CONDUCTION DISTURBANCES AND OPERATIVE RESULTS AFTER CLOSURE OF VENTRICULAR SEPTAL DEFECTS BY THREE DIFFERENT SURGICAL APPROACHES

TOMIO ABE, M.D. AND SAKUZO KOMATSU, M.D.

A total of 135 patients with ventricular septal defect (VSD) under 15 years of age, without associated cardiac lesions, underwent surgical repair by 3 different approaches of trans-pulmonary arteriotomy (PA), right atriotomy (RA) and right ventriculotomy (RV) between 1977 and 1981. Six hospital deaths (4.4%) occurred among the 135 patients. Of 41 children with PA, 53 with RA and 41 with RV, one child (2.4%), one child (1.9%) and 4 children (9.9%) died, respectively. In the trans-PA approach, 8 of 40 children (20.0%) developed complete right bundle branch block (CRBBB), but there was no occurrence of left axis deviation (LAD), transient complete heart block (CHB) and arrhythmias postoperatively.

In the RA approach, 11 of 52 children (21.2%) developed CRBBB and 2 (3.8%) had a combination of LAD and CRBBB. Four of 52 children (7.7%) had a combination of LAD, CRBBB and CHB, but CHB has been treated successfully with medication. Three patients (5.8%) developed arrhythmias, such as junctional rhythm.

In the trans-RV approach, 11 of 37 children (29.7%) developed CRBBB and 4 of the 37 (10.8%) had the combination of LAD and CRBBB. Two patients (5.4%) had arrhythmias which disappeared one month after surgery.

All incidences of conduction disturbances and arrhythmias after closure of VSD were significantly less in the trans-PA than in the trans-RA or in the trans-RV ($p < 0.01$). However, in the present study, the development of conduction disturbances and postoperative arrhythmias after closure of VSD was not significantly different between the trans-RA and the trans-RV approach.

CONDUCTION disturbances are a common complication following surgical closure of ventricular septal defect (VSD),¹⁻³ but opinions differ regarding the damaged area in the conduction system.⁴⁻⁵ Recently, with the introduction

of approaches for the closure of VSD *via* the pulmonary artery or the right atrium, which avoid right ventriculotomy, the occurrence of conduction disturbances and postoperative arrhythmias has been decreasing. In cases with advanced pulmonary vascular obstructive disease, the transpulmonary and the trans-atrial approaches have also been advocated to maintain the right ventricular function after surgery.⁶⁻⁸

In the present study, we will undertake a retrospective evaluation of the frequency of conduction disturbances and postoperative

Key Words:

Ventricular septal defect
Trans-pulmonic approach
Trans-ventricular approach
Trans-atrial approach
Complete right bundle branch block

(Received June 23, 1982; accepted November 1, 1982)

The Department of Thoracic and Cardiovascular Surgery, Sapporo Medical College, Sapporo, Japan

Mailing address: Tomio Abe, M.D., Department of Cardio-Thoracic Surgery, Sapporo Medical College, Sapporo 060, Japan

Fig.1. Surgical approach for VSD and operative mortality in 135 patients under 15 years old.
P.A. = pulmonary artery, R.A. = right atrium, R.V. = right ventricle

arrhythmias and of the operative results of the closure of isolated VSD in 135 children under 15 years of age with reference to the 3 different surgical approaches of transpulmonary arteriotomy (PA), right atriotomy (RA) and right ventriculotomy (RV).

PATIENTS AND METHODS

The present series consisted of 135 children with isolated ventricular septal defects (VSD) confirmed by cardiac catheterization. All children were less than 15 years of age at the time of surgery (Fig. 1). Their operations were performed at Sapporo Medical College Hospital between January, 1977 and December, 1981.

Group I: Forty-one patients underwent VSD repair through the pulmonary valve after a pulmonary arteriotomy. Thirty-nine of these 41 patients had the supracristal type of VSD and 2 the bulboventricular type. These 41 consisted of 23 girls and 18 boys, ranging in age from 4 months to 14 years and 9 months (mean age: 5 years and 2 months). One operative death

(2.4%) occurred in this group.

Group 2: Fifty-three patients underwent VSD repair through the tricuspid valve after an atriotomy. This group consisted of 32 girls and 21 boys, ranging in age from 4 months to 15 years (mean age: 3 years and 9 months). One patient (1.9%) died 7 days after surgery.

