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THE INFLUENCE OF PULMONARY INSUFFICIENCY ON VENTRICULAR FUNCTION FOLLOWING TOTAL CORRECTION OF FALLOT'S TETRALOGY: EVALUATION USING RADIONUCLIDE VENTRICULOGRAPHY AND CLINICAL FINDINGS*

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SUMMARY: Arsan S, Yorgancıoğlu C, Paşaoğlu İ, Erbaş B, Bozer YB. (Department of Thoracic and Cardiovascular Surgery, Hacettepe University Faculty of Medicine, Ankara, Turkey). The influence of pulmonary insufficiency on ventricular function following total correction of Fallot's tetralogy: evaluation using radionuclide ventriculography and clinical findings. Turk J Pediatr 1993; 35: 323-331.

Long-standing pulmonary insufficiency after repair of tetralogy of Fallot may adversely affect ventricular function. We evaluated 20 patients postoperatively by radionuclide ventriculography and clinical findings after total correction of tetralogy of Fallot. Patients were divided into two groups as follows: Group I patients (10) had no pulmonary insufficiency; Group II patients (10) had moderate or severe pulmonary insufficiency. Preoperatively, there was no difference between groups in terms of age, functional capacity according to the New York Heart Association criteria, hemoglobin and hematocrit level, cardiothoracic ratio, McGoon ratio, left and right ventricular ejection fraction, cardiac output or cardiac index. Postoperatively, right ventricular ejection fraction was 40.10 ± 2.28 in Group I and 29.5 ± 2.86 in Group II, $p < 0.01$. Left ventricular ejection fraction was 59.3 ± 2.90 in Group I and 50.9 ± 4.19 in Group II, $p < 0.01$. Radionuclide ventriculography is a useful means of identifying right ventricular dysfunction following repair of tetralogy of Fallot. The dysfunction appears significantly worse in patients with pulmonary insufficiency. *Key words: tetralogy of Fallot, pulmonary insufficiency, radionuclide ventriculography.*

Complete repair of tetralogy of Fallot (TOF) can be accomplished with low operative mortality and excellent long-term symptomatic benefits[1,2]. Current expectations following complete repair of TOF include low operative risk, abolition of arterial desaturation and polycythemia, prevention of secondary complications,

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the capability to engage in a physically unrestricted lifestyle, and a relatively normal life expectancy. The natural history of surgically repaired TOF still requires additional decades of observation before final conclusions can be formulated[3-6]; however, there is little doubt that surgical treatment has dramatically improved life expectancy.

The technique used to relieve the right ventricular outflow tract obstruction is an important determinant of early and late cardiac function[7,8]. Repair with a transannular patch resulted in pulmonary insufficiency and in some cases exercise intolerance. In particular, longstanding severe pulmonary insufficiency may result in significant right ventricular dysfunction and symptoms[9].

We studied a group of 20 patients after repair of TOF. This report correlates the presence or absence of postrepair pulmonary insufficiency with ventricular function as measured by radionuclide ventriculography.

Material and Methods

A total of 20 patients underwent complete preoperative and postoperative evaluation consisting of echocardiography and radionuclide ventriculography before and after repair of TOF. None of them had additional cardiac defects. The mean age of patients was 5.2 ± 2.1 years (range 2 to 11 years). The functional capacity was noted according to the New York Heart Association criteria. Cardiothoracic ratios were calculated from standard posteroanterior chest roentgenograms. The diameter of the main pulmonary artery, the left and right branches, and the aortic diameter at the level of the diaphragm were measured by M-mode echocardiography, and the McGoon ratio[1] was calculated. Radionuclide ventriculography was performed preoperatively and three days post-operatively by labeling red blood cells with ^{99m}Tc pertechnetate. Phase and amplitude analysis of scintigraphic images and multiharmonic Faurier analysis of time activity curve were generated. Systolic and diastolic functional parameters (right and left ventricular ejection fraction, cardiac output and index and regurgitant fraction) were also calculated. Intra-operatively, right and left ventricular peak systolic pressure, right ventricle end diastolic pressure, and pulmonary artery systolic and diastolic pressure were measured approximately 30 minutes after cardiopulmonary bypass. The post-repair ratio between peak pressure in the right ventricle and that in the left ventricle ($P_{RV/LV}$) was calculated.

