Correlation Between Interventricular Septal Motion and Left Ventricular Systolic-Diastolic Function in Patients With Left Bundle Branch Block

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Abstract

The echocardiographic correlation between abnormal interventricular septal motion including systolic paradoxical, flat motion and early diastolic notch and ejection fraction, mean ventricular circumferential fiber shortening and early diastolic mitral filling velocity was studied in 46 patients with complete left bundle branch block. Systolic normal interventricular septal motion was used as the control.

Ejection fraction was significantly smaller in the paradoxical (0.44 ± 0.13, $p < 0.02$) and flat motion groups (0.38 ± 0.09, $p < 0.001$) than in the normal group (0.54 ± 0.1). Mean ventricular circumferential fiber shortening was significantly smaller in the flat motion group than in the normal group (0.72 ± 0.19 vs 0.99 ± 0.23 circ/sec, $p < 0.002$). The size of the notch was significantly smaller in the flat motion group than in the normal group (2.3 ± 0.2 vs 4.8 ± 0.8 mm, $p < 0.0001$). The deceleration rate of the notch was significantly slower in the paradoxical and flat motion groups than in the normal group (37.3 ± 12.2, 31.3 ± 8.1 vs 69.1 ± 2.5 cm/sec, $p < 0.0001$). Early diastolic mitral filling velocity was slower in the flat motion group than in the other 2 groups.

In conclusion, systolic flat interventricular septal motion showed more severe disturbances of left ventricular systolic and diastolic function than paradoxical interventricular septal motion in patients with complete left bundle branch block.

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Key Words

■ **Echocardiography (transthoracic)** ■ **Doppler ultrasound**
■ **Electrocardiography (complete left bundle branch block)** ■ **Ejection fraction**
■ **Diastole**

INTRODUCTION

Patients with complete left bundle branch block (CLBBB) exhibit various abnormal patterns of interventricular septal motion due to electronic asynchrony between the left and right ventricles[1–4]. Systolic paradoxical motion and protodiastolic protrusion toward the left ventricle (the so-called notch) of the interventricular septal motion are especially well-known outstanding patterns[5]. Systolic function of the left ventricle is disturbed due to abnormal septal motion and asynchrony[6]. However, the correlation between early diastolic interventricular septal motion and left ventricular diastolic function is less well-known[7,8].

We studied the correlation between abnormal

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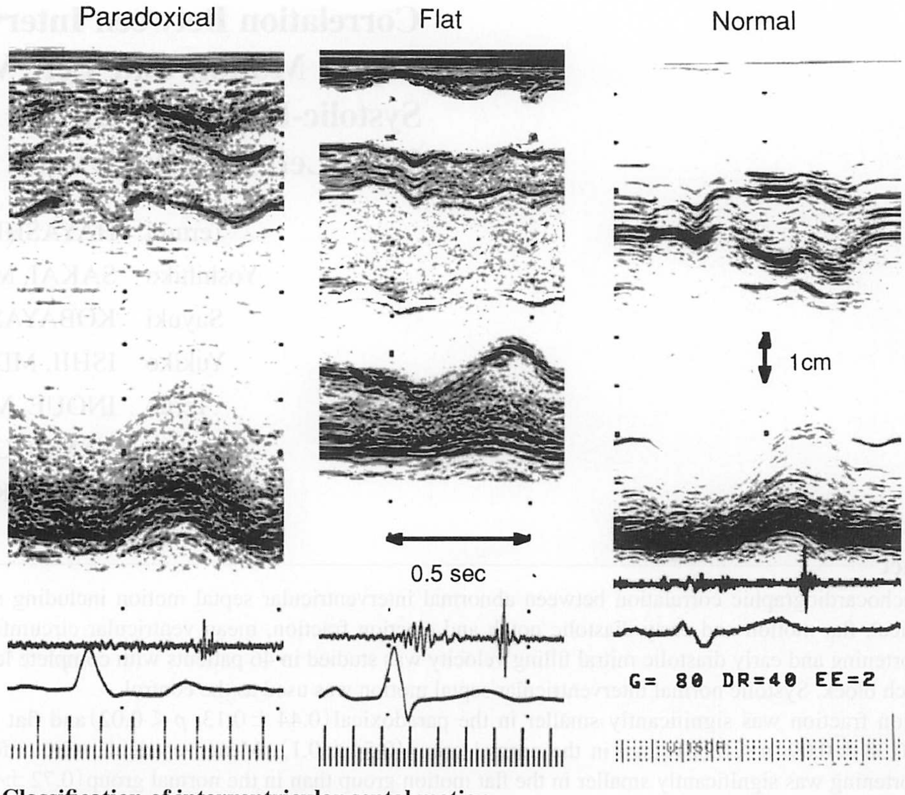

