Long-term Results Following Surgical Operation of Tetralogy of Fallot

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TOTAL correction of tetralogy of Fallot can be achieved with a low mortality rate and with gratifying clinical results. It is necessary to evaluate postoperative state from the standpoint of electrophysiology and hemodynamics. A complete understanding of the problems following corrective surgery for tetralogy of Fallot will lead to more rational and effective therapy.

MATERIALS AND METHODS

(1) *Electrocardiogram (ECG)*

The ECGs of 84 patients who underwent surgical correction of tetralogy of Fallot were reviewed. This number represents all patients surviving surgery at Kyoto University Hospital from April, 1964 to April, 1974, in whom adequate pre- and postoperative ECGs were available. Complete right bundle-branch block (CRBBB) was diagnosed when the duration of the QRS was 0.12 sec or longer and when a terminal conduction delay was found. Incomplete RBBB (ICRBBB) was considered to be present when the QRS duration was 0.10 to 0.11 sec. Combined RBBB and left anterior hemiblock (CRBBB-LAH) was diagnosed when, in addition to the presence of CRBBB, the mean frontal QRS axis was found to be superiorly oriented, between -60° and -120° , with a Q_1Sv_3 pattern.

(2) *Vectorcardiogram (VCG)*

Nineteen patients who showed CRBBB on ECG after corrective surgery for tetralogy of Fallot were studied vectorcardiographically using

Frank lead system. The maximum leftward and rightward forces projected on the X axis were termed Rx and Sx respectively (Fig. 1) and their ratio Rx/Sx were measured. These results were compared with those in 12 CRBBB patients without organic heart disease.

Fig.1. Measurements of the QRS loop in the transverse plane.

(3) *Cardiac Catheterization*

Left ventricular end-diastolic volume (LVEDV) and left ventricular ejection fraction (LVEF) were quantified in 27 patients, 2 months to 10 years (mean 2.7 years) after corrective surgery for tetralogy of Fallot. The ages at the time of the postoperative study ranged from 2 to 29 years (mean 7.8 years) and the ages at surgery from 6 months to 28 years (mean 5.2 years). The results were compared with those in 15

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TABLE I INCIDENCE OF CONDUCTION ABNORMALITIES AND DEATH

	Number	%	Death
CRBBB only	50	59%	1
CRBBB + PVC	10	12%	0
CRBBB + LAH	5	6%	2 (40%)
ICRBBB	8	10%	0
no RBBB	10	12%	0
Complete A-V Block	1	1%	0
Total	84		3 (4%)

CRBBB = complete right bundle-branch block, PVC = premature ventricular contraction, LAH = left anterior hemiblock, ICRBBB = incomplete right bundle-branch block

TABLE II

NYHA	Number
1	40
2	4
3	2
Dead	3
Total	49

control patients without organic heart disease. The method has been previously published in detail! The LV pressures of 8 of the above-mentioned 27 patients were recorded by a catheter-tip micromanometer and were processed with a digital computer. V_{CE} and V_{max} were calculated by the method of Mason et al². Normal values for isovolumic phase indices were derived from a study of 8 patients without heart disease.

RESULTS

(1) Electrocardiogram

Among the 84 ECGs recorded one month after corrective surgery, 65 were found to have CRBBB (77%) (Table I). Five patients (6%) showed CRBBB-LAH. Sudden death occurred in 2 of the 5 patients (40%) with CRBBB-LAH, 6 months and 6 years respectively following surgery. One patient who showed CRBBB died immediately after intramuscular injection. This death was likely to be caused by anaphylactic shock. Forty-two ECGs among the 84 patients which were recorded for the last one year were reviewed. Any progression of CRBBB to CRBBB-

Fig. 2. The magnitude of the maximum rightward QRS force projected on the X axis (S_x) and the ratio of leftward to rightward forces (R_x/S_x) in postoperative T/F patients and CRBBB patients without organic heart disease.

LAH was not found.

(2) Vectorcardiogram

There was no significant difference for the magnitude of the maximum rightward QRS forces projected on the X axis (S_x) between postoperative T/F patients and CRBBB patients without organic heart disease (Fig. 2). However,

TABLE III CORRECTIVE SURGERY FOR TETRALOGY OF FALLOT FROM APRIL 1964 TO APRIL 1974 — POSTOPERATIVE ECG FINDINGS (APRIL 1978 TO APRIL 1979)

	Number	%
CRBBB only	27	65%
CRBBB + PVC	1	2%
CRBBB + LAH	3	7%
ICRBBB	6	14%
no RBBB	4	10%
Complete A-V Block	1	2%
Total	42

Fig.3. Left ventricular end-diastolic volume (LVEDV) corrected for body surface area as a function of body surface area in patients after corrective surgery. The solid and dashed lines indicate the regression line and two standard deviations of normal. (LVEDV $\text{ml/m}^2 = 32.3 (\text{BSA}) + 41.4 \pm 12.0$).

significant difference was found for the ratio of the leftward to rightward QRS forces (R_x/S_x) between these two groups. R_x/S_x is less than 2.0 in all postoperative T/F patients except one.