Group 3: Forty-one patients underwent VSD repair after a right ventriculotomy (RV). The group consisted of 19 girls and 22 boys, ranging in age from 6 months to 14 years and 11 months (mean age: 3 years and 6 months). Four children died soon after the closure of VSD.

All patients, who died during the operation, were excluded from the evaluation because there were no immediate postoperative electrocardiograms taken. Regarding the types of VSD, we utilized the anatomic classification of Kirklin et al.⁹ (Fig. 2). Forty-one of the 135 patients (30.4%) had Type I defects which were situated between the crista supraventricularis and the pulmonary valve. There was one operative death or 2.2% mortality. Eighty-seven of the patients (64.4%) had Type II defects which occurred just

Fig.2. Types of VSD and surgical mortality in 135 patients under 15 years old (Jan., 1977–Dec., 1981).

TABLE I CONDUCTION DISTURBANCES AFTER VSD REPAIR IN 135 PATIENTS UNDER 15 YEARS OLD (Jan., 1977 – Dec., 1981)

Surgical approach	(Methods)	No. of patients (death)	CRBBB	LAD+ CRBBB	Transient CHB	LAD+ CRBBB +CHB	Arrhythmia	Total
Trans-PA	(Patch)	30	7/30 (23.3%) 1/10 (10.0%)	0/30 0/10	0/30 0/10	0/30 0/10	0/30 0/10	7/30 (23.3%) 1/10 (10.0%)
	(Direct)	11 (1)						
Trans-RA	(Patch)	24 (1)	6/23 (26.1%) 5/29 (17.2%)	1/23 (4.3%) 1/29 (3.4%)	1/23 (4.3%) 1/29 (3.4%)	3/23 (13.0%) 1/29 (3.4%)	2/23 (8.6%) 1/29 (3.4%)	13/23 (56.6%) 9/29 (31.0%)
	(Direct)	29						
Trans-RV	(Patch)	23 (3)	6/20 (30.0%) 5/17 (29.4%)	3/20 (15.0%) 1/17 (5.8%)	1/20 (5.0%) 0/17	0/20 0/17	1/20 (5.0%) 1/17 (5.8%)	11/20 (55.0%) 7/17 (41.2%)
	(Direct)	18 (1)						
Total	(Patch)	77	30/129 (23.1%)	6/129 (4.6%)	3/129 (2.3%)	4/129 (3.0%)	5/129 (3.8%)	48/129 (37.2%)
	(Direct)	58						

Abbreviations: CRBBB = complete right bundle branch block; LAD = left axis deviation; CHB = complete heart block; PA = pulmonary artery; RA = right atrium; RV = right ventricle

TABLE II CONDUCTION DISTURBANCES ACCORDING TO AGE AT VSD REPAIR
(Jan., 1977 – Dec., 1981)

Age (year)	No. of patients	CRBBB	LAD + CRBBB	Transient CHB	LAD + CHB + CRBBB	Arrhythmia	Total
0 < ≤ 1	15	6	4		1	1	12
1 < ≤ 2	22	5	1	1	1	1	9
2 < ≤ 3	10	2			1		3
3 < ≤ 4	11	3		1	1		5
4 < ≤ 5	18	4				1	5
5 < < 15	53	10	1	1		2	12
Total	129	30	6	3	4	5	48

Abbreviations are the same as in Table I.

caudal to the crista supraventricularis. There were 5 deaths or 5.7% mortality in this type. Two patients had Type III defects, which were located posterior beneath the septal leaflet of the tricuspid valve. In one patient, the defect was found in the muscular septum (Type IV). There were no operative deaths in these 2 types of VSD. The maximum follow-up period was 5 years, and preoperative hemodynamics and operative and postoperative records were reviewed.

All available serial pre- and post-operative electrocardiograms (ECG) were analyzed for mean QRS axis, QRS duration, PQ interval, and atrial and ventricular hypertrophy. The diagnosis of complete right bundle branch block (CRBBB) was done according to the classification of Ziegler et al.¹⁰ Left axis deviation (LAD) was considered to be present when the mean QRS axis was lying between 240 and 360° on the frontal plane, being far to the left as compared with that in normal children.¹¹ We excluded 2 patients who had LAD before surgery and all fatal cases as there were no available postoperative ECGs.

RESULTS

Of the 41 children in Group I, 53 in Group 2 and 41 in Group 3, one child (2.4%), one child (1.9%) and 4 children (9.9%) died, respectively, showing no statistically significant differences among 3 groups (Fig. 1).