Patient Groups: The 20 patients were divided into two groups on the basis of the presence or absence of pulmonary insufficiency. Group I (n = 10) consisted of patients with no pulmonary insufficiency on whom a transannular patch was not used and pulmonary valves were protected. Group II (n = 10) consisted of the remaining patients who had moderate or severe pulmonary insufficiency treated by placement of a transannular patch and excision of pulmonary valve tissue.

Surgical Techniques: All surgery was performed with moderate hypothermia. Aortic cross-clamping was done with topical hypothermia and cold crystalloid cardioplegia. Ventriculotomy was performed vertically in all patients, and the ventricular septal defects were patched by means of interrupted and continuous suture techniques. Infundibular muscle resection was carried out to variable degrees, and commisurotomy was performed when valvular stenosis was also present. In 10 patients, a transannular patch was placed and pulmonary valve tissue was excised.

Statistical analysis: Statistical significance at the 95% confidence level was determined by the two-tailed t test for the difference between two means. Chi square test was also used. Results are expressed as mean ± standard error.

Results

The preoperative features for the 20 patients are shown in Table I. There was no difference in the functional capacity, cardiothoracic ratio, McGoon ratio, right and left ventricular ejection fraction, cardiac output or index between groups. The operative and postoperative features are shown in Table II. The post-repair ratio between peak pressure in the right ventricle and that in the left ventricle, and right ventricular end diastolic pressure were higher in patients with pulmonary regurgitation. In contrast, the peak systolic gradients from the right ventricle to the pulmonary artery were lower in patients with pulmonary regurgitation.

Comparison of ventricular function between the two groups by means of radionuclide ventriculography showed better right and left ventricular function in patients without pulmonary insufficiency. Right ventricular ejection fraction was impaired in both groups, although it was 40.1 ± 2.28 in patients without pulmonary insufficiency (Group I) compared to 29.5 ± 2.86 in patients with pulmonary insufficiency (Group II), $p < 0.01$ (Figs. 1 and 2). Left ventricular ejection fraction as well as cardiac output and index were also better in those patients without residual pulmonary insufficiency (59.3 ± 2.90) than in those with pulmonary insufficiency (50.9 ± 4.19), $p < 0.01$.

There was an inverse correlation ($r = 0.8436$) between the regurgitant fraction and the RVEF (Fig. 3).

Cardiothoracic ratios (Tablo II) in those patients with pulmonary insufficiency in whom a transannular patch had been used (Group II) were significantly greater than those in Group I, $p < 0.01$.

Functional capacity according to New York Heart Association criteria were found to be better in those patients without pulmonary insufficiency than in those patients with pulmonary insufficiency (Fig. 3).

Table I: Preoperative Features

Pts.	FC	CTR	McG.	RVEF	LVEF	CO	CI
Group I.							
1	III	48	0.55	41	68	420	745
2	III	45	0.52	35	56	386	711
3	II	49	0.46	47	65	600	1150
4	II	51	0.35	53	68	558	1053
5	II	55	0.31	51	65	555	1150
6	II	51	0.30	52	82	495	912
7	IV	50	0.58	58	65	588	975
8	III	53	0.51	48	62	493	846
9	III	48	0.48	40	61	1280	1660
10	II	48	0.38	47		612	956
Group II.							
1	III	54	0.45	48	53	412	855
2	II	53	0.32	58	60	715	1360
3	II	50	0.33	44	78	366	844
4	II	48	0.40	48	68	450	812
5	II	46	0.38	52	67	480	952
6	III	45	0.48	43	55	512	945
7	III	48	0.51	51	71	432	915
8	III	51	0.55	59	58	392	769
9	III	55	0.49	47	64	612	1055
10	IV	52	0.55	58	62	512	931

FC : Functional Capacity (According to New York Heart Association).
CTR : Cardiothoracic Ratio (%).
McG : McGoon Ratio.
CO : Right Ventricle Ejection Fraction (%).
RVEF : Cardiac Output (ml/m).
CI : Cardiac Index (ml/m/mP²).

$$\text{McGoon Ratio} = \frac{\text{Diameter of descending aorta}}{\text{Diameter of left and right pulmonary artery}}$$

