Early and Late Results of Total Correction of Tetralogy of Fallot

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Received: 2 Jan. 2008; Received in revised form: 19 Apr. 2008; Accepted: 14 May 2008

Abstract- The purpose of this study was to evaluate the early and late outcome after total correction of tetralogy of fallot (TOF) in 101 consecutive patients with a mean age of 8.23 ± 4.90 years underwent repair of surgery at one institution between 1995 and 2006. Forty two patients had initial palliative operations. A transannular patch was inserted in 60 (58.5%) patients. Risk factors for operative mortality were analyzed. Follow-up was obtained from clinical appointments and telephone questionnaires. The operative mortality was 6.9%. Aortic cross-clamp time more than 90 minutes (P<0.01) and cardiopulmonary bypass time more than 120 minute (P<0.01), affected operative mortality, whereas previous palliative procedure, hematocrit level, and use of transannular patch did not. Mean follow-up is 34.08 ± 31.09 months (range, 1 month to 120 months). Actuarial survival is 91% alive 10 years after total correction. On Postoperative echocardiography, 22 patients had mild pulmonary regurgitation, 19 had a right ventricular outflow tract gradient more than 50 mmHg, and 10 had a small residual ventricular septal defect. There were two late deaths. Late sudden death from cardiac causes occurred in one patients. Total correction of TOF can have low operative mortality and provide excellent long-term survival. This experience suggests that the key factor in the total correction of TOF is to correct the pathology completely, to protect the myocardium, and to manage the complication properly.

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Acta Medica Iranica 2010; 48(2): 117-122.

Key words: Heart defects, congenital; mortality; tetralogy of fallot

Introduction

Tetralogy of to fallot (TOF) is the most common cyanotic congenital disease with approximately 3000 new cases diagnosed in the United States each year (1).

The first completed repair of TOF was successfully performed by C. Walton Lillehei and his team in 1954 (2). Despite some advocates of routine primary repair in infancy (3, 4), unacceptable early mortality resulted in wide acceptance of a two-stage repair with excellent results (5, 6).

During the early 1990s reports documented improved early results with primary repair in infancy (1, 7) and suggested that primary repair was associated with improved outcome compared to a two-stage approach (8). The purpose of this study was to analyze early postoperative and late results in total correction of TOF.

Patients and Methods

Patients

Between March 1995 and 2006, 101 consecutive patients with TOF underwent intracardiac correction at the Cardiac Surgery Department, Tabriz University of Medical Science. There were 59 (58.4%) male and 42 (41.6%) female patients. Age ranged from 1 year to 25 years (mean, 8.23 ± 4.90 years) (Figure 1). Weight was 23.00 ± 12.99 kg (range, 7.5 to 66 kg). These included patients with classic TOF with pulmonary stenosis (TOF-PS) but exclude other complex associated pathologic processes such as absent pulmonary valve syndrome or common atrioventricular canal. There were 101 patients in the study group. Fifty nine (58.4%) patients had primary complete repair of TOF without an initial palliative procedure (primary repair group). Forty two (41.6%) patients had initial palliative followed by a complete repair at later stage (staged repair group).

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Table 1. Preoperative Variables

Variable		value
Age	Mean (y)	8.23±4.90
	Range (y)	1-25
	Mean weight (kg)	23.00±12.99
Symptom	syncope	9
	squatting	18
	cyanosis	50
	clubbing fingers & toes	95
Signs	systolic murmur	
	< Grade 2	23
	> Grade 3	78
ECG	RVH	83
	RVH dilation of right atrium	18
Chest roentgenogram	Boot-shape heart & oligemia of the lung	100 (99.9%)
labratory	Hematocrit level (%) > 45%	58 (57.4%)
Echocardiography	Typical TOF	101(100%)
	Tricuspid valve regurgitation	6(5.9%)
Angiocardiography	Typical TOF	101
	Hypoplasia of pulmonary arteries	23
	Stenosis in the pulmonary valve annulus	59
	Stenosis in the origin of the LPA	1
	Stenosis in the origin of the RPA	2
	Absent left PA	1

ECG= electrocardiography; LPA= left pulmonary artery; PA= pulmonary artery; RPA= right pulmonary artery; RVH= right ventricular hypertrophy; TOF= tetralogy of Fallot

Palliation included 33 patients with right modified blalock taussig shunts 7 with left modified blalock taussig shunts and 2 with modified Waterston shunts. The preoperative variable of these groups of patients are summarized in Table 1.