The conduction disturbances and arrhythmias observed in each approach one week after surgery (closure of the VSD using a patch (P) and a direct suture closure (D)) are shown in Table I. Of the children who underwent surgical repair of

VSD through the pulmonary artery (Group I), 8 out of 40 (20.0%) (7/30 = 23.3% with P and 1/10 = 10% with D) developed CRBBB. There was, however, no occurrence of LAD, transient complete heart block (CHB) or arrhythmia after surgery.

In the approach *via* an atriotomy (Group 2), 11 out of 52 children (21.2%) (6/23 = 26.1% with P and 5/29 = 17.2% with D) developed CRBBB, 2 of 52 (3.8%) (1/23 = 4.3% with P and 1/29 = 3.4% with D) had a combination of LAD and CRBBB and 2 of 52 (3.8%) had transient CHB. Four of the 52 children (7.7%) had a combination of LAD, CRBBB and CHB (3/23 = 13% with P and 1/29 = 3.4% with D). Three patients (5.8%) (2/23 = 8.6% with P and 1/29 = 3.4% with D) developed arrhythmias after the closure of VSD. All these patients had junctional rhythm, which was transient in one, but which still has continued in 2 for 3 years and 4 years 3 months, respectively.

In Group 3, 11 of 37 (29.7%) children (6/20 = 30.0% with P and 5/17 = 29.4% with D) developed CRBBB, and 4 of 37 (10.8%) (3/20 = 15% with P and 1/17 = 5.8% with D) had the combination of LAD and CRBBB. There was one child with P who had transient CHB postoperatively. No patient had the combination of LAD, CRBBB and CHB.

One patient each with the P and the D method had postoperative arrhythmias (one with junctional rhythm and one with A-V dissociation, respectively), but these arrhythmias completely disappeared 2 weeks and 4 weeks after surgery.

On the whole, incidences of conduction disturbances and postoperative arrhythmias were significantly less in the trans-PA than the trans-RA and the trans-RV ($p < 0.01$), and the

TABLE III CONDUCTION DISTURBANCES FOLLOWING VSD REPAIR ACCORDING TO THE TYPE OF VSD

Type of VSD	No. of patients (Death)	Surgical approach (Death)	CRBBB	LAD + CRBBB	Transient CHB	LAD + CRBBB + CHB	Arrhythmia	Total
I	45 (1)	T-PA: 40 (1)	8/39 (20.5%)	0/39	0/39	0/39	0/39	8/39 (20.5%)
		T-RV: 5 (0)	1/5 (20.0%)	0/5	0/5	0/5	0/5	1/5 (20.0%)
II	87 (5)	T-PA: 1 (0)	0/1	0/1	0/1	0/1	0/1	0/1
		T-RA: 52 (1)	11/51 (21.2%)	1/51 (1.9%)	2/51 (3.8%)	4/51 (7.8%)	3/51 (5.9%)	21/51 (41.2%)
		T-RV: 34 (4)	10/30 (35.5%)	4/30 (12.9%)	1/30 (3.2%)	0/30	2/30 (6.4%)	17/30 (56.7%)
III	2 (0)	T-RA: 1 (0)	0/1	1/1 (100%)	0/1	0/1	0/1	1/1 (100%)
		T-RV: 1 (0)	0/1	0/1	0/1	0/1	0/1	0/1
IV	1 (0)	T-RV: 1 (0)	0/1	0/1	0/1	0/1	0/1	0/1
Total	135 (6)		30/129 (23.1%)	6/129 (4.6%)	3/129 (2.3%)	4/129 (3.0%)	5/129 (3.8%)	47/129 (37.2%)

frequency of CRBBB and the combination of LAD and CRBBB was greater in the trans-RV than in the trans-RA. There were, however, no statistically significant differences in these 2 approaches.

We analyzed and compared conduction disturbances and arrhythmia according to the ages at surgery (Table II).

The development of CRBBB and the combination of LAD and CRBBB was significantly more frequent in infants (10/15 = 66.7%) than in children over one year of age (26/114 = 22.8%) ($p < 0.01$). The total frequency of conduction disturbances and arrhythmias after surgery was also significantly greater in infants (12/15 = 80.0%) than in children over one year of age (36/114 = 31.6%, $p < 0.01$).

We also compared the incidences of conduction disturbances through 3 different surgical approaches according to the types of VSD (Table III). In type I VSD the incidences of CRBBB were almost equal in the trans-PA and the trans-RV (8/39 = 20.5% and 1/5 = 20%, respectively). In type II VSD the development of conduction disturbances and postoperative arrhythmias was less in the trans-RA than in the trans-RV, but this difference was not statistically significant.

