ECHOCARDIOGRAPHIC ASSESSMENT OF LEFT VENTRICULAR FUNCTION IN PATIENTS WITH COMPLETE LEFT BUNDLE BRANCH BLOCK

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To elucidate the mechanism, cardiac function and prognosis of complete left bundle branch block (CLBBB), 32 patients with CLBBB were studied using echocardiographic and vectorcardiographic methods. They were classified into 5 types: according to the presence or absence of early systolic notch and paradoxical motion of interventricular septum. Type I, an early systolic notch and paradoxical motion of the interventricular septum; type II, an early systolic notch and a flat septal motion, type III, an early systolic notch but no paradoxical motion; type IV, an early systolic notch of a slight degree but no paradoxical motion; type V, showed neither early systolic notch nor paradoxical motion.

Type I patients had enlarged left ventricular dimension, severe cardiac damage and poor prognosis while type IV patients had a good ventricular function and prognosis with no complications. In type V patients, intraventricular conduction disturbances were apparent; a wide QRS loop in horizontal plane with no significant terminal delay. In type II and III, there were no typical findings. The histology revealed that the left bundle branch block was located at the bifurcation.

COMplete left bundle branch block (CLBBB) has been studied echocardiographically¹⁻³ with regard to septal and posterior left ventricular motion and electrophysiologically using ECG^{4,5} vectrocardiography (VCG) and epicardial mapping⁶. Correlation among the findings in echocardiography (Echo), VCG⁷⁻⁹ and echophonocardiography¹⁰ have also been reported.

Since the prognosis of patients with CLBBB depends on the severity of the underlying heart disease and related complications, the purpose

of this study is to elucidate the excitatory process, wall motion, ventricular function and histopathology of cardiac conduction system in patients with CLBBB. Correlations between the electrical (ECG, VCG) and mechanical phenomena (Echo) of CLBBB are also given attention.

MATERIALS AND METHODS

Thirty-two patients with CLBBB were studied using VCG (Frank system) and echocardiography. They were 16 men and women, ranging in age from 44 to 81 (mean 66) years. The clinical diagnosis was ischemic heart disease in 14 and hypertension in 6 patients. Five had an old myocardial infarction, 3 dilated cardiomyopathy, and one each of aortic regurgitation, ventricular septal defect, gallbladder cancer and one was free

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Fig. 1. Simultaneous echocardiograms of mitral (MV) and aortic valve (AV) in a patient with CLBBB.

ICT = isovolumetric contraction time, IRT = isovolumetric relaxation time, ET = ejection time.

from disease. Myocardial infarction was diagnosed based on clinical history, increased serum enzyme activity and ECG findings. In three patients who died of cardiac failure, the diagnosis was confirmed at autopsy. The control group included 38 healthy subjects, ranging in age from 28 to 74 (mean 47) years. Thirty were men and 8 were women. Echocardiograms were obtained using a Toshiba SSL-51U with a 10 mm diameter, 2.25 mHz transducer, focused at 7.5 cm with a repetition rate of 1000 impulses per second. Recordings were made using a Honeywell 1856 strip chart recorder. The transducer was placed at the fourth or fifth intercostal space close to the left border of the sternum. Patients were examined in the supine or left lateral decubitus position. The mitral and aortic echocardiograms were recorded simultaneously with lead II ECG and phonocardiogram at a paper speed of 50 mm/sec. As shown in Fig. 1, the

aortic valve (AV) and mitral valve (MV) echoes were simultaneously recorded according to Fujino et al.¹¹

The time intervals from the onset of QRS in lead II of ECG to mitral valve closure (QM_c) and mitral valve opening (QM_o), aortic valve opening (QA_o) and aortic valve closure (QA_c) were measured on the tracings. From these, isovolumetric contraction time (ICT), i.e., time QM_c minus QA_o, isovolumetric relaxation time (IRT), i.e., time QA_c minus QM_o, and ejection time (ET), i.e., QA_o minus QA_c were calculated. The corrected ET was calculated by $ET/\sqrt{RR}$. VCG was recorded using Frank's orthogonal lead system. The frontal (FP), left sagittal (LSP) and horizontal planes (HP) were obtained using a Fukuda VA-3D vectorcardiograph. Selected for study were 32 patients with QRS prolongation with patterns resembling left bundle branch block.¹² Statistical comparisons were made

Fig.2. Echocardiograms showing 5 types of septal motion in patients with CLBBB.