The diagnosis of TOF for all patients was made by preoperative echo-cardiography and cardiac catheterization. All patients had uncomplicated TOF and fifty (49.5%) patients possessed other associated congenital cardiac abnormalities (Table 2). Operative details of the patients are depicted in Table 3.

Table 2. Associated Cardiopulmonary Abnormalities

Variable	Number	Percent
No associated Abnormalities	51	50.5
Patent ductus arteriosus	12	11.9
Patent foramen ovale	3	2.9
Atrial septal defect	16	15.8
Right aortic arch	14	13.8
Aortic Insufficiency	2	1.9
Tricuspid Regurgitation	6	5.9
Left superior vena cava	2	1.9
Others	7	6.93

LAD= left anterior descending coronary artery; RCA= right main coronary artery; LPA= left pulmonary artery ; PA= pulmonary artery.
others include Discrete subaortic stenosis (1), Mitral valve prolapse (1), Situs inversus (1), Dextrocardia (1), LAD from the RCA (1), Absent LPA (1) and Small PA branches (1).

Table 3. Operative detailes of patients with tetralogy of fallot

Procedure	Number	Percent
Transatrial VSD repair	80	79.2
Transventricular VSD repair	21	20.8
Reconstruction of the RVOT		
PV comissurotomy	47	46.5
Subvalvular stenosis repair	97	96.0
Transannular patch	60	58.5
MPA repair with PP	9	8.9
LPA repair with PP	1	0.99
RPA repair with PP	2	1.9
Closure ASD	16	15.8
Closure PFO	3	2.9
Closure PDA	12	11.9
Closure shunt	42	41.6
TV repair	6	5.9
Subaortic stenosis resection	1	0.99

VSD= ventricular septal defect; RVOT= right ventricular outflow tract; PP= pericardial patch; MPA= main pulmonary artery; LPA= left pulmonary artery; RPA= right pulmonary artery; PV=pulmonary valve, ASD= atrial septal defect; PFO= patent foramen ovale; TV= tricuspid valve

Data collection

From review of the medical record, data were collected relevant to the date of complete repair. An attempt was made to achieve follow-up on all the patients by means of telephone interviews with the patients, their parents, cardiology clinic follow-up visits were also reviewed. Recent follow-up was achieved in 88 (87.1%) patients. Mean follow-up was 34.08 ± 31.09 months (range, 1 to 120 months).

Operative procedure

The heart was exposed through a median sternotomy, a patch of pericardium was removed for right ventricular outflow tract reconstruction, and previously placed shunts were encircled with silk ties and ligated. The operation was performed under cardiopulmonary bypass with hypothermia (nasopharyngeal temperature was between 25° and 28° C). A median sternotomy was used routinely. Conventional nonpulsatile bypass with a membrane oxygenator was used. Intermittent doses of crystalloid or cold blood potassium cardioplegia and topical cooling were used for myocardial protection. A vertical right ventriculotomy was used to expose the right ventricular outflow tract. The ventricular septal defect was closed through a right atriotomy in 80 patients and through a right ventriculotomy in 21. A Gore-Tex patch was used and it was sewn with continuous sutures or buttressed interrupted mattress sutures. The right ventricular outflow tract or pulmonary artery were enlarged with autologous pericardium in 69 (68.3%) of the patients. A transannular patch was used in 60 (58.5%) patients. In cases of right or left pulmonary artery stenosis, the patch was carried beyond the point of obstruction. All identified atrial septal defects, including a patent foramen ovale present in 21 of patients, were closed.

Statistical methods

Data are presented in mean +/- standard deviation. SPSS version 11.5 was used to evaluate all data. A survival curve was constructed according to the actuarial method. Fisher's two-tailed exact test was used to test risk factors for operative deaths as well as to compare the mortality between primary and 2-stage repair group. A Kaplan-Meier survival analysis with log rank (Mantel-Cox) for comparison was performed to show the influence of shunt placement on the patients' survival over the follow-up period. A P value less than 0.05 were considered statistically significant.

Results

Early results

Overall hospital mortality was 6.9% (7/101). Three patients died from cardiac and respiratory failure, 3 from heart failure, 1 from multi organ failure. There were 3 (5.08%) hospital deaths in the primary and 4 (9.52%) in the 2-stage group. Aortic clamping time was 41 to 143 minutes (mean, 92.32 ± 21.27 minutes), and the cardiopulmonary bypass time was 63 to 200 minutes (mean, 136.08 ± 24.45 minutes). Factors affecting operative survival were analyzed. Bypass time more than 120 minutes ($P<0.01$), aortic cross-clamp time more than 90 minutes ($P<0.01$) affected operative survival. Previous palliative procedures, did not adversely affect operative mortality (Table 4).

