrast effects were considered definitive evidence of an atrial or ventricular septal defect (Figs. 1-4).

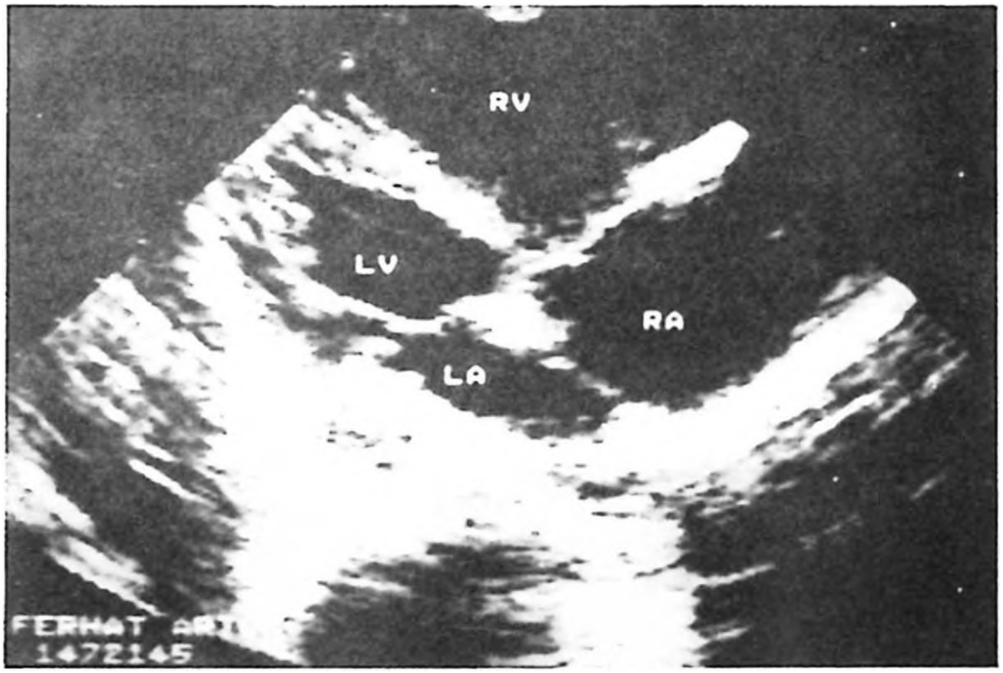

Fig. 1: Apical four-chamber view.