Fig. 1 Classification of interventricular septal motion
The left panel shows paradoxical motion. A large early diastolic notch follows the concave pattern during systole and a small protodiastolic notch. The center panel shows the flat pattern which indicates a small early diastolic notch and systolic akinesis, and a tiny protodiastolic notch. The right panel shows the normal pattern which means systolic normal contraction and a large protodiastolic notch. All 3 patterns reveal normal pattern of the posterior wall.

interventricular septal motion and the systolic and diastolic functions of the left ventricle in patients with CLBBB using M-mode and pulsed Doppler echocardiography.

METHODS

Patients

This study included 46 patients with CLBBB, 19 men and 27 women (mean age 65.1 ± 11.6 years), with one of 3 types of systolic septal motion based on M-mode echocardiograms: 14 patients with paradoxical motion (mean age 61 years); 12 patients with flat motion (mean age 68 years); and normal group, 20 patients with normal motion (mean age 65 years). We excluded patients with severe coronary heart disease, dilated cardiomyopathy, and overt congestive heart failure. We explained the purpose of the examination to all subjects and obtained informed consent and approval.

Echocardiographic recording

Recordings were made using a Toshiba SSH 160A echocardiograph with a 2.5 or 3.5 MHz transducer and a line-scan recorder at a paper speed of 50 mm/sec. Echocardiography was performed in the usual way. The views obtained included the parasternal long-axis, short-axis, and apical 4 chamber views. Chamber dimensions were obtained from M-mode echocardiograms taken in the parasternal long-axis view guided by a two-dimensional echocardiogram and were measured according to American Society of Echocardiography recommendations[9]. Left ventricular end-systolic and end-diastolic volumes were derived from the M-mode echocardiograms by Teichholz's formula[10]. Phonocardiograms were recorded simultaneously with a line-scan recorder. Pulsed Doppler echocardiograms were recorded by placing the sample volume at the tip of the mitral valves in the apical long-axis view.

Measured parameters included ejection fraction

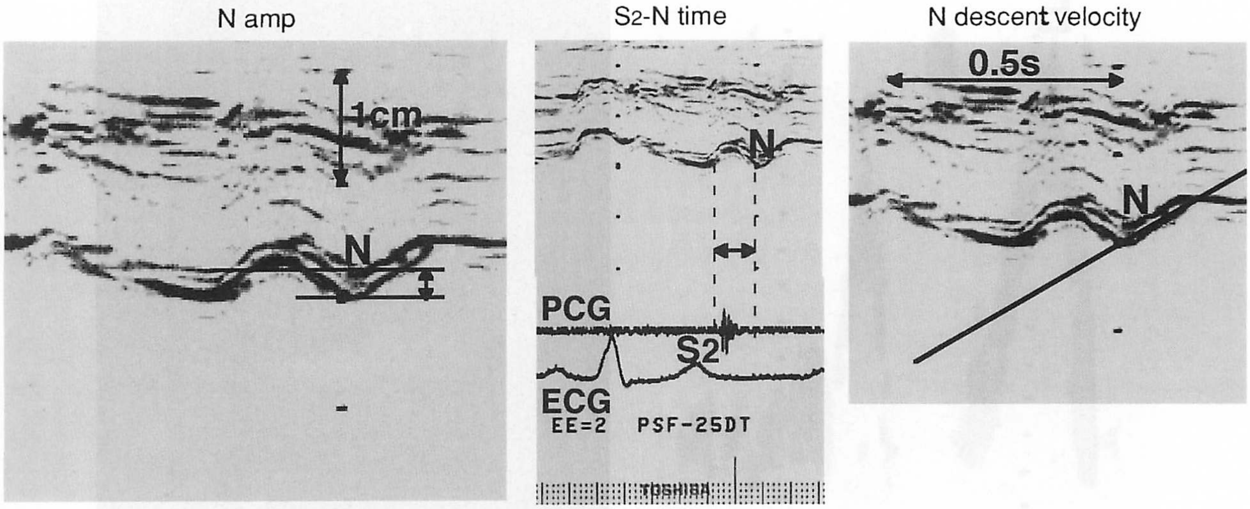

Fig. 2 Measurement of interventricular septal motion

The left panel shows the measurement of the amplitude of the notch (N amp) from the baseline to the peak of the notch (*arrow*). The center panel shows the measurement of the timing of the peak of the notch (S_2-N time) from the beginning of the second heart sound to the peak of the notch (*arrow*). The right panel shows the measurement of the descent velocity of the notch by a tangential line along the early diastolic slope of the notch .