Table 4. Variables Associated With Operative Deaths

Variable	P	N	Number of Operative Deaths (%)
Cardiopulmonary bypass time > 120 minutes	0.000	78	7(8.97%)
Aortic cross-clamp time > 90 minutes	0.000	57	7(12.28%)
Transanular patch	0.234	59	6(10.16%)
Previous palliative operation	0.446	42	4(9.52%)
Age of operation (<1 year)	1.000	2	0(0%)
Hematocrit level >50%	0.416	36	1(2.77%)

Table 5. Postoperative complication

Complication	No.	Percent
Rebleeding	11	10.8
Arhythmia		
Junctional rhythm	8	7.9
Complete AV block	4	3.9
PVC	2	1.9
Bradycardia	1	0.99
Acute heart failure	8	7.9
Pneumothorax	2	1.9
Pleural effusion	3	2.9
Respiratory failure	5	4.9
Epilepsy	2	1.9
Acute renal failure	3	2.9
Fever	2	1.9
Others	7	6.93

AV= atrioventricular; PVC= premature ventricular contraction; MOF= multi organ failure.

Others include Pericardial effusion (1), Hemiplegia (1), Brain ischemia (1), Brain emboli (1), MOF (1), Sterile sternal dehiscence (1) and Urethritis (1).

Among operative measurements, construction of the right ventricular outflow tract with a patch was not related to early mortality (P > 0.05). Among preoperative measurements, Hematocrit level was not significantly related to early mortality (P > 0.05) (Table 4).

Postoperative ventilation more than 48 hours was necessary in 13 (12.8%) of patients. Use of a temporary pacemaker was required in 13 (12.8%) of patients. Transient heart failure requiring inotropic support occurred in 77 (76.2%) of the patents. No patient required permanent pacemaker implantation in the perioperative period. Temporary renal dysfunction was seen in 3 (2.9%) of patients that in two patients dialysis were performed. Thirty four early complications were observed in 28 of surviving patients. Postoperative complications were shown in Table 5. The median length of stay in the intensive care unit was 4.64 ± 1.82 days (Range, 1 to 11 days). The median hospital stay was 11.42 ± 4.52 days (Range, 2 to 27 days). Residual anatomical defect were first diagnosed by clinical examination, echocardiography, or both. Ten patients had a small residual ventricalar septal defect (1.4/1 left-right shunt). Nineteen patients had moderate residual pulmonary stenosis (gradient of 50 mmHg) and twenty two had mild pulmonary regurgitation.

Late results

Mean follow-up time was 34.08 ± 31.09 months (range, 1 month to 120 months). Six patients were lost to follow-up within the first year after total correction. Eighty eight patients (87.1%) were followed up from 1 month to 10 years. Kaplan-Meier analysis revealed that there was no significant difference between the survival rate of primary (CI = 18.8-38.6) and 2-stage repair (CI = 25.2-41.5) groups over a follow-up period of 120 months (P>0.05; Figure 2)

Actuarial survival, inclusive of operative mortality, demonstrates 92%, 91% and 91 % alive 1, 5 and 10 years after total correction, respectively (Figure 3). There were two late deaths, the first death occurred 19 months after repair and also resulted from subacute bacterial aortic valve endocarditis and cerebral emboli. The second late died from sudden cardiac death 24 months after hospital discharge. The other patients were doing well.

Figure 1. Age distribution of patients at the time of total correction of tetralogy of Fallot