Fig.3. Four types of QRS loop in the vectorcardiogram of patients with complete left bundle branch block. 1 mV

Fig.4. Vectorcardiogram of patients with complete left bundle branch block. 1 mV

TABLE I ECHO AND VCG CORRELATIONS

IVS Notch paradoxical			VCG											
			Orientation of initial vector				QRS pattern in HP.				Axis of the max. QRS vector in FP.

			LAI	LAS	RAI	LPI					$\geq 30^\circ$	$29^\circ \sim -29^\circ$	$\leq -30^\circ$	
UCG														
I	+	+				X		X					6	
II	+	+											7	
III	+	-												7
IV	+	-												8
V	-	-												4
			19	5	5	3	12	12	3	5	18	2	12	

Abbreviations: ● = CLBBB; ○ = CLBBB, myocardial infarction and died; X = CLBBB and died; △ = CLBBB and myocardial infarction; LAI = inferiorly, anteriorly and to the left; LAS = superiorly, anteriorly and to the left; RAI = inferiorly, anteriorly and to the right; LPI = inferiorly, posteriorly and to the left; IVS = interventricular septum; Notch = early systolic notch; Paradoxical = paradoxical movement

between the CLBBB and normal groups using the two tailed t-test. At autopsy, heart weight and the coronary artery lesions were given particular attention. Myocardial infarction was considered to be present when, in the fixed preparation, there was an area of confluent necrosis or a fibrosis of 1.5 cm or more in diameter. The bundle of His and both bundle branches were serially sectioned and every 10th section was stained, for histological studies according to the method of Lev et al.¹³

RESULTS

Echo findings were classified into five types as follows (Fig. 2):

Type I: Six patients had abnormal septal motion with early systolic notch (arrow) and paradoxical motion. This pattern was considered typical of CLBBB.

Type II: Seven patients had a slight and atypical notch (arrow) in early systole. There was a flat septal motion compared with Type I (open arrow).

Type III: Seven patients had an early systolic notch (arrow) but no paradoxical motion.

Type IV: Eight patients had an early systolic notch (arrow) but only to a slight degree, compared with Type III. In no case did the excursion of the early systolic notch (arrow) exceed half of the interventricular septum.

Type V: Four patients had neither early systolic notch nor paradoxical motion.

VCG findings were classified as follows:

i) QRS loop in HP (Fig. 3)

Type A: There were 12 cases in this group. The major portion of the QRS loop was directed posteriorly and to the left and was inscribed clockwise.

Type B: There were 12 cases in this group. The major portion of the QRS loop was directed posteriorly and to the left and was inscribed in a figure-eight pattern.

Type C: There were 3 cases in this group. The QRS loop was inscribed clockwise (cw) and the width/length ratio was over one third.

Type D: There were 5 cases in this group. The QRS loop was inscribed counterclockwise (ccw) and the width/length ratio was over one third.

ii) QRS axis in FP (Fig. 4)