N = notch; N amp = amplitude of notch; S_2-N = interval of second heart sound to notch; PCG = phonocardiogram; ECG = electrocardiogram.

and mean ventricular circumferential fiber shortening as the systolic left ventricular functions and early diastolic mitral inflow velocity by pulsed Doppler echocardiograms as the early diastolic function. We analyzed patterns of the early diastolic notch including amplitude and timing of the peak, which was measured from the beginning of the second heart sound, and the velocity of its descent.

Classification of interventricular septal motion

Fig. 1 displays the 3 classifications of interventricular septal motion. All 3 examples in **Fig. 1** show protodiastolic notches.

Measurement of notch parameters

Fig. 2 shows how we measured protodiastolic notch parameters of interventricular septum. The distance from the bottom to the peak of the notch was measured to evaluate notch amplitude. Timing of the notch was measured as the interval from the beginning of the second heart sound (S_2) to the peak of the notch. A method similar to the mitral valve diastolic descent rate measurement, in which a tangential line drawn along the slope of descent motion, was used to measure the descent velocity of the notch.

Measurement of mitral inflow velocity

Fig. 3 shows representative examples of mitral inflow velocity sample volume and mitral inflow velocity pattern. E is the peak velocity of early diastolic filling at the mitral orifice. A is the peak velocity of diastolic filling at the atrial contraction period.

Statistical analysis

Data are presented as mean ± standard deviation. Statistical analysis was performed using the unpaired Student's *t*-test, and a level of $p < 0.05$ was accepted as statistically significant.

RESULTS

Systolic function

Ejection fraction decreased significantly in the paradoxical motion (0.44 ± 0.13, $p < 0.02$) and flat motion groups (0.38 ± 0.09, $p < 0.001$), but we observed no significant difference between the paradoxical group and the flat group (**Fig. 4–left**). Although mean ventricular circumferential fiber shortening was significantly smaller only in the flat pattern group in comparison to the normal pattern group (0.72 ± 0.19 vs 0.99 ± 0.23 circ/sec, $p < 0.002$), the paradoxical motion group showed large variance (0.44 ± 0.13) and no significant correla-

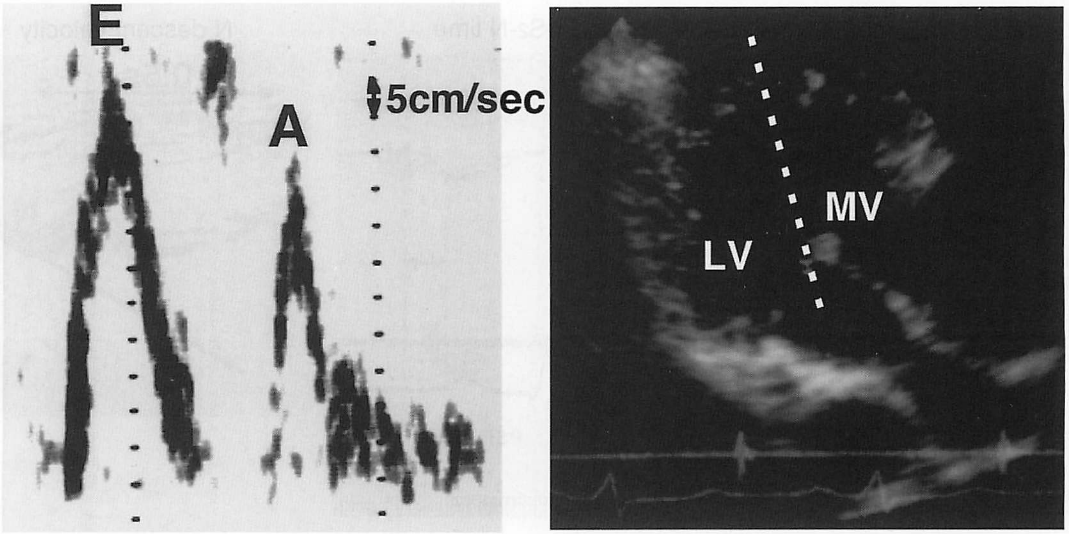

Fig. 3 Representative mitral inflow velocity pattern
The left panel shows the mitral inflow velocity pattern. The right panel shows a sample volume of the mitral inflow velocity. The dotted line shows the echo beam which is parallel to the inflow blood stream.
E = peak velocity of early diastolic filling of the left ventricle; A = peak filling velocity of atrial contraction period of the left ventricle; LV = left ventricle; MV = mitral valve.