Table II: Operative and Portoperative Features

Pts.	$P_{RV/LV}$	RVEDP	Grad.	RVEF	LVEF	CO	CI	CTR
Group I.								
1	0.45	6	12	40	67	430	707	47
2	0.44	10	18	33	60	355	657	46
3	0.30	5	20	50	63	700	1228	46
4	0.29	5	15	52	70	600	1132	45
5	0.36	9	18	45	62	502	1045	45
6	0.35	13	20	38	54	387	716	46
7	0.56	17	23	42	70	560	833	46
8	0.40	11	22	35	51	398	686	48
9	0.41	18	14	36	55	1112	1444	45
10	0.68	22	25	30	41	338	528	45
Group II.								
1	0.64	20	20	35	50	428	892	55
2	0.42	18	10	48	62	815	1538	48
3	0.38	12	8	38	83	405	988	50
4	0.62	21	11	22	40	215	390	55
5	0.36	23	15	28	43	245	490	56
6	0.70	20	13	25	42	270	500	62
7	0.43	18	22	34	53	305	649	55
8	0.56	22	15	24	52	179	351	58
9	0.56	25	17	20	43	302	621	59
10	0.56	20	21	21	41	360	654	57

FC : Functional Capacity (According to New York Heart Association).
CTR : Cardiothoracic Ratio (%).
McG : McGoon Ratio.
RVEF : Right Ventricle Ejection Fraction (%).
CO : Cardiac Output (ml/m).
CI : Cardiac Index (ml/m/mP^2).

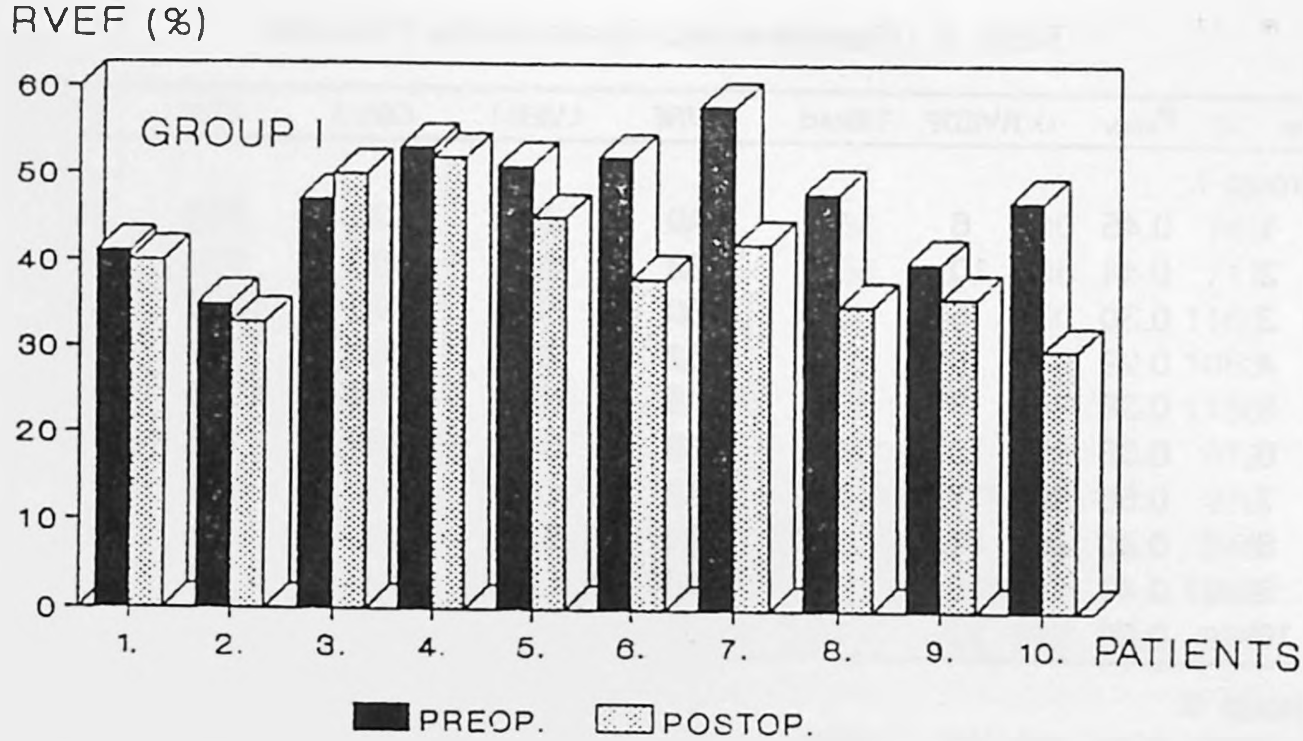

Fig. 1: Comparison of RVEF in Group II patients. RVEF: Right ventricle ejection fraction (%), Preop.: Preoperative, Postop.: Postoperative.