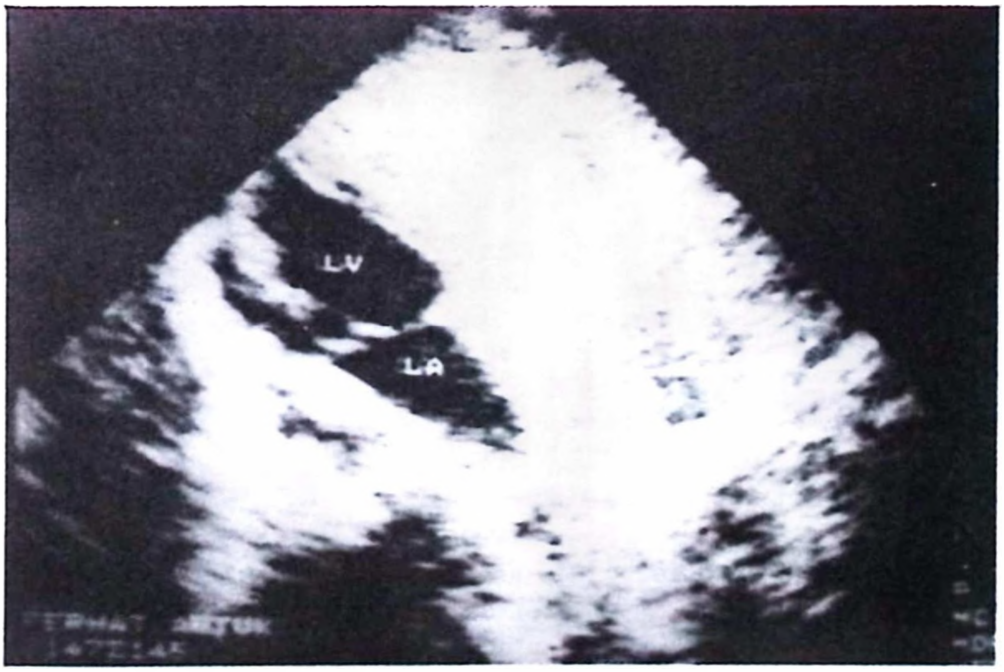

Fig. 2: Contrast material is seen in the right atrium and the right ventricle.

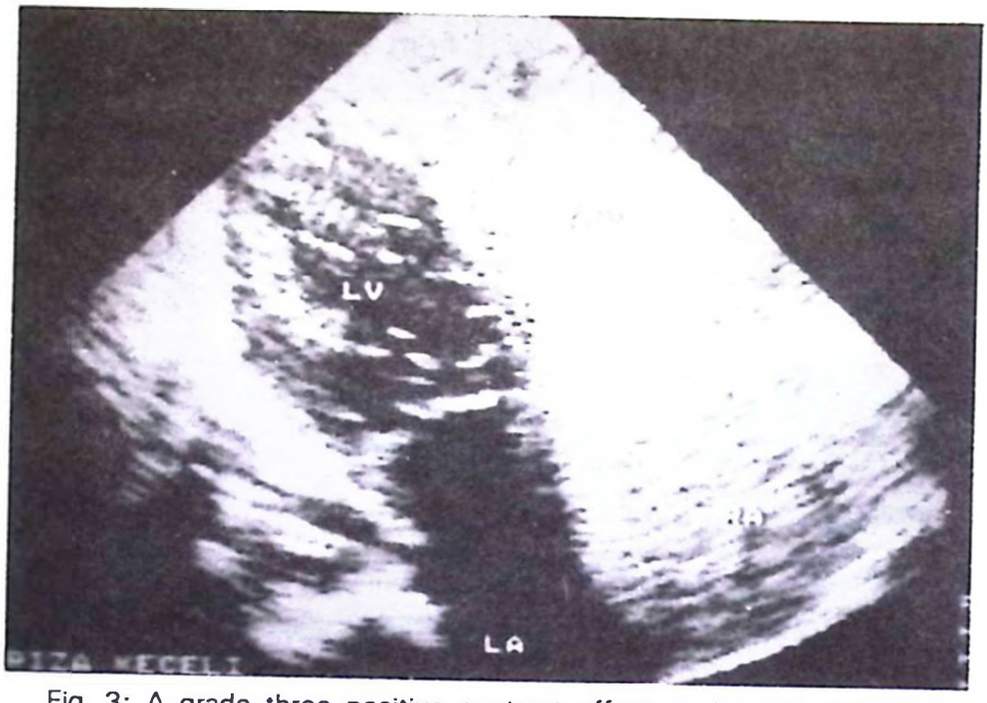

Fig. 3: A grade three positive contrast effect in the left ventricle.