Late results of CRBBB are shown in Table IV. In a follow-up study of all 40 patients with CRBBB over a maximum 5 years, CRBBB disappeared in 6 (15%) from one month to 2 years and 7 months (mean: 4 months) after surgery. In the 3 surgical approaches, CRBBB was observed to have disappeared in one child, who had his VSD repaired through the trans-PA approach with P, one year and 3 months after surgery. In 5 children who had the VSD closure through the trans-RA approach, CRBBB disappeared (4/5 with D and 1/5 with P) from one month to 2 years and 2 months after surgery. There were no children, however, in whom CRBBB disappeared after the VSD repair through the trans-RV approach. In all 4 patients CHB was treated successfully with medications and there was no significant increase of the cardiac silhouette postoperatively.

During the follow-up period, there were no further ECG changes and no late deaths in the 129 survival children.

DISCUSSION

The surgical procedure for severe types of

TABLE IV LATE RESULTS OF CRBBB AFTER VSD REPAIR IN 40 PATIENTS
(Jan., 1977 – Dec., 1981)

Approach (Methods)		CRBBB (at 7 days)	CRBBB disappearance time					Last status
			1 mo	6 mos	1 year	2 years	3 years	
Trans-PA	Patch	7			1			6
	Direct	1						1
Trans-RA	Patch	10				1		9
	Direct	7	3	1				3
Trans-RV	Patch	9						9
	Direct	6						6
Total		40	3	1	1	1	—	34

Abbreviations are the same as in Table I.

VSD consists of either pulmonary artery banding (PAB) or one-stage closure of VSD. In the past, PAB was favored^{12,13} but recently, because of the development and improvement of deep hypothermia with the aid of cardiopulmonary bypass and cardioplegia, one-stage closure of VSD has become popular in a number of institutes.^{14–16}

In our institute, we have closed isolated VSD in infants using the technique of deep hypothermic circulatory arrest and a cardioplegic solution for protecting the myocardium. Among 135 patients after VSD closure, there were 6 hospital deaths (4.4%), but no late deaths during the follow-up period. All 6 deaths occurred in 1977 and 1978 in children under 4 years of age who needed the aid of mechanical respiratory and ventilation support preoperatively. They fell into a low-output state soon postoperatively and died within 7 days after surgery. However, there have been no operative deaths since 1979 when we used a high potassium and magnesium cardioplegic solution.

Comparison of the results according to the 3 different surgical approaches is important to determine the optimal repairing method for VSD. Although a number of patients has been treated for a long time *via* a right ventriculotomy, conduction disturbances and postoperative arrhythmias, which influence the early postoperative course of the patients, are major complications existing in this approach. Especially in patients with severe respiratory failure, in whom an elevated pulmonary artery pressure is not expected to be lowered soon after repair of VSD, the avoidance of ventriculotomy by utilizing an atriotomy has been suggested in order

to maintain the postoperative right ventricular function^{6,15,17,18}. Other cardiovascular lesions associated with VSD also influence the postoperative conduction disturbances and arrhythmias. Therefore, in analyzing our results, we excluded those patients who were complicated by other cardiovascular anomalies.

The development of CRBBB has been found to occur in 60–80% of the cases with VSD repaired *via* ventriculotomy^{3–5}. To avoid this sequela following ventriculotomy, some investigators have utilized atriotomy^{6,19} and pulmonary arteriotomy^{20,21} for repairing VSD with incidences of CRBBB from 0 to 44.4% in the trans-RA^{3,4} and 23% in the trans-PA approach²¹.

In patients with VSD of the infracristal type, the repair is easily performed through the tricuspid valve after an atriotomy, but in patients with VSD of the supracristal type, it is impossible to use this approach. The trans-pulmonary artery approach for the closure of VSD is technically easy when the defect is localized in the supracristal and conal position, even though herniation of the aortic cusp, resulting in aortic insufficiency, is associated with it. This approach provides a much better view of the inside of the pulmonary cusp than the trans-RV one. Moreover, the incidence of CRBBB was the lowest among the 3 approaches.