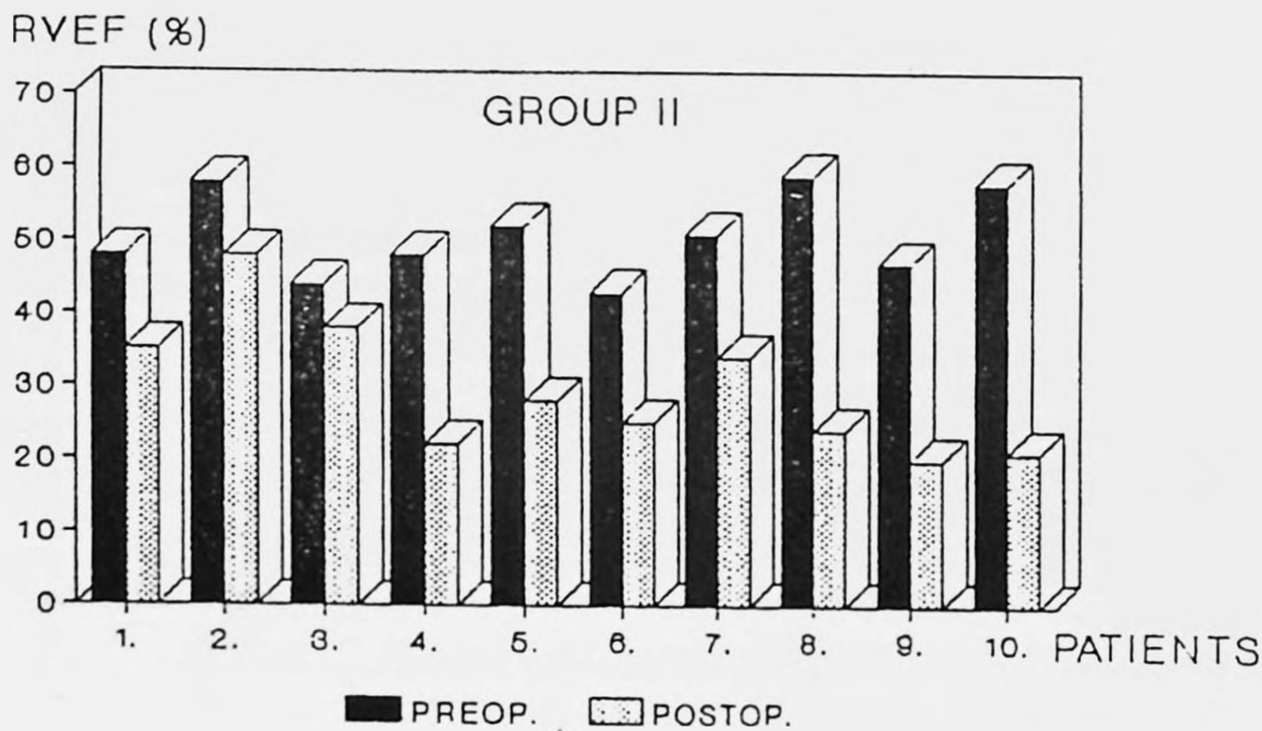

Fig. 2: Comparison of RVEF in Group II patients. RVEF: Right ventricle ejection fraction (%), Preop.: Preoperative, Postop.: Postoperative.