Type a: 18 patients showed a QRS axis of

TABLE II RELATION BETWEEN TYPES OF INTERVENTRICULAR SEPTAL MOTION AND ECHOCARDIOGRAPHIC FINDINGS IN PATIENTS WITH CLBBB

Type of UCG	Control	I	II	III	IV	V
number	38	6	7	7	8	4
age	47.6 ± 9.5	68.1 ± 8.6	62.1 ± 1.9	60.0 ± 12.5	72.2 ± 12.4	65.5 ± 13.6
LVDd (cm)	46.5 ± 7.0	62.5 ± 7.6****	53.9 ± 9.9*	53.6 ± 10.7*	47.3 ± 7.3	55.3 ± 7.1*
LA (cm)	30.6 ± 3.8	35.8 ± 4.9***	29.6 ± 4.8	35.9 ± 7.3**	32.5 ± 3.8	38.3 ± 10.8***
Q-Mc (msec)	43.5 ± 11.9	107.5 ± 10.8****	65.7 ± 12.7****	71.4 ± 34.3****	48.1 ± 13.6	70.0 ± 18.3****
Q-Mo (msec)	480.0 ± 35.5	586.7 ± 44.6****	520.0 ± 42.0	537.1 ± 53.1****	587.1 ± 49.1****	540.0 ± 33.7***
Q-Ao (msec)	85.7 ± 8.7	183.3 ± 22.5****	154.3 ± 22.3****	147.1 ± 27.5****	132.5 ± 16.7****	147.5 ± 22.1****
ICT (msec)	42.1 ± 17.5	75.8 ± 28.7****	88.6 ± 24.1****	75.7 ± 19.9****	84.4 ± 24.0****	77.5 ± 35.0***
IRT (msec)	81.9 ± 20.5	127.5 ± 18.9****	101.4 ± 12.2*	101.4 ± 36.3	93.8 ± 26.7	80.0 ± 14.1
ET (msec)	309.6 ± 22.1	275.8 ± 39.0****	264.3 ± 23.7****	290.0 ± 43.9****	332.5 ± 16.7****	287.5 ± 15.0****
QAo/ET	0.3 ± 0.1	0.7 ± 0.1****	0.6 ± 0.1****	0.5 ± 0.2****	0.4 ± 0.1****	0.5 ± 0.1****

Values are mean ± SD. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.005$, **** $p < 0.001$

Abbreviations: LVDd = left ventricular diastolic dimension; LA = left atrial dimension; Q-Mc, Q-Mo, Q-Ao = time from onset of QRS to mitral valve closure, mitral valve opening, aortic valve opening, respectively; ICT = isovolumetric contraction time; IRT = isovolumetric relaxation time; LVET = left ventricular ejection time; QAo/ET = Q-Ao/Ejection time

Fig.5. Correlation between left ventricular diastolic dimension in Echo and magnitude of maximum QRS vector in VCG.

greater than +30 degrees.

Type b: 2 patients showed a QRS axis between -29 to +29 degrees.

Type c: 12 patients showed a left axis deviation of -30 degrees or more.

Correlation between Echo and VCG is shown in Table I.

In type I Echo (6 cases), the direction of the initial vector differed. QRS loop in the HP was inscribed cw in 5 patients and a figure-eight pattern in one patient. The QRS axis was $\geq 30^\circ$ in 3 patients, $\leq -30^\circ$ in 3 patients.

In type II Echo (7 cases), the direction of the initial vector differed. QRS loop in the HP was inscribed cw in 3 patients and a figure-eight pattern in 4 patients. QRS axis was $\geq 30^\circ$ in 6 patients and $\leq -30^\circ$ in only one patient.

In type III Echo (7 cases), the initial vector was oriented differently. The QRS loop in HP was cw in 3 patients and figure-eight pattern in one. Here the width/length ratio increased over one third in 3 patients. The loop with a marked increase in left axis deviation suggested an intraventricular conduction defect (IVCD).

In type IV Echo (8 cases), the initial vector was always oriented inferiorly, anteriorly and to the left. The QRS axis was fairly normal.

In type V Echo (4 cases), the QRS loops in HP all increased in width/length ratio, thereby suggesting a marked IVCD with left axis deviation.

In 4 patients with anteroseptal myocardial infarction, shown by the open circles and triangles in Table I, the orientation of the initial force of QRS vector was anteriorly, inferiorly and to the left in 3 patients, and anteriorly, inferiorly and to the right in one patient. The QRS loop in the HP showed cw rotation in 3 patients and a figure-eight pattern in one.

Fig.6. Histological findings in 3 patients with CLBBB.

A. 73 yr. old man. CLBBB plus myocardial infarction. B. 74 yr. old man. CLBBB plus myocardial infarction. C. 76 yr. old woman. CLBBB without myocardial infarction. Left bundle branch shows fibrosis at the bifurcation in each panel. Weigert-van Gieson stain $\times 40$, LBB = left bundle branch, IVS = Interventricular septum.