Postoperative CRBBB developed in 11 of 37 consecutive patients (29.7%), in whom we closed VSD through the trans-RV approach. This percentage was much higher than that seen in patients who underwent the closure of VSD through the trans-PA and the trans-RA approaches, that is, 8 of 40 patients (20.0%) and

11 of 52 (21.2%), respectively. The difference between these percentages is probably due to the difference in the location of VSD in relation to the conduction system. Gelband et al⁴ and Massig et al²² have mentioned that an incision on the right ventricle causes damage to the peripheral branches of the right bundle branch. Otherwise, the origin of the development of CRBBB in the pulmonary and atrial approaches is considered to be centrally located, because the direct injury to the main right bundles may occur due to suture in the posteroinferior portion of VSD. Kulbertus et al⁵ have explained that the high frequency of conduction disturbances after repair of VSD is closely related to the injury to the bundle in the margin of the VSD. Titus et al¹ and Lev et al² have also stated that the development of CRBBB, transient CHB and arrhythmias may occur due to a direct surgical trauma, localized hemorrhage, edema and a disruption around the right bundle branch and the His bundle. To avoid such surgical injuries to the conduction system, Kaiser et al²³ and Kawamura et al²⁴ have reported that at the time of surgery the localization of the conduction pathway must be ascertained using an electrode probe in each patient. This mapping technique, however, requires a beating state of the hearts, thus, resulting in clinical difficulties in detecting the fine pathway during the surgical procedures under deep hypothermic and cardioplegic cardiac arrest. Similarly, Wolf et al²⁵ and Izukawa et al²⁶ have stated that patients with a combination of LAD and CRBBB after closure of VSD have a high risk for the development of late CHB and late sudden death. Hobbins et al²⁷ have reported that in spite of the high incidences of RBBB and LAD plus CRBBB after the trans-RV repair of VSD, no late CHB and sudden death appeared during a relatively limited follow-up period.

Our present results indicate that the frequency of the development of CRBBB and postoperative arrhythmia was reduced significantly in patients in whom VSD was repaired through the trans-PA approach as compared with patients who were treated by the trans-RA and the trans-RV approach. However, the reduced frequency of postoperative conduction disturbances and arrhythmias in the trans-PA approach may relate to the age at the time of surgery. The total frequency of conduction disturbances and arrhythmias after surgery was significantly greater in infants than in children over one year of age. The mean age of the

patients with the trans-PA approach (5 years and 2 months) was higher than that of the patients with the trans-RA approach (3 years and 9 months) and with the trans-RV approach (3 years and 6 months), respectively. The high incidence of postoperative conduction disturbances following a ventriculotomy may be due to the combined peripheral and central injury to the right bundle. The development of postoperative CRBBB after closure of VSD following a pulmonary arteriotomy and an atriotomy is considered to be a central injury to the conduction system in its origin, and such patients should be carefully observed throughout their postoperative period. During our 5-year follow-up period, none of our patients developed further conduction disturbances, arrhythmias or late death. The utilization of the surgical approach with a pulmonary arteriotomy and a right atriotomy in patients with severe pulmonary obstructive disease has resulted in the maintenance of a good postoperative right ventricular function and a reduced operative mortality. However, in the present study, the frequency of the development of conduction disturbances and arrhythmia in patients with repaired VSD was not significantly different between the trans-RA and the trans-RV approach.

REFERENCES

1. TITUS JL, DAUGHERTY GW, KIRKLIN JW, EDWARDS JE: Lesions of the atrioventricular conduction system after repair of ventricular septal defect: Relation to heart block. *Circulation* **28**: 82, 1963
2. LEV M, FELL EH, ARCILLA R, WEINBERG MH: Surgical injury to the conduction system in ventricular septal defect. *Am J Cardiol* **14**: 464, 1965
3. OKOROMA ED, GULLER B, MALONEY JD: Etiology of right bundle-branch block pattern after surgical closure of ventricular septal defects. *Am Heart J* **90**: 14, 1975
4. GELBAND H, WALDO AL, KAISER GA, BOWMAN FO, HOFFMAN BF, MALM JR: Etiology of right bundle-branch block in patients undergoing total correction of tetralogy of Fallot. *Circulation* **44**: 1022, 1971
5. KULBERTUS ME, COYNE JJ, HALLIDIC-SMITH K: Conduction disturbances before and after surgical closure of ventricular septal defect. *Am Heart J* **77**: 123, 1969
6. BJÖRK VO: The transatrial approach to ventricular septal defect. *J Thorac Cardiovasc Surg* **47**: 178, 1964
7. ABE T: Experimental studies of the radical repairs for tetralogy of Fallot: The influence of right ventricular contraction and function after right ventriculotomy and coronary artery ligation with