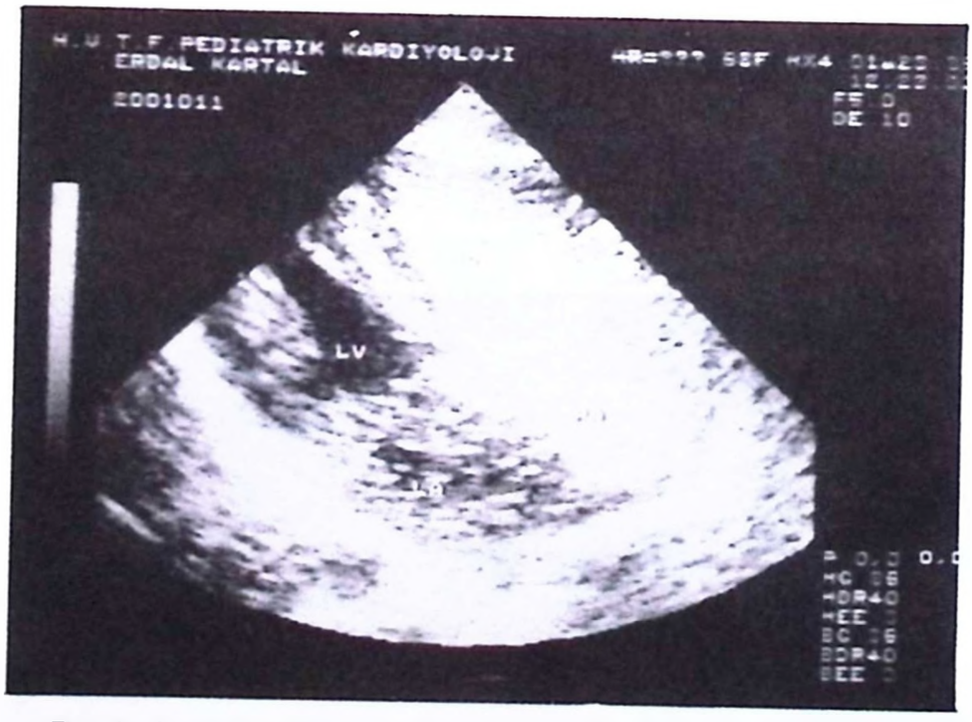

Fig. 4: A grade three positive contrast effect in the left atrium.

70 patients with left-to-right shunts and 10 controls were studied by radionuclide angiography using either the Siemens Scintiview II camera or the Toshiba GCA-501 S digital camera. Radionuclide angiography was performed under the computerized gamma camera with the patients in a supine position. We used the

gamma function area rate method in our study[11-15]. After administering a bolus of intravenous ^{99m}Tc sodium pertecnetate, as the radionuclide material, curves of time-activity were obtained from the areas taken on the chest. By analyzing these histograms by the gamma function method, the pulmonary flow/systemic flow (QP/QS) ratio was calculated. A value of up to 1.20 was considered normal while values greater than this were regarded as definite evidence of a left-to-right shunt[1].

Results

Twelve out of 80 cases (15%) were excluded from the study because of unsuccessful radionuclide estimations: there was bolus failure in nine patients, uncooperativeness in two patients, and a registration fault in one patient.

The QP/QS values of the 10 children in the control group were found to be between 1.05-1.15 (average 1.07 ± 0.09) using the radionuclide method.

Table II illustrates the distribution of 58 patients with left-to-right shunts according to diagnosis. Group A consisted of 36 cases with ventricular septal defect, five with secundum atrial septal defect and four with patent ductus arteriosus. Group B consisted of six cases with ventricular septal defect, four with secundum atrial septal defect and three with patent ductus arteriosus (Table II).

TABLE II: Distribution of 58 Patients With Left-to-Right Shunts

	Group A	Group B
VSD	36	6
ASD	5	4
PDA	4	3
Total	45	13

In group A, four of 36 cases with VSD showed a grade three or four positive contrast effect and the radionuclide QP/QS values ranged between 1.70-3.60 (average 2.40 ± 0.14) in these patients. As a result of these findings all the patients underwent surgical closure for ventricular septal defect. These procedures were successful in all patients operated on and the defects were large. Another three cases with VSD showed a grade two or one positive contrast effect. We saw no positive contrast effect in the 19 cases with VSD. Radionuclide angiography revealed that the QP/QS values ranged between 1.10-1.80 (average) 1.40 ± 0.04) in these 22 patients. According to this data, we decided that surgical repair was not indicated in these 22 patients.

A grade three or four positive contrast effect was found in the four cases with atrial septal defect. The radionuclide QP/QS values varied between 1.93 and 2.94 (average 2.34 ± 0.23). Accordingly, all four cases with ASD underwent atrial septal defect closure. The surgical results confirmed that the defect was large. We could not find any positive contrast effect in one case with ASD whose QP/QS value was 1.20, as measured by the radionuclide technique; catheterization was performed in this case. The patient was operated on and the defect was not large.