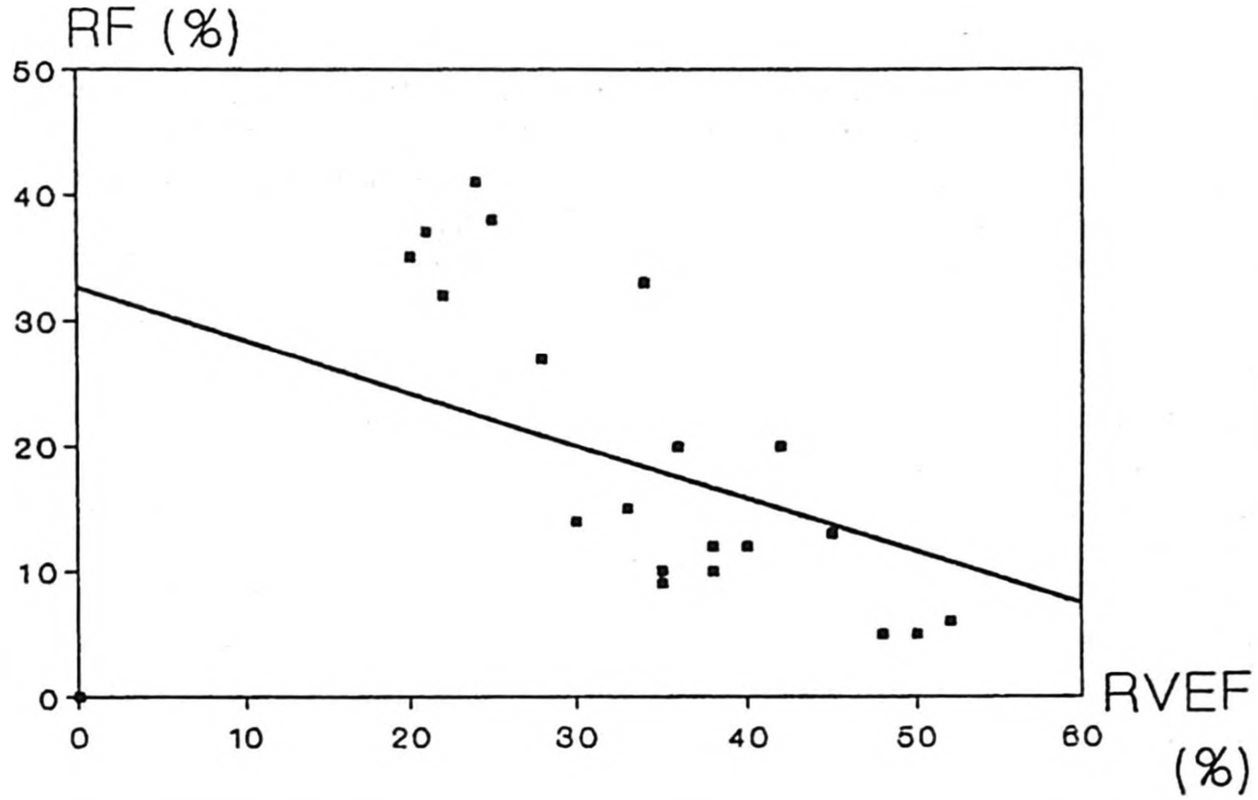

Fig. 3: Inverse correlation between RF and RVEF. RF: Regurgitant fraction (%). RVEF: Right ventricle ejection fraction (%).