Table II shows the relations among types of interventricular septal motion and echocardiographic findings in patients with left bundle branch block. There was no significant correlation between age and echo findings in any types, while type IV tended to be seen in senile patients with a mean age of 73 years. Left ventricular diastolic dimension (LVDD) increased in all, except type IV. Left atrial dimension increased in types I, III and V, whereas no significant cardiac enlargement was seen in groups II and IV. QMc was most often prolonged in type I, and, to some extent in types II, III and V, while there was no prolongation in type IV.

QMc, QAO, QAC and ICT were prolonged in all types. IRT was prolonged, except in type IV. ET in type IV was increased compared with findings in 38 control subjects. In types I and II, ET was shortened. QAO/ET was increased in all types. There were no correlations between the duration of the QRS in ECG and the echocardiographic ventricular function.

Echo types and the magnitude and direction of maximum QRS vectors showed no correlation.

The correlation coefficient (r) between LVDD and magnitude of maximum QRS vectors was 0.62 in type IV, but there was no correlation in type I (Fig. 5). In type I patients with

myocardial infarction, LVDD was increased but the magnitude of the maximum QRS vectors was decreased.

Fig. 6 shows the left bundle branch of 2 patients with myocardial infarction (A, B) and one patient without myocardial infarction (C) in whom there was evidence of fibrosis at the bifurcation.

DISCUSSION

In left bundle branch block, activation of the left ventricle seems to involve various pathways. McDonald¹ and Bevans and Rapaport¹⁴ reported a correlation between the Echo and ECG in patients with CLBBB.

In healthy individuals, the LBBB appears insignificant; in other clinical settings, it is found to be associated with a significant mortality. Survival of patients with LBBB depends on the severity of the underlying heart disease. Alboni¹⁵ considered that, in the presence of LBBB, it was difficult and often impossible to detect a healed myocardial infarction. Pietras et al¹⁶ reported criteria by which myocardial infarction was correctly predicted in 25 of 28 hearts (89%) and the lesion was correctly localized in 21 hearts (75%). There were 12 (35%)

cases of false positive diagnosis.

Autopsy tissues were available in 4 of 6 patients (67%) with type I Echo. We could not diagnose myocardial infarction by the direction of the initial QRS vector alone, but the magnitude of the maximum QRS vector was small in cases with myocardial infarction and large in one patient with no myocardial infarction. So we confirmed the difference between the presence of myocardial infarction with type I Echo and its absence using the magnitude of the maximum QRS vector. The left ventricular ET was prolonged and QAO/ET was decreased in type II compared with data in type I patients.

In type II UCG group, myocardial infarction was noted in only one case, who showed normal ventricular function and low voltage. The difference between type I and II was that in type II myocardial infarction, if present, was much less extensive and there were fewer disturbances in conduction.

Type I with early systolic notch and interventricular septal paradoxical movement was most characteristic of CLBBB. The LVDd was increased and QMc and QAO were prolonged. The decrease in the ET and the increase in QAO/ET were also evident. Autopsy revealed myocardial infarction in 3 (75%) of these hearts with decreased ventricular function, while there was no myocardial infarction in one (25%) with normal ventricular function and an marked high voltage in VCG.

Type IV was more frequently observed in the old age group in which there were disturbances in the cardiac conduction system but no evidence of hemodynamic dysfunction.

Burggraf¹⁰ reported that prolonged isovolumetric contraction time (ICT) indicated a decreased rate of rise of left ventricular pressure or abnormal sequence of depolarization. QMc was prolonged, except in type IV patients with a normal ventricular function. ICT was prolonged in all types. These results suggest that the prolongation of ICT may be the result of prolongation of QMc and an abnormal sequence of depolarization. With regard to the axis of the QRS loop in FP, there was a marked left axis deviation of over 50% in types I, III and V. These findings suggest that in these groups, myocardial infarction and IVCD have to be considered. Five of 12 patients (42%) with marked left axis deviation and only one (6%) with a normal axis died. Beach¹⁷ et al. have suggested that determination of the mean QRS in

FP may be clinically significant for LBBB.

Four of 6 patients (67%) with type I, one of 4 patients (25%) with type V and one of 7 (14%) with types II and III died. There were no deaths in patients classed as type IV.

Autopsy studies revealed myocardial infarction and the site of the block of left bundle branch was located at the bifurcation. There was some correlation between the site of the left bundle branch block and the motion of the interventricular septum seen on the Echo.

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