The QP/QS values of four patients with PDA ranged between 1.25-1.67 (average 1.47 ± 0.22) for the right lung and 1.30-1.89 (average 1.63 ± 0.14) for the left lung. Contrast echocardiography was not used in these cases. All of these patients underwent surgery (Table III).

The radionuclide QP/QS values were found to be between 1.70 and 3.60 (average 2.39 ± 0.13) in a total 18 cases (14 VSD, 4 ASD). These cases also showed a grade three or four positive contrast effect. They underwent surgical closure for atrial or ventricular septal defects. In 23 cases (22 VSD, 1 ASD), the radionuclide QP/QS values ranged between 1.10 and 1.80 (average 1.39 ± 0.04), and they showed a grade two or one positive contrast effect. It was thus decided that all the VSD cases should be followed up. After catheterization and angiography, the ASD case was operated on. When the difference between the mean QP/QS value and the grade of positive contrast effect was tested statistically, "p" was found to be less than 0.001 (Table IV; Fig. 5).

There were 13 cases (6 VSD, 4 ASD, 3 PDA) in group B (Table V). Cardiac catheterization, radionuclide angiography and contrast echocardiography were performed in combination in each patient with VSD or ASD. However, in the patients with PDA, only cardiac catheterization and radionuclide angiography were used.

Two out of six patients with VSD showed either a grade three or a grade one positive contrast effect, and the QP/QS value was found to be 2.70 and 2.40 in the catheterization and 2.40 and 2.70 in the radionuclide angiography. We decided that surgical repair was indicated in these patients. Another patient with VSD showed a grade two positive contrast effect and QP/QS values of 1.20 in the catheterization and 1.34 in the radionuclide angiography. We could not find any positive contrast effect in three of the six cases with VSD. In these three patients the QP/QS values were between 1.00-1.70 (average 1.34 ± 0.20) in the catheterization and 1.29-1.50 (average 1.39 ± 0.05) in the radionuclide angiography. Surgery was not recommended, and these four patients were managed conservatively. The remaining two patients with VSD underwent surgery for ventricular septal defect closure. During the operation the sizes of the defects were found to be between 1.15 cm.

TABLE III: Data of 45 Patients Studied by Two-Dimensional Echocardiography and Radionuclide Angiography (Group A)

Diagnosis	Number of Patients	Positive Contrast Effect in Echocardiography	Radionuclide QP/QS	Treatment
VSD	7	+4	2.04 – 3.60 (2.78 ± 0.19)	Surgery
VSD	7	+3	1.70 – 2.70 (2.05 ± 0.12)	Surgery
Total	14	(+4, +3)	1.70 – 3.60 (2.40 ± 0.14)	Surgery
VSD	1	+2	1.80	Clinical follow-up
VSD	2	+1	1.43 – 1.67 (1.55 ± 0.11)	Clinical follow-up
VSD	19	No positive contrast effect	1.10 – 1.60 (1.37 ± 0.03)	Clinical follow-up
Total	22	+2, +1, or no positive contrast effect	1.10 – 1.80 (1.40 ± 0.04)	Clinical follow-up
ASD	1	+4	2.94	Surgery
ASD	3	+3	1.93 – 2.50 (2.34 ± 0.27)	Surgery
Total	4	(+4, +3)	1.93 – 2.50 (2.34 ± 0.23)	Surgery
ASD	1	No positive contrast effect	1.20 (For left lung)	Surgery
PDA	4	--	1.30 – 1.89 (1.63 ± 0.14)	Surgery
Total	**45**			

TABLE IV: Comparative Data of Radionuclide QP/QS Values and Degree of Positive Contrast Effect in Echocardiography