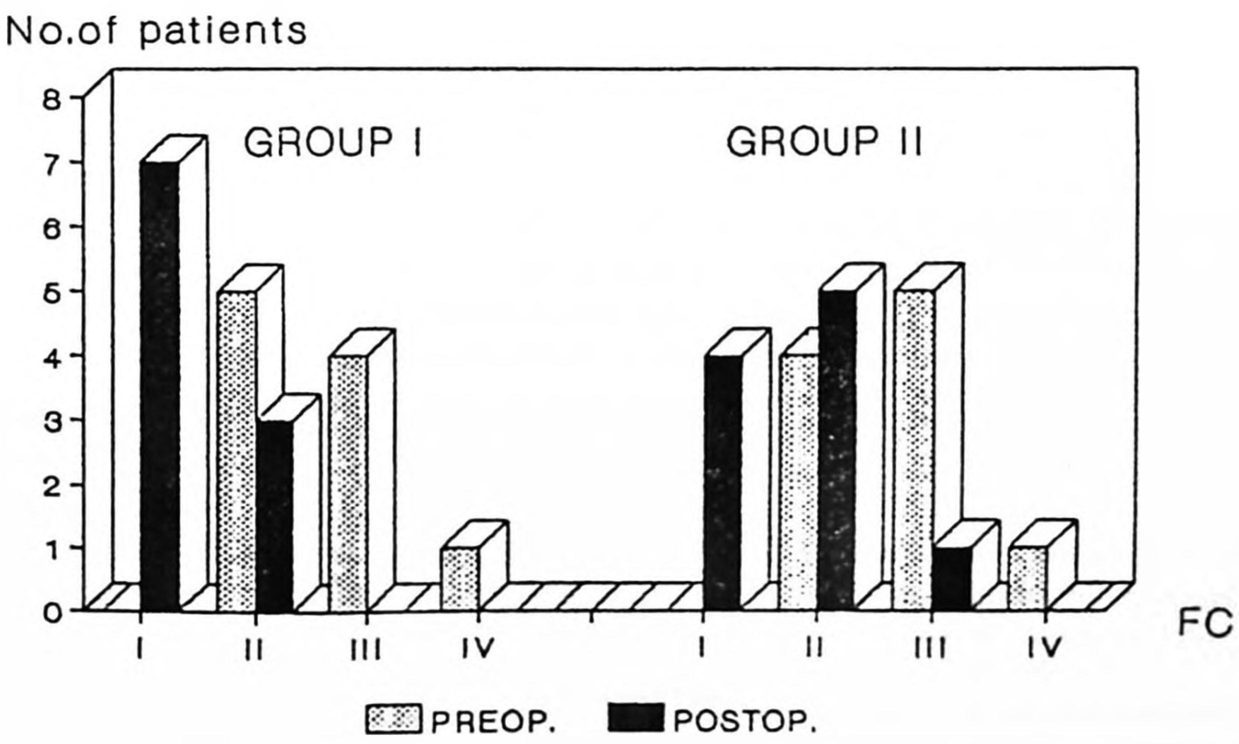

Fig. 4: Comparison of FC according to NYHA in Group I and II patients. FC: Functional capacity.

Discussion

The development of ventricular dysfunction is a widely recognized problem following repair of TOF[10]. The present study indicates that evaluation of symptoms alone is sufficient for detecting patients with impaired ventricular function in the early postoperative period. This study was designed to evaluate selectively the problem of pulmonary insufficiency after repair of TOF.

Radionuclide ventriculography is a proved method of evaluating left ventricular function[11]. Although less well established, its use in evaluating right ventricular function appears to be accepted. Because this technique is independent of the geometry of the ventricular chamber, it is particularly appropriate for use with the right ventricle. Our data indicate that patients with clinically moderate to marked pulmonary insufficiency following repair of TOF have diminished left and right ventricular function compared to patients with no or minimal regurgitation[12-14]. LVEF was normal in Group I patients and below normal in Group II patients. RVEF was impaired in both groups, although group I patients' levels (40.1 ± 2.28) fell not far below the accepted normal of 0.45.

In fact, asymptomatic pulmonary insufficiency after corrective surgery does not seem to guarantee that the patients remain asymptomatic for longer periods[2,5]. The question of surgery for pulmonary insufficiency remains controversial, but there are many good reasons for early repair[15]; one of great relevance is the protection of right ventricular function. If one waits for only the most severe symptoms of right ventricular dysfunction to develop, advanced and irreversible right ventricular damage can occur before the hemodynamic protection of a competent valve is provided. The last problem is perhaps the most intriguing: the alternatives available for creating outflow valve competence. Mechanical valves, heterografts, dacron or porcine conduits and monocusp patch are not suitable in this position[16-18]. Now, the improved characteristics of the viable allograft (aortic or pulmonary) make it the logical choice for all pulmonary ventricle outflow tract reconstructions in patients for whom a valve is indicated[19-22].

In conclusion, the method of radionuclide ventriculography is the most useful noninvasive assessment tool in evaluating postoperative pulmonary insufficiency in asymptomatic patients with an outflow patch across the pulmonary annulus. The deterioration of left and right ventricular function is also correlated with pulmonary insufficiency.

REFERENCES

1. Albertal G, Swan HJG, Kirklin JW. Hemodynamic studies two weeks to six years after repair of tetralogy of Fallot. *Circulation* 1964; 29: 582-8.
2. Arciniegas E, Farooki Z, Hakimi M, et al. Early and late results of total correction of tetralogy of Fallot. *J Thorac Cardiovasc Surg* 1980; 80: 770-8.