- the use of strain gauge arch. *J Jap Assoc Thorac Surg* 17: 1014, 1969 (in Japanese)
8. MARCH HW, ROSS JK, GERBODE F, WEIRICH W: The influence of the ventriculotomy site on the contraction and function of the right ventricle. *Circulation* 24: 572, 1961
 9. KIRKLIN JW, HARSHARGER HG, DONALD DE, EDWARDS JE: Surgical correction of ventricular septal defect: Anatomic and technical consideration. *J Thorac Cardiovasc Surg* 33: 45, 1957
 10. ZIEGLER RF: Electrocardiographic Studies in Normal Infants and Children. Charles C Thomas, Springfield, 1951, p 129
 11. GUNTHEROTH WG: Pediatric Electrocardiography. WB Saunders, Philadelphia, 1965, p 11
 12. WADA J, IWA T: Two staged treatment of ventricular septal defect with pulmonary hypertension. *Ann Thorac Surg* 8: 415, 1969
 13. HUNT CE, GORMANEK G, LEVINE MA, CASTANEDA AR, MOLLER JH: Pulmonary arterial banding results in 111 children. *Circulation* 43: 395, 1971
 14. BARRATT-BOYS BG, NEUTZE JM, CLARKSON PM, SHARDEY GC, BRANDT PWT: Repair of ventricular septal defect in the first two years of life using profound hypothermia circulatory arrest techniques. *Ann Surg* 184: 376, 1976
 15. REIN JG, FREED MD, NORWOOD WI, CASTANEDA AR: Early and late results of closure of ventricular septal defect in infancy. *Ann Thorac Surg* 24: 19, 1976
 16. RIZZOLI G, BLACKSTONE EM, KIRKLIN JM, PACIFICO AD, BARGERON LM: Incremental risk factors in hospital mortality rate after repair of ventricular septal defect. *J Thorac Cardiovasc Surg* 80: 494, 1980
 17. MORRIS JH, McNAMARA DG: Residue, sequelae and complications of surgery for congenital heart disease. *Prog Cardiovasc Dis* 18: 1, 1975
 18. YASUI H, TAKEDA Y, YAMAGUCHI S, KOMORI M, HONDA S, SUNAGAWA H, KAWACHI Y, TOKUNAGA K: The deleterious effects of surgically induced complete right bundle branch block on long-term follow-up results of closure of ventricular septal defect. *J Thorac Cardiovasc Surg* 74: 210, 1977
 19. KAY JH, ANDERSON RM, DYKSTRA P, SHARPIRO MJ, MEIHASU JE, MAGIDSON O: The surgical repair of high pressure ventricular septal defect through the right atrium. *Surgery* 48: 65, 1960
 20. IDRIS SF, NIKAI DOH H, PAUL HM, BLUMENSCHEIN DS, RIKER LW: Early repair of ventricular septal defect in infants and young children. *Arch Surg* 103: 265, 1971
 21. KAWASHIMA Y, FUJITA T, MORI T, IHARA K, MANABE H: Transpulmonary arterial closure of ventricular septal defect. *J Thorac Cardiovasc Surg* 74: 191, 1977
 22. MASSIG GK, JAMES TN: Conduction and block in the right bundle branch block. *Circulation* 45: 1, 1972
 23. KAISER GA, WALSO AL, BEACH PA, BOWMAN F, HOFFMAN BF, MALM JR: Specialized cardiac conduction system: Improved electrophysiologic identification technique at surgery. *Arch Surg* 101: 673, 1970
 24. KAWAMURA T, MAEDA M, KUROSAWA H, IMAI Y, TAKAMIZAWA K, TAKAO A: Analysis of surgically induced right bundle branch block pattern using epicardial mapping technique at surgery. *The Heart* 9: 884, 1977 (in Japanese)
 25. WOLF GS, ROWLAND JW, ELLISON RC: Surgically induced right bundle-branch block with left anterior hemiblock: An ominous sign in postoperative tetralogy of Fallot. *Circulation* 46: 587, 1972
 26. IZUKAWA T, SANDHEIMER HM, TRUSLER GA: Conduction disturbances after repair of ventricular septal defect and tetralogy of Fallot. *In The Child with Congenital Heart Disease after Surgery*, ed by KIDD BSL, MOUNT KISCO NY, Futura Publishing Co, 1976, p 421
 27. HOBBS SM, IZUKAWA T, RADFORD DJ, WILLIAMS WG, TRUSLER GA: Conduction disturbances after surgical correction of ventricular septal defect by the atrial approach. *Br Heart J* 41: 289, 1979