Degree of Positive Contrast Effect in Echocardiography	x	$S_{\bar{x}}$	n	t
VSD (+4, +3)	2.40	0.14	14	
				6.38 $p < 0.001$
VSD (+2, +1, no positive contrast effect)	1.40	0.04	22	
VSD (14), ASD (4) (+4, +3)	2.39	0.13	18	
				7.23 $p < 0.001$
VSD (22), ASD (1) (+2, +1, no positive contrast effect)	1.39	0.03	23	

(41 patients with ASD or VSD in Group A)

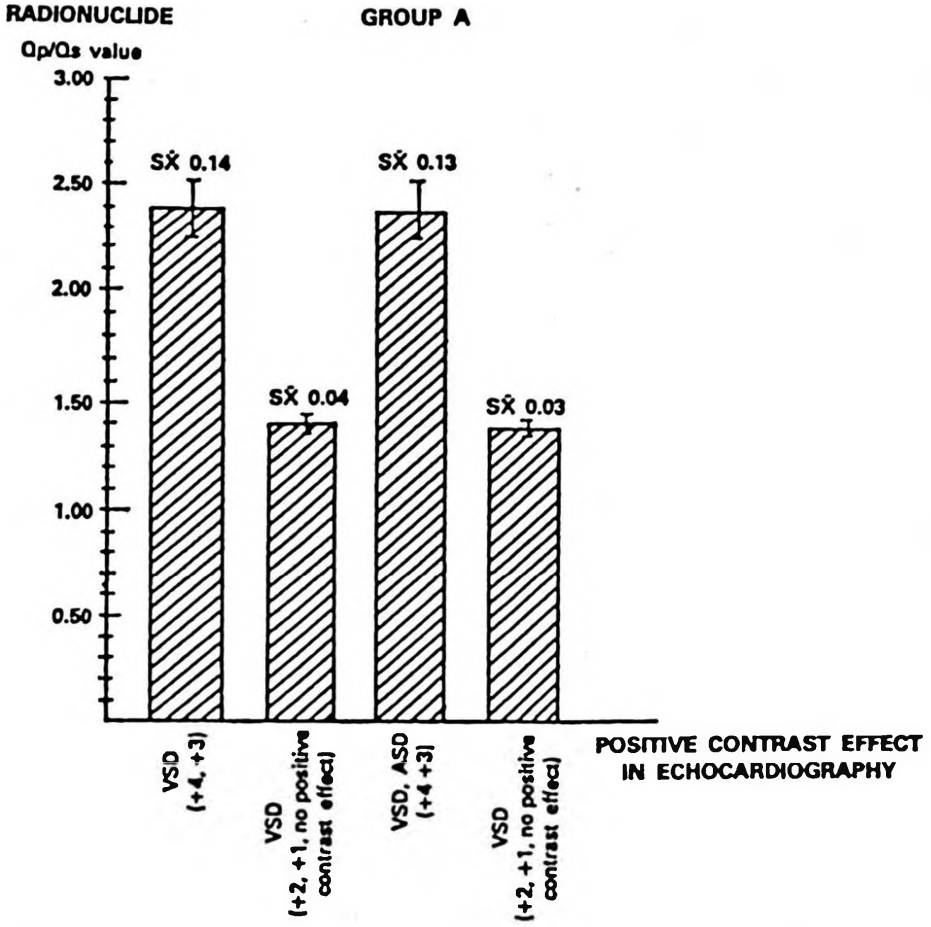

Fig. 5: Comparative values of radionuclide QP/QS vs. degree of positive contrast effect in echocardiography.

Two of the four patients with ASD showed a grade three positive contrast effect. In addition the QP/QS values ranged between 1.60-1.90 (average 1.75 ± 0.14) in the catheterization and 1.70-2.60 (average 2.15 ± 0.44) in the radionuclide angiography. In the other two cases associated with ASD, no contrast effect was observed. Their QP/QS values ranged between 1.60-2.50 (average 2.05 ± 0.44) in the catheterization and 1.90-3.00 (average 2.45 ± 0.54) in the radionuclide study. The size of these defects varied between 1.5-3 cm.

The radionuclide QP/QS values in the patients with PDA were calculated for the left lung. The patients were operated on.