3. Blackstone EH, Kirklin JW, Bertranou EG, et al. Preoperative prediction from cineangiograms of postrepair right ventricular pressure in tetralogy of Fallot. *J Thorac Cardiovasc Surg* 1979; **78**: 542-52.
4. Borow MK, Green LH, Castenada AR, et al. Left ventricular function after repair of tetralogy of Fallot and its relationship to age at surgery. *Circulation* 1980; **61**: 1150-8.
5. Calder AL, Barratt-Boyes BG, Brandt PW, et al. Postoperative evaluation of patients with tetralogy of Fallot repaired in infancy. Including criteria for use of outflow patching and radiologic assessment of pulmonary regurgiatiton. *J Thorac Cardiovasc Surg* 1979; **17**: 704-20.
6. Ebert PA. Second operations for pulmonary stenosis or insufficiency after repair of tetralogy of Fallot. *Am J Cardiol* 1982; **50**: 637-40.
7. Hopkins RA. Right ventricular outflow tract reconstructions: the role of valves in the viable allograft era (editorial). *Ann Thorac Surg* 1988; **45**: 593-4.
8. Horneffer PJ, Zahka KG, Rowe SA, et al. Long-term results of total repair of tetralogy of Fallot in childhood. *Ann Thorac Surg* 1990; **50**: 179-83.
9. Zhao HX, Miller DC, Reitz BA, et al. Surgical repair of tetralogy of Fallot: long-term follow up with particular emphasis on late death and reoperation. *J Thorac Cardiovasc Surg* 1985; **89**: 204-20.
10. de Lorgeril M, Friedl B, Assimacopoulos A. Factors affecting lef ventricular function after correction of tetralogy of Fallot. *Br Heart J* 1984; **52**: 536-41.
11. Parrish MD, Graham TP, Jr Born ML, et al. Radionuclide stroke count ratios for assessment of right and left ventricular volume overload in children. *Am J Cardiol* 1983; **51**: 261-4.
12. Furuse A, Mizuno A, Shindo G, et al. Pulmonary regurgitation following total correction of tetralogy of Fallot. *Jpn Heart J* 1977; **18**: 621-8.
13. Ilbawi MN, Idriss FS, DeLeon SY, et al. Long-term results of porcine valve insertion for pulmonary regurgitation following repair of tetralogy of Fallot. *Ann Thorac Surg* 1986; **41**: 478-82.
14. Ionescu MI, Tandon AP, Macartney FJ. Long-term sequential hemodynamic evaluation of right ventricular outflow tract reconstruction using a valve mechanism. *Ann Thorac Surg* 1979; **27**: 426-34.
15. Bove EL, Kavey RW, Byrum CJ, et al. Improved right ventricular function following late pulmonary valve replacement for residual pulmonary insufficiency or stenosis. *J Thorac Cardiovasc Surg* 1985; **90**: 50-5.
16. Boyce SW, Turley K, Yee ES, et al. The fate of the 12 mm porcine valved conduit from the right ventricle to the pulmonary artery. A ten-year experience. *J Thorac Cardiovasc Surg* 1988; **95**: 201-7.
17. Finck SJ, Puga FJ, Danielson GK. Pulmonary valve insertion during reoperation for tetralogy of Fallot. *Ann Thorac Surg* 1988; **45**: 610-13.
18. Fleming WH, Sarafian LB, Moulton AL, et al. Valve replacement in the right side of the heart in children: long-term follow-up. *Ann Thorac Surg* 1989; **48**: 404-8.
19. Burczynski PL, McKay R, Arnold R, et al. Homograft replacement of the pulmonary artery bifurcation. *J Thorac Cardiovasc Surg* 1989; **98**: 623-31.
20. Campbell DN, Clarke DR. Use of the allograft aortic valved conduit. *Ann Thorac Surg* 1990; **50**: 320-2.
21. Clarke DR, Campbell DN, Pappas G. Pulmonary allograft conduit repair of tetralogy of Fallot. An alternative to transannular patch repair. *J Thorac Cardiovasc Surg* 1989; **98**: 730-7.
22. Fontan F, Choussat A, Deville C, et al. Aortic valve homografts in the surgical treatment of complex cardiac malformations. *J Thorac Cardiovasc Surg* 1984; **87**: 649-57.