(3) Cardiac catheterization

The LVEDV corrected for body surface area is shown as a function of body surface area in Figure 3. Below 0.8 m^2 of body surface area, LVEDV was significantly higher in about half the number of patients with corrective surgery than in the controls. Above 0.8 m^2 of body surface area, all patients except one had a greatly increased LVEDV. LVEF was significantly depressed in patients with corrective surgery, although there was a considerable overlap with

Fig.4. A comparison of left ventricular ejection fraction between controls and patients who underwent corrective surgery for tetralogy of Fallot. Each bar and number indicate mean values of ejection fraction.

control group (Fig. 4). Peak dp/dt , V_{pm} , V_{max} were also depressed significantly (Fig. 5).

DISCUSSION

(1) ECG

The overall incidence of sudden death during at least 5 years period of follow-up was 4%, mortality being highest in those with CRBBB and LAH (40%). The prognostic significance of com-

Fig.5. A comparison of peak dp/dt, Vpm, and Vmax between two groups.

bined CRBBB and LAH are still controversial. Wolff et al³ observed a high frequency of sudden death in patients with this postoperative complication. However, others have not found an ominous prognosis in these patients^{4,5}. Quattlebaum et al⁶ reported a high risk of sudden death in patients with RBBB and premature ventricular contractions following tetralogy repair. However, we have not found this relationship. Although progression of RBBB to bifascicular and trifascicular block occurred in their series⁶ from one month to seven years postoperatively, we have not observed such a progression. Continued clinical evaluation is needed to settle these controversies.

(2) VCG

The ratio of leftward to rightward QRS forces projected on the X axis (R_x/S_x) is less than 2.0 in all postoperative T/F patients except one. This probably reflects residual right ventricular hypertrophy.

(3) Cardiac catheterization

Problems of left ventricular performance following corrective surgery for tetralogy of Fallot remain controversial^{1,7,8,9}. From our

study, it is apparent that depressed LVEF in addition to increased LVEDV indicates impaired LV performance. Then significantly depressed isovolumic phase indices such as peak dp/dt, Vpm, and Vmax suggest some change in myocardial contractility. The reasons for these LV dysfunction are unclear. Patients who had corrective surgery for tetralogy of Fallot are subjected to neither pressure load nor volume load, but they have histories of decreased LVEF, LVEDV⁷ and chronic hypoxemia. Krymskii¹⁰ described focal fibrosis of the left ventricle and diffuse fibrosis of the right ventricle in tetralogy of Fallot. These LV dysfunction may be related to irreversible histological alterations of the myocardium.

SUMMARY

(1) The ECGs of 84 patients who survived corrective surgery for tetralogy of Fallot were reviewed. The overall incidence of sudden death during at least 5 years period of follow-up was 4%, mortality being highest in those with CRBBB and LAH (40%).

(2) The ratio of leftward to rightward QRS forces projected on the X axis (R_s/S_x) is significantly decreased in postoperative T/F patients.

(3) Twenty-seven patients who had corrective surgery for tetralogy of Fallot underwent cardiac catheterization postoperatively. LVEF was mildly, but significantly diminished and LVEDV was increased significantly, while peak dp/dt, Vpm and Vmax were significantly depressed. These findings indicate that patients who had corrective surgery for tetralogy of Fallot have impaired left ventricular function.

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REFERENCES

1. NISHIOKA K: Left ventricular function after corrective surgery for tetralogy of Fallot. *Ann Paediat Jpn* 24: 202, 1978
2. MASON DT, SPANN JF, ZELIS R: Quantification of the contractile state of the intact human heart. *Am J Cardiol* 26: 248, 1970
3. WOLFF GS, ROWLAND TW, EFFISON RC: Surgically induced right bundle-branch block with left anterior hemiblock: An ominous sign in postoperative tetralogy of Fallot. *Circulation* 46: 587, 1972

4. DOWNING JW, KAPLAN S, BOVE KE: Postsurgical left anterior hemiblock and right bundle-branch block. *Br Heart J* 34: 263, 1972
5. PAHLAJANI DB, SERRATTO M, MEHTA A, MILLER RA, HASTERITER A, ROSEN KM: Surgical bifascicular block. *Circulation* 52: 82, 1975
6. QUATTLEBAUM TG, VARGHESE PJ, NEIL CA, DONAHOO JS: Sudden death among postoperative patients with tetralogy of Fallot: An follow-up study of 243 patients for an average of twelve years. *Circulation* 54: 289, 1976
7. JARMAKANI JM, GRAHAM TP, CANENT RV, JEWETT PH: Left heart function in children with tetralogy of Fallot before and after palliative or corrective surgery. *Circulation* 46: 478, 1972
8. SUNDERLAND CO, MATARAZZO RG, LEES MH, MENASHE VD, BONCHECK LI, ROSENBERG JA, STARR A: Total correction of tetralogy of Fallot in infancy: Postoperative hemodynamic evaluation. *Circulation* 48: 398, 1973
9. ROCCHINI AP, KEANE JF, FREED MD, CASTANEDA AR, NADAS AS: Left ventricular function following attempted surgical repair of tetralogy of Fallot. *Circulation* 57: 798, 1978
10. KRYMSKII LD: Pathologic anatomy of congenital heart disease. *Circulation* 32: 814, 1965