Catheterization performed on patients in group B revealed QP/QS values which varied between 1.00-2.70 (average 1.84 ± 0.15). However this ratio was found to be between 1.29-3.00 (average 2.02 ± 0.08) in the radionuclide angiography (Table V).

TABLE V: Data of 13 Patients Studied by Two-Dimensional Echocardiography, Radionuclide Angiography and Cardiac Catheterization (Group B)

Diagnosis	Number of Patients	Positive Contrast Effect in Echocardiography	Radionuclide QP/QS	Cardiac Catheterization QP/QS	Treatment
VSD	1	+3	2.40	2.70	Surgery
VSD	1	+1	2.70	2.40	Surgery
VSD	1	+2	1.34	1.20	Clinical follow-up
VSD	3	No positive contrast effect	1.29 – 1.50 (1.39 ± 0.05)	1.00 – 1.70 (1.34 ± 0.20)	Clinical follow-up
ASD	2	+3	1.70 – 2.60 (2.15 ± 0.44)	1.60 – 1.90 (1.75 ± 0.14)	Surgery
ASD	2	No positive contrast effect	1.90 – 3.00 (2.45 ± 0.54)	1.60 – 2.50 (2.05 ± 0.44)	Surgery
PDA	3	—	1.62 – 2.60 (2.17 ± 0.28)	1.00 – 2.70 (1.84 ± 0.15)	Surgery
Total	13		1.29 – 3.00 (2.02 ± 0.08)	1.00 – 2.70 (1.84 ± 0.15)	

When the differences between the QP/QS values calculated by radionuclide angiography and oximetry during cardiac catheterization were tested statistically, they were not found to be significant ($p > 0.05$) in 13 patients (Table VI; Fig 6).

In this study, contrast echocardiography was used in 51 cases with VSD or ASD for detection and evaluation of intracardiac shunts. This procedure was successful in most of the patients. However, in two cases with ASD, and in one case with VSD from group B, the QP/QS values were found to be above 1.2 by catheterization while in radionuclide angiography either no positive or a grade one

positive contrast effect was observed in contrast echocardiography. It is concluded that contrast echocardiography demonstrated 5.8% false negative results in 51 patients with septal defect.

TABLE VI: Differences Between QP/QS Values Calculated by Radionuclide Angiography and Oximetry During Cardiac Catheterization Tested Statistically

Group B (13 Patients)