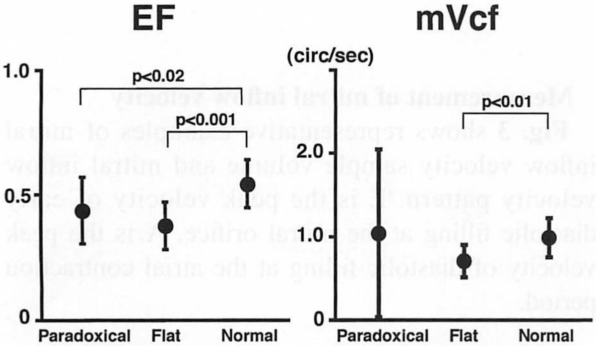

Fig. 4 Systolic functions obtained by M-mode echocardiogram
The bars show mean ± SD.
EF = ejection fraction; mVcf = mean ventricular circumferential fiber shortening.

tion in comparison to the other 2 groups (**Fig. 4–right**).

Notch parameters

Notch amplitude was significantly smaller in the flat group (2.3 ± 0.2 mm) than in the normal pattern group (4.8 ± 0.8 mm, $p < 0.0001$). The paradoxical motion group showed a wide range of values and there was no significant correlation compared to the other 2 groups (**Fig. 5–left**). Second heart sound to notch peak interval showed a longer interval in the flat group compared to the abnormal and normal motion groups (**Fig. 5–right**).

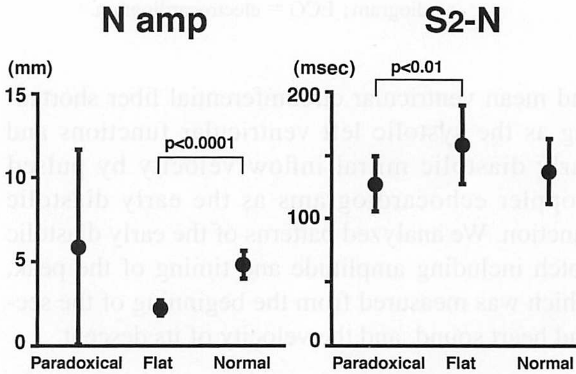

Fig. 5 Measurement of parameters of the notch
Abbreviations as in Fig. 2.

Notch descent velocity in both paradoxical and flat pattern groups was significantly slower than that in the normal group (37.3 ± 12.2, 31.3 ± 8.1 vs 69.1 ± 2.5 cm/sec, $p < 0.0001$). However, there was no significant difference in velocities between the paradoxical group and the flat pattern group (**Fig. 6–left**).

Mitral inflow velocity

Early diastolic mitral filling velocity showed a weak tendency towards a slower velocity in the flat group compared to the other 2 groups, but there was no statistical significance (**Fig. 6–right**).

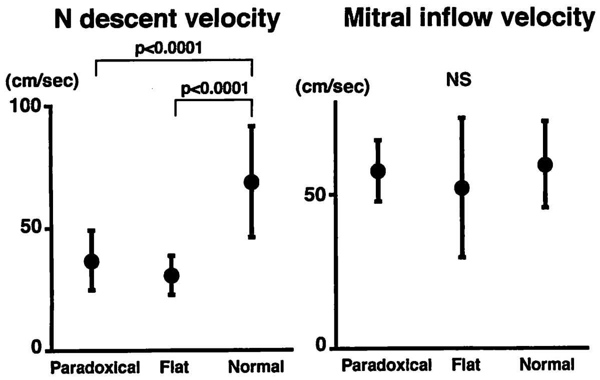

Fig. 6 Early diastolic functions obtained by interventricular septal motion and mitral inflow velocity
Abbreviation as in Fig. 2.

DISCUSSION

Patients with isolated left bundle branch block suffer a delay in the onset of left ventricular contraction, resulting in changes to both right and left ventricular function[6,11]. Left ventricular abnormalities manifest as abnormal diastolic filling times, ventricular septal motion, and left ventricular ejection fraction[8,12]. CLBBB causes various abnormal interventricular septal