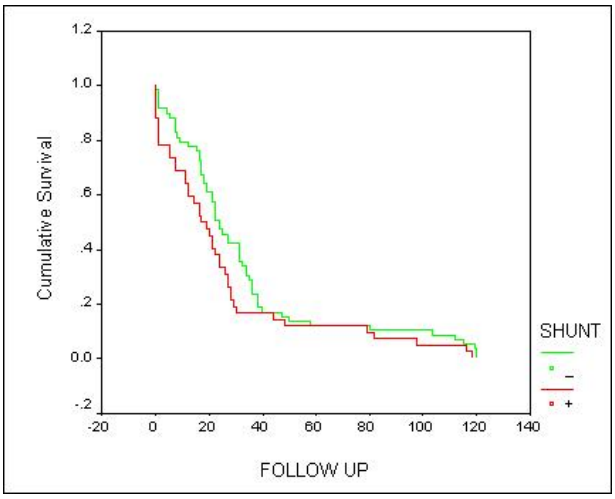

Figure 2. Survival rate of primary and 2-stage repair groups

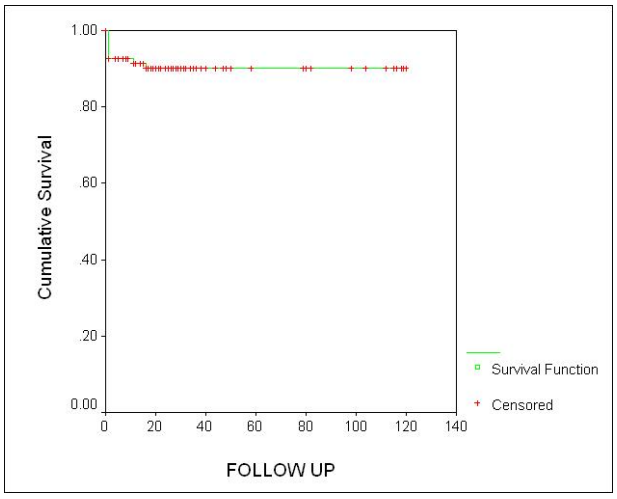

Figure 3. Actuarial percent survival of patients after total correction of tetralogy of Fallot

Discussion

Despite total correction of TOF being a common cardiac surgical procedure for more than 40 years, some controversy still exists regarding the optimal treatment method. Some groups advocated routine two-staged procedures for TOF, with a shunt for symptomatic patients during infancy, and total correction within 1.5 years of palliation (9). Other investigators propose selective staged management with initial shunting, particularly in patients with less than ideal anatomy (8, 10). However, patients undergoing staged treatment of TOF, using a palliative shunt and subsequent total correction, accrue the risk of two operative procedures and the potential complications of right–to–left intracardiac shunting, compromised ventricular function, and fibrosis with ongoing hypoxemia and myocardial ischemia (11, 12). The selective operative treatment of TOF has developed from previous surgical failures and surgical successes with the operative management of various subsets of patients with the TOF. We originally thought that a significantly higher operative mortality might be found in those patients with the most severe intracardiac malformations.

It was in this subset of patients with hypoplastic pulmonary arteries and diminutive outflow treats that we initially considered to be the greatest operative risks for total correction and therefore advised palliative operations as their first operative procedure. When our results were analyzed it became evident than there was no significant difference in the operative mortality between the subgroups of patients with localized outflow tract obstruction and those with diffuse infundibular obstruction and a small pulmonary annulus. The lake of correlation of operative mortality in these two subsets could likely be explained by the selective approach to their management. In those infants and children with hypoplastic outflow tracts, a temporizing palliative shunt provided time for growth so that total correction proved easier at a later date.

Our early mortality rate of 5.08% for primary complete repair of TOF without an initial palliative procedure compares very favorably with the mortality of just an initial shunt operation for this congenital defect (13, 14). In addition awaiting final correction after palliation has its own attrition rate. One finding was that operative mortality was significantly higher with longer cardiopulmonary bypass and aortic cross-clamp times (table 4). The higher mortality with longer cases, possibly related to more complex anatomy or difficulty of repair, is not unique to this condition and is seen with other cardiac operations. Placement of a transannular patch may lead to late pulmonary insufficiency and right ventricular volume overload. Although Kinner *et al.*., (15) identified the use of a transannular patch as a risk factor for late mortality, the results of the study of James *et al.*, (16) and a large study by Kirklin *et al.*, (17) suggested that the compensatory responses to right ventricular overload were adequate for a 20-year period, at least with respect to mortality.

Our data extend these observations and do not demonstrate any difference in survival among patients without a patch, and those with a transannular patch, although other investigators have implicated transannular patching as a risk factor for reoperation.

A high hematocrit level was considered another high- risk factor for total correction by some authors (18). In the group presented here, 36 patients (35.6%) with hematocrit level of more than 50% underwent complete repair with one death and hematocrit level was not significantly related to early mortality ($P>0.05$).

The long-term survival repair of TOF with a variety of protocols at different ages is known to be very good, although not identical with that of the general population (1, 8, 18-20). The actuarial 10-year survival of 95.6 (Figure 3), in this series, with the two late death, is most rewarding and demonstrates that a near normal survival expectancy after repair of TOF can be reasonably anticipated. In conclusion, we believe that the key factor in the total correction of TOF is to correct the pathology completely, to protect the myocardium, and to manage the complications properly. Most patients, even with hypoplasia of pulmonary artery, old age and a high hematocrit, can obtain satisfactory result from total correction of TOF.

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