$X_D = 0.18$
$S_D = 0.11$
$t = 1.151$
$p > 0.05$

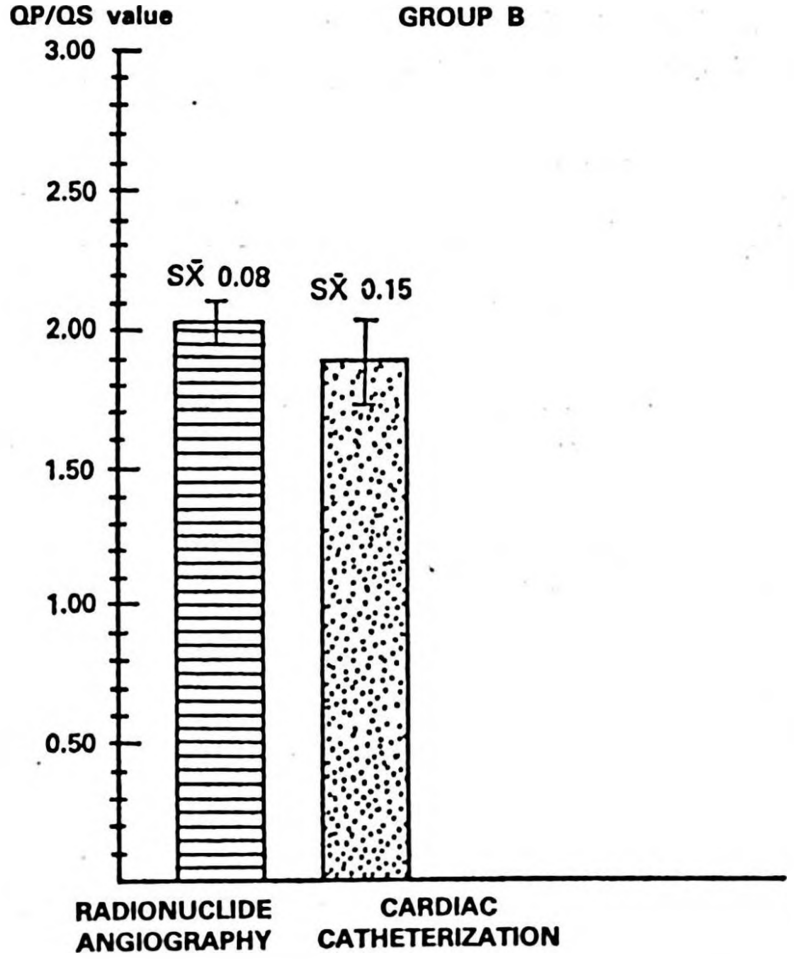

Fig. 6: QP/QS values in radionuclide angiography and cardiac catheterization.

Discussion

Cardiac catheterization and angiocardiography, which are the best means for visualizing the morphologic and functional properties of the heart in a living organism, maintain their importance and reliability in the face of advancing knowledge and techniques. However these methods require a well-trained team and a careful laboratory study. In addition, they carry some risks for the patient and the examiner[2]. Hemodynamic and angiocardiographic studies have shown that in ASD patients without complications there is only right-to-left shunt of small magnitude during the early systolic period[7]. In ASD patients, who undergo two-dimensional echocardiography, it has been observed that after injection into the right side, visualization of the contrast substance in the left atrium or left ventricle is very specific for left-to-right shunts[3,4,8-10,16]. Contrast echocardiography in patients with VSD has shown that the flow of the contrast substance from the right ventricle to the left at ventricular level occurs during the isovolumetric relaxation period of the ventricle (early diastole, after the closure of the aortic valve, and before the opening of the mitral valve)[8].

In this article we discussed two noninvasive techniques, namely, two-dimensional echocardiography and radionuclide angiography used in combination to deterimine the need for surgical intervention in our patients. 41 patients with VSD or ASD (group A) were studied. The degree of positive contrast effect was compared with the QP/QS values found by the radionuclide angiography. The difference between the two results was found to be significant ($p < 0.001$).

After a thorough search of the literature, we found that there have been no reports of studies performed in which both techniques were used in combination. There are some reports, however, that compare hemodynamic studies with the results of contrast echocardiography in adult ASD patients[8-10]. In addition, there are documented studies which show that it is possible to have a positive contrast substance flow from right to left at ventricular level in patients with a right ventricle/left ventricle pressure ratio of more than 0.50 or 0.71[8,17]. The QP/QS values of the 13 patients with VSD, ASD and PDA in group B were determined using catheterization and radionuclide angiography. When the results of the two methods were compared, no significant difference was found between the two groups ($p > 0.05$). These findings correlate with the results found in the literature. In the research done by McIlveen et al[12] the number of small shunts could not be estimated by oximetry, however, they were able to demonstrate them all by using radionuclide angiography. Askenazi et al[13] found a high correlation between the two studies in their investigation of 105 patients, and Sorensen and Starling[18] confirmed this correlation. Our study showed a good correlation between the QP/QS values obtained from catheterization and radionuclide angiography. All of these studies prove the sensitivity and reliability of the radionuclide method. The

results demonstrate that radionuclide techniques are most valuable in detecting simple cardiac defects such as isolated ASD or VSD. The definition of more complex malformations usually requires more invasive diagnostic methods.

In our study two noninvasive methods, contrast echocardiography and radionuclide angiography were used in combination to determine the indication for surgery in VSD or ASD cases. A good correlation was found between the results of the two techniques. We conclude that these methods can be applied together easily and safely for definite detection and quantitation of left-to-right shunts especially in isolated ASD or VSD cases.

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