Volume 110 Number 4 Part 1 October 1995

The Journal of
THORACIC AND CARDIOVASCULAR SURGERY

SURGERY FOR CONGENITAL HEART DISEASE

CARDIAC STATUS AND HEALTH-RELATED QUALITY OF LIFE IN THE LONG TERM AFTER SURGICAL REPAIR OF TETRALOGY OF FALLOT IN INFANCY AND CHILDHOOD

The long-term results of surgical repair of tetralogy of Fallot were assessed by means of extensive cardiologic examination of 77 nonselected patients 14.7 ± 2.9 years after surgical repair of tetralogy of Fallot in infancy and childhood. Because of the frequent use of a transannular patch (56%) for the relief of right ventricular outflow tract obstruction, the prevalence of elevated right ventricular systolic pressure was low (8%), but the prevalence of substantial right ventricular dilation with severe pulmonary regurgitation was high (58%). The exercise capacity of patients with a substantially dilated right ventricle proved to be significantly decreased (83% ± 19% of predicted) when compared with that of patients with a near normal sized right ventricle (96% ± 13%). Eight out of 10 patients who had needed treatment for symptomatic arrhythmia had supraventricular arrhythmia, which makes supraventricular arrhythmia—in numbers—a more important sequela in the long-term survivors than ventricular arrhythmia. Older age at the time of the operation and longer duration of follow-up were not associated with an increase in prevalence or clinical significance of sequelae. (J THORAC CARDIOVASC SURG 1995;110:883-91)

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Received for publication Sept. 1, 1994.

Accepted for publication Jan. 20, 1995.

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Reports on the long-term results of surgical repair of tetralogy of Fallot are numerous and emphasize several complications that may occur. However, most reports deal with either selected patient populations, and thus do not reveal the real prevalence of postoperative sequelae,[1-3] or with consecutive

0022-5223/95 $5.00 + 0 **12/1/63557**

Table I. *Baseline characteristics*

	Year of operation		
	1968-1975	*1976-1980*	*1968-1980*
No. of patients	39	38	77
Palliation			
No palliation	24 (61%)	28 (74%)	52 (68%)
Waterston shunt	5 (13%)	8 (21%)	13 (17%)
Blalock-Taussig shunt	10 (26%)	2 (5%)	12 (15%)
Surgical repair			
Age at repair (yr) (range)	5.9 ± 3.0 (0.3-12.7)	2.6 ± 2.0 (0.1-6.8)	4.7 ± 3.4 (0.1-13.0)
CPB, moderate hypothermia	29 (74%)	17 (45%)	46 (60%)
Deep hypothermia/circ. standstill	10 (26%)	21 (55%)	31 (40%)
Cold cardioplegia	7 (18%)	24 (63%)	31 (40%)
VSD closure with Dacron fabric patch	39 (100%)	38 (100%)	77 (100%)
Relief of RVOT obstruction by			
Transannular patch	13 (33%)	30 (79%)	43 (56%)
Infundibulectomy	17 (44%)	6 (16%)	23 (30%)
Patch, not transannular	2 (5%)	1 (3%)	3 (4%)
AO monocusp RV-PA	7 (18%)	0	7 (9%)
Hancock prosthesis	0	1 (3%)	1 (1%)
Reoperations			
No. of patients	6 (15%)	7 (18%)	13 (17%)
Interval from surgical repair to reoperation (yr) (range)	7.8 ± 8.7 (0.1-21.6)	3.0 ± 3.6 (0.1-8.3)	5.4 ± 6.8 (0.1-21.6)
Type of reoperation			
Closure of residual VSD	1 (3%)	5 (13%)	6 (8%)
Relief of residual RVOT obstruction	3 (8%)	1 (3%)	4 (5%)
Hancock prosthesis because of severe PR	0	1 (3%)	1 (1%)
Pacemaker implantation			
Because of AV block	1 (3%)	0	1 (1%)
Because of SND	1 (3%)	1 (3%)	2 (3%)
Antiarrhythmic medication			
Because of SVT/AF/AFl	4 (10%)	1 (3%)	5 (6%)
Because of sustained VT	1 (2%)	0	1 (1%)
Because of sustained VT and SVT	0	1 (2%)	1 (1%)

CPB, Cardiopulmonary bypass; *circ.,* circulatory; *VSD,* ventricular septal defect; *RVOT,* right ventricular outflow tract; *AO,* aorta; *RV-PA,* right ventricle to pulmonary artery; *PR,* pulmonary regurgitation; *AV,* atrioventricular; *SND,* sinus node dysfunction; *SVT,* supraventricular tachycardia; *AF,* atrial fibrillation; *AFl,* atrial flutter; *VT,* ventricular tachycardia.

series of patients in whom only questionnaires were used.[4,5] Because the absence of symptoms does not rule out the presence of (undetected) sequelae,[6] questionnaires do not give insight into the prevalence of sequelae either. Therefore we conducted a follow-up study by means of extensive cardiologic examination in a consecutive series of patients with long-term survival after surgical repair of tetralogy of Fallot in infancy or childhood. Special emphasis was put on the relation between anatomic, hemodynamic, and electrophysiologic sequelae and on the impact on the long-term results of the differences in age at operation, duration of follow-up, and surgical techniques.

Methods

Patient selection and follow-up procedure. The follow-up study started in April 1989. The clinical records of all 142 patients who underwent surgical repair of tetralogy of Fallot in our institution between 1968 and 1980 and who were younger than 15 years old at the time of operation were reviewed for baseline characteristics. The year 1968 was chosen as the starting point because in this year the first heart operation with the use of cardiopulmonary bypass was performed in our institution, and 1980 was chosen as the end point so we would have at least 10 years of follow-up for all patients. Patients were traced through local registrars' offices. Twenty-seven patients (19%) had died, of whom 4 (3%) died more than 1 year after the operation. Four patients (3%) had moved abroad and 2 (2%) were untraceable. The remaining 109 patients received a letter in which the objective of the study was explained with an invitation to participate in an extensive cardiologic examination. A total of 77 patients (71% of those eligible for follow-up) agreed to participate.

Forty-five patients were male (58%) and 32 female (42%). The baseline characteristics of the 77 participants are shown in Table I. Because of the many changes in baseline variables between 1968 and 1980, this period was arbitrarily divided in two to create two subgroups: patients

operated on before 1976 and patients operated on since then. These two subgroups were analyzed separately. There were no differences in baseline characteristics between the patients who participated in the follow-up study and the patients who were known to be alive but did not participate in the follow-up study. The cardiac examination included medical history, physical examination, standard 12-lead electrocardiography (ECG), echocardiography (M-mode, two-dimensional, and pulsed, continuous wave, and color-flow Doppler), exercise testing by bicycle ergometry, and 24-hour ECG.

The study was approved by the local medical ethical committee.

Measurements and definitions. The diagnosis of tetralogy of Fallot was established during preoperative diagnostic cardiac catheterization. Patients with pulmonary atresia were excluded.

The history consisted partly of a standardized questionnaire on personal health assessment validated in a sample of 1510 Dutch adults younger than age 35 years.[7]

Echocardiography was done with a Toshiba SSH 160-A echocardiograph (Toshiba Medical Co., Ltd., Tokyo, Japan). Elevated systolic right ventricular pressure was judged to be present if the velocity of a tricuspid regurgitation jet or pulmonary artery flow exceeded 3.5 m/sec or if a nonrestrictive ventricular septal defect was found. Because right ventricular dilation cannot be measured reliably, this feature was judged independently by two experienced investigators. Substantial right ventricular dilatation was defined as the presence of a right ventricle that in diameter was equal to or larger than the left ventricle in both the parasternal long-axis view and the apical four-chamber view. The degree of pulmonary regurgitation (minimal, mild, moderate, severe) was estimated with color Doppler echocardiography by the width and length of the regurgitant jet in the right ventricle and with pulsed Doppler echocardiography by the velocity and pattern of the regurgitant flow in the right ventricular outflow tract and pulmonary artery.[8]

Maximal exercise capacity was assessed by bicycle ergometry with stepwise increments of the workload of 20 watts per minute until the patient was exhausted. Patients were not tested if a concomitant factor could affect the test result (severe psychomotor retardation, spastic hemiplegia).

Arrhythmias were defined as symptomatic if patients used antiarrhythmic drugs, if direct-current countershock had been necessary in the past, or if a pacemaker had been implanted. Sinus node dysfunction was defined as the presence of atrial flutter, atrial fibrillation, and a bradycardia-tachycardia syndrome. The following phenomena were interpreted as possible indicators of sinus node dysfunction: a sinoatrial block, a beat-to-beat variation of the heart rate of more than 200%, a sudden change from sinus rhythm to an escape rhythm with a frequency more than 25% lower than the sinus rhythm, a nighttime bradycardia of less than 30 beats/min, and a daytime bradycardia of less than 40 beats/min.[9] Premature ventricular contractions, recorded during the 24-hour ECG were considered to be abnormal if monoform premature ventricular contractions occurred in a frequency exceeding 3600/24 hour, if premature ventricular contractions were multiform, or if premature ventricular contractions presented as doublets or ventricular tachycardia. Short ventricular tachycardia was defined as at least 3 and not more than 10 consecutive beats that originated from a ventricle, with a rate exceeding 120 beats/min.

Table II. *Personal health assessment of 77 patients in the long term after complete repair of tetralogy of Fallot compared with a sample of 1510 Dutch adults younger than age 35 years*

	Patients		*Normal population*		
	No.	*%*	*No.*	*%*	*p Value*
Excellent	13	17	611	40	<0.001*
Good	50	65	755	50	<0.014*
Fair	11	14	127	9	NS
Not good	3	4	17	1	NS
Bad	0	0	0	0	NS

NS, Not significant.
*Significant difference.

Data analysis. All values are expressed with their mean value and standard deviation, unless indicated otherwise. The χ^2 test and Fisher's exact test were used for the comparison of discrete variables and Student's t test was applied to compare continuous variables in the presence of a normal distribution. In the presence of a nongaussian distribution, the Mann-Whitney rank-sum test was used. In all analyses the level of significance was chosen as $p < 0.05$.

Results

History. Fifty-three patients (69%) had been seen by a cardiologist or pediatric cardiologist regularly at least once every 3 years, in contrast to 24 patients (31%) who were not regularly seen by a cardiologist in the past 10 years. All patients were asked their opinion about their own health. The outcome was compared with that in the normal population (Table II). The personal health assessment of patients who had not been checked regularly by a cardiologist was significantly better than that of patients who underwent regular checkups. A less than "good" personal health assessment was not associated with older age at the time of surgical repair, longer duration of follow-up, or medical or surgical interventions after the surgical repair. The three patients who assessed their health as "not good" proved to have substantial abnormalities at echocardiographic examination: two had a large nonrestrictive ventricular septal defect, and all three had elevated systolic right ventricular pressure.

Physical examination. The mean values of length, body weight, and blood pressure corrected for age and sex did not differ significantly from those

Table III. *Summary of the results of the echocardiography, bicycle exercise test, and 24-hour ECG*

	Year of operation		
	1968-1975	*1976-1980*	*1968-1980*
No. of patients	39	38	77
Age at the time of the follow-up study (yr) (range)	22.9 ± 4.5 (15.9-34.9)	15.0 ± 3.1 (9.9-20.6)	19.0 ± 5.5 (9.9-34.9)
Duration of follow-up (yr) (range)	17.0 ± 2.7 (14.5-22.2)	12.4 ± 1.6 (9.5-15.2)	14.7 ± 2.9 (9.5-22.2)
Echocardiography			
RV size			
Near normal/moderately dilated RV and mild/moderate PR	19 (49%)	13 (35%)	32 (42%)
Severely dilated RV and moderate/severe PR	20 (51%)	25 (65%)	45 (58%)
RV pressure			
Normal	36 (92%)	35 (92%)	71 (92%)
Elevated	3 (8%)	3 (8%)	6 (8%)
Ventricular septum			
Intact	28 (72%)	35 (92%)	63 (82%)
Large VSD	2 (5%)	0	2 (3%)
Small VSD	9 (23%)	3 (8%)	12 (15%)
Exercise test			
Maximal exercise capacity (% of normal, range)	88 ± 16 (46-117)	89 ± 17 (38-118)	90 ± 18 (38-118)
<50%	1 (3%)	1 (3%)	2 (3%)
50%-80%	6 (18%)	7 (19%)	13 (18%)
>80%	27 (79%)	29 (78%)	56 (79%)
Not tested	5	1	6
24-hour ECG			
No. of patients without arrhythmia	8 (26%)	11 (31%)	19 (28%)
No. of patients with arrhythmia	23 (74%)	25 (69%)	48 (72%)
No registration	8	2	10
No. of patients with ventricular arrhythmia	16 (52%)	17 (49%)	33 (49%)
Multiform PVCs	13 (42%)	14 (39%)	27 (40%)
PVC doublets	6 (19%)	9 (25%)	15 (22%)
VT 3-10 beats	2 (6%)	3 (8%)	5 (7%)
VT >10 beats	0	1 (3%)	1 (1%)
No. of patients with supraventricular arrhythmia	7 (22%)	12 (33%)	19 (28%)
SVT	1 (3%)	3 (8%)	4 (6%)
Possible SND	6 (19%)	8 (22%)	14 (21%)
AF	0	0	0
AFl	0	0	0
Bradycardia/tachycardia syndrome	0	1 (3%)	1 (3%)

RV, Right ventricle; *PR,* pulmonary regurgitation; *VSD,* ventricular septal defect; *PVC,* premature ventricular contraction; *VT,* ventricular tachycardia; *SVT,* supraventricular tachycardia; *SND,* sinus node dysfunction; *AF,* atrial fibrillation; *AFl,* atrial flutter.

of the normal Dutch population. A systolic murmur was heard in 75 patients (97%) and a diastolic murmur in 63 patients (82%). Nine patients (12%) had moderate to severe chest deformity and scoliosis. Of these, three had a lateral thoracotomy because of shunting (Blalock-Taussig in 2, Waterston in 1) done before the surgical repair, and two others had severe psychomotor retardation and spastic hemiplegia. Four patients (5%) had psychomotor retardation and spastic hemiplegia.

Echocardiography. In Table III the findings concerning right ventricular size, systolic right ventricular pressure, and interventricular septum are summarized. The left ventricular outflow tract was unobstructed in all patients. The aortic anulus was dilated (>95th percentile for body weight) in three patients (4%). Twelve patients (16%) had evidence of minimal aortic regurgitation; severe aortic regurgitation was not seen. Moderate to severe tricuspid regurgitation was seen in 17 patients (22%). All had a severely dilated right ventricle. The antegrade flow velocity in the pulmonary artery did not differ significantly between patients with and without a transannular patch (1.7 ± 0.7 m/sec versus 2.0 ± 0.8 m/sec; $p = 0.09$). Severe pulmonary regurgitation and substantial dilatation of the right ventricle were seen more often after surgical repair with the use of a transannular patch ($p < 0.01$) or an aortic monocusp valve ($p < 0.05$) than after other surgical techniques. The following baseline variables were

tested, but proved to be not significantly correlated with substantial right ventricular dilatation and pulmonary regurgitation: older age at the time of the operation, longer duration of follow-up, moderate hypothermia and complete cardiopulmonary bypass versus deep hypothermia and circulatory arrest, and absence of cold cardioplegia. The prevalence of substantial right ventricular dilatation and severe pulmonary regurgitation was significantly higher in patients who had been regularly seen by a cardiologist than in patients who had not been seen regularly by a cardiologist. Other hemodynamic variables did not differ between the two groups.

Bicycle ergometry. Seventy-one patients exercised to maximum effort. Four patients were not tested because of mental retardation, and two patients refused the test. The results are summarized in Table III. The mean value for maximal exercise capacity (89% ± 16%) is significantly lower than that of the normal population ($p < 0.01$). Patients with a near normal or moderately dilated right ventricle had a maximal exercise capacity of 96% ± 13% versus 83% ± 19% in patients with a substantially dilated right ventricle ($p = 0.002$). The maximal exercise capacity of the six patients with an elevated systolic right ventricular pressure was 87% ± 12%, which is significantly different neither from that of patients with a near normal or moderately dilated right ventricle nor from that of patients with a substantially dilated right ventricle. Fourteen of the 15 patients with an exercise capacity of less than 80% of predicted had a substantially dilated right ventricle. The maximal exercise capacity of patients who had a transannular patch (86% ± 18%) or an aortic monocusp valve (81% ± 15%) at surgical repair was significantly lower ($p < 0.03$) than that of patients who had another type of relief of the right ventricular outflow tract obstruction (95% ± 14%).

There was no significant difference in maximal exercise capacity between patients who were checked regularly by a cardiologist and patients who were not. Palliative operation before the surgical repair, older age at the time of the surgical repair, and longer duration of follow-up were not associated with a decreased exercise capacity. Eleven patients had arrhythmia during or directly after the exercise test. One patient, who was not known to have ventricular arrhythmia, had a short ventricular tachycardia (<10 beats) during exercise. Nine patients, of whom only three had ventricular arrhythmia on the 24-hour ECG registration, had multiple premature ventricular contractions. One patient, who was known to have a supraventricular tachycardia with a 2:1 conduction, had a 1:1 conduction at exercise.

Twelve-lead ECG. A narrow QRS complex was seen in 20 patients (26%), of whom 11 (14%) had completely normal ECG findings; the remaining 9 patients showed signs of right ventricular hypertrophy. A wide QRS complex was found in 57 patients (74%). Forty-five patients (58%) had a complete right bundle branch block, 9 patients (12%) had both a complete right bundle branch block and a left anterior hemiblock, and 3 patients (4%) had a pacemaker rhythm with a wide QRS complex. The mean PR interval was 0.15 ± 0.03 seconds (range 0.10 to 0.24 seconds).

No significant differences were found between patients with a bundle branch block and those without with regard to the type of surgical relief of the right ventricular outflow tract obstruction, age at the time of the operation, or duration of follow-up.

Twenty-four–hour ECG. A complete 24-hour ECG could be obtained in 67 patients. The results are summarized in Table III. In 39 patients with a dilated right ventricle in whom a 24-hour ECG was obtained, 23 (59%) had ventricular arrhythmia. Of the 28 patients with a normal or slightly enlarged right ventricle, 10 (36%) had ventricular arrhythmia. This difference is not significant ($p = 0.1$). Five patients with an elevated systolic right ventricular pressure had a complete 24-hour ECG registration; three had ventricular arrhythmia, and two of these had ventricular tachycardia. This prevalence is significantly higher than that in patients with normal right ventricular pressure (2 of 5 patients versus 3 of 62 patients; $p = 0.04$). Older age at the time of operation, longer duration of follow-up, and older age at the time of the follow-up study were not associated with a higher prevalence of ventricular or supraventricular arrhythmia.

There was no significant difference in prevalence of ventricular or supraventricular arrhythmias between patients who received cold cardioplegia at surgical repair and patients who did not or between patients in whom deep hypothermia with circulatory arrest was used and patients who had undergone the procedure with moderate hypothermia and cardiopulmonary bypass. In patients who had a palliative procedure before surgical repair, or who had undergone reoperation, the prevalence of arrhythmia was not higher than that in patients who had had one operation. There was no difference in prevalence or type of arrhythmia on the 24-hour ECG between

patients who were checked regularly by a cardiologist and patients who were not.

Discussion

This study shows that the long-term results of surgical repair of tetralogy of Fallot in infancy and childhood are good in terms of health assessment and exercise capacity: 82% of the long-term survivors described their health as "excellent" or "good," and 79% had an almost normal exercise capacity of more than 80% of the predicted value. If one considers the patients who assessed their health as "good" or "excellent" as one group, the personal health assessment is even as good as that of the normal Dutch population. A similar good health assessment after surgical repair of tetralogy of Fallot was reported by others.[10] Obviously, a good health assessment is an important determinant for the quality of life. However, we did not find a correlation between a "good" or "excellent" health assessment and the absence of symptoms (decreased exercise capacity) or sequelae (substantial right ventricular dilation, ventricular or supraventricular arrhythmia). This confirms that personal health assessment is not a good indicator for the objective clinical condition of the patient.[11]

If the long-term results of the surgical repair of tetralogy of Fallot were judged on the presence of a normal cardiac anatomy or electrophysiologic findings, the score would not be good: 58% of the patients had a substantial dilatation of the right ventricle with severe pulmonary regurgitation and 72% of the patients had ventricular or supraventricular arrhythmia on the 24-hour ECG. The prevalence of postoperative sequelae in our study population is reliably assessed as a result of the study design, but the clinical significance of many sequelae is still unclear and remains subject to debate.

Anatomic and hemodynamic sequelae. The prevalence of elevated right ventricular systolic pressure because of residual right ventricular outflow obstruction was relatively low (8%).[5, 12, 13] This is probably partly because of the absence of patient selection in our follow-up study; patients with elevated right ventricular systolic pressure are likely to have symptoms and are therefore probably overrepresented in other types of follow-up studies. Another explanation is that the frequent use of a transannular patch in our study population was responsible for both the relatively low prevalence of elevated right ventricular systolic pressure and the high prevalence of substantial right ventricular dilatation and severe pulmonary regurgitation.

The clinical importance of elevated right ventricular systolic pressure is its association with ventricular arrhythmias and late sudden death.[14-16] Also in our study the prevalence of ventricular tachycardia was significantly higher in these patients than in patients with normal systolic right ventricular pressure. Pooled data of 39 studies on postoperative tetralogy of Fallot (comprising 4627 patients) revealed that 80% of the patients who had died suddenly had both abnormal hemodynamics (especially elevated right ventricular systolic pressure) and ventricular arrhythmias on the 24-hour ECG.[17] Therefore treatment for these patients must be considered with surgical relief of the residual right ventricular outflow tract obstruction only or with surgical treatment in combination with antiarrhythmic medication.

The interpretation of the clinical importance of right ventricular dilatation and pulmonary regurgitation is much more controversial than that of elevated right ventricular pressure. Because there is no standardized method to quantify either pulmonary regurgitation or right ventricular dimensions, these features are assessed by means of many different techniques in the many follow-up studies (clinical evidence,[18] angiography,[19, 20] radionuclide angiography,[3] echocardiography[21]), which makes comparison in this respect among studies hazardous. In our study we did not find a correlation between substantial right ventricular dilatation and arrhythmia.[22] However, like others[3, 4, 23, 24] we did find that the exercise capacity was substantially decreased in patients with substantial right ventricular dilatation and severe pulmonary regurgitation. Because it has been demonstrated that even long-standing pulmonary regurgitation and right ventricular dilatation (>30 years) has no negative effect on long-term survival,[18] a decreased exercise capacity seems to be the only consequence of substantial right ventricular dilatation. Longer follow-up will be necessary to see whether these assumptions will turn out to be true.

Other anatomic sequelae that were frequently seen were residual ventricular septal defect and aortic regurgitation. Except for two patients who had a large, nonrestrictive ventricular septal defect who were operated on as a result of this finding at the follow-up study, these sequelae had no hemodynamic significance.

Electrophysiologic sequelae. In our study there were two patients (2%) with sustained ventricular

tachycardia. About the clinical significance of sustained ventricular tachycardia there is not much discussion: these patients are considered to be at risk for sudden death and antiarrhythmic medication is indicated. Furthermore, 32 patients (48%) had complex premature ventricular complexes, including 5 patients with nonsustained ventricular tachycardia. This is within the wide range of the reported prevalence of ventricular arrhythmia (range 2% to 77%)[19] and comparable with the prevalence of ventricular arrhythmias in two studies of consecutive patients (respectively 41% and 42%).[25, 26] The clinical significance of asymptomatic complex premature ventricular complexes and nonsustained ventricular arrhythmia is still controversial.[16] Are they possible determinants for the occurrence of sustained arrhythmia (and sudden death) and should they therefore be treated prophylactically, even if the risk for a sustained ventricular tachycardia is very small?[18] Or have these patients such a low risk for the development of sustained ventricular tachycardia that prophylactic treatment with potentially dangerous side effects should be omitted?[13] Because of the nature of this study our data do not provide new arguments to support one of the two opposing views.

Supraventricular arrhythmia and sinus node dysfunction have been reported earlier in repaired tetralogy of Fallot.[14, 25, 27] In our study population, 7 of the 10 patients who were treated because of rhythm disturbances had supraventricular arrhythmia. This emphasizes that supraventricular arrhythmia and sinus node dysfunction are clinically important sequelae after surgical repair of tetralogy of Fallot, the clinical importance of which has been underestimated so far. Next to these patients with symptomatic supraventricular arrhythmia, 28% of the patients had asymptomatic supraventricular arrhythmia. It can be questioned whether these arrhythmias are abnormal, because 24-hour ECG studies in normal adolescents and young adults have demonstrated that these arrhythmias are also frequently present in the normal population.[28-31] On the other hand, in this group of patients with such a high prevalence of proven sinus node dysfunction, it is possible that these findings are indeed signs of a compromised sinus node function and as such predictors for clinically relevant arrhythmias later. Possible causative mechanisms could be cannulation of the right atrium for cardiopulmonary bypass[32] or decreased right ventricular function leading to elevated right atrial pressures and dimensions. More specific studies on this subject and a longer duration of follow-up will be necessary to establish the clinical importance of these findings.

Reoperation. Freedom from reoperation is one of the hallmarks of successful surgical repair. In our study population the freedom from reoperation was 88%, which is similar to results published by others.[33] As in other series, the most important indication for reoperation was closure of a residual ventricular septal defect.[34] Only one patient with severe pulmonary regurgitation and right-sided heart failure had a pulmonary valve replacement. The benefits of pulmonary valve replacement for this indication have been documented.[35] Others have advocated pulmonary valve replacement as an essential part of the treatment of symptomatic ventricular arrhythmias in the presence of poor right ventricular hemodynamics and severe pulmonary regurgitation. Only improvement of the right ventricular hemodynamic situation would make successful medical therapy possible. However, our data indicate that there is no correlation between right ventricular dilatation and symptomatic arrhythmia, and therefore we do not support this view. Furthermore no study on the efficacy of this regimen has been published yet.

In contrast to results in other reports there were no deaths associated with reoperation, and we did not find an increased prevalence of ventricular arrhythmias in patients who underwent reoperation compared with that in patients who did not undergo reoperation.[36]

Year of operation, age at surgical repair, and duration of follow-up. These factors, which are closely related to each other, changed significantly and simultaneously in the period between 1968 and 1980.[37] All could possibly affect the eventual outcome of the surgical repair. Except for the use of a transannular patch, which proved to be associated with severe pulmonary regurgitation and right ventricular dilatation, univariate analysis failed to identify a single determinant in these baseline characteristics that was associated with one of the sequelae at follow-up. We did not find a correlation between older age at surgical repair and ventricular arrhythmia; this is in contrast to the findings of many others.[38-40] Unlike others we did not find that longer duration of follow-up was associated with an increase in prevalence of substantial right ventricular dilation, a decrease in exercise capacity,[41] or an increase of the prevalence of arrhythmia. This suggests that the factor "time" has little impact on the long-term results of surgical repair of tetralogy of

Fallot and therefore that the outlook for the future of these patients is promising. Because at univariate analysis to determine whether differences in baseline characteristics led to significant differences in sequelae at follow-up only one determinant (transannular patch) proved to be statistically significant and all other determinants (age at surgical repair, palliation before the surgical repair, moderate or deep hypothermia, cold cardioplegia, reoperation, duration of follow-up, age at follow-up) had p values >0.15, we did not perform multivariate analysis.

Selection bias. Apart from being selected on the grounds of the definition of the study population—patients with tetralogy of Fallot who underwent surgical repair before age 15 years in our institution between 1968 and 1980—patients in this study were not purposely selected. We examined only 71% of those eligible for follow-up, not 100%, and we were not informed about the reasons why patients who did not participate in the follow-up study actually refused, and therefore we cannot exclude the possibility that we saw an unintentionally selected patient group. However, all patients were approached uniformly, and there were no significant differences in any of the baseline characteristics as summarized in Table I between patients who participated in the follow-up study and those who did not. Therefore we assume that there was no selection bias and consider the patients who participated in the follow-up study as a nonselected population.

Conclusion. Long-term follow-up of a nonselected group of patients who underwent surgical repair of tetralogy of Fallot reveals a substantial prevalence of sequelae, similar to that in earlier reports on selected patient groups. However, the prevalence and clinical relevance of these sequelae and their correlations with age at operation, different surgical techniques, and duration of follow-up are assessed more reliably. The frequent use of a transannular patch, which is a reflection of the state of the art of the surgical approach in the 1960s and 1970s, but substantially different from current-day techniques, has led to a low prevalence of elevated systolic right ventricular pressures and therefore a low prevalence of potentially life-threatening ventricular arrhythmias. The negative aspect of this approach was the high prevalence of obligatory severe pulmonary regurgitation and right ventricular dilatation, which was clearly associated with a decreased exercise capacity.

We thank Ron van Domburg, MS, for his assistance in making the CLINT database management system available on personal computer and for his advice on data management; Eric Boersma, MS, for the statistical analysis of the data; and Jacky McGhie for the excellent quality of the ECG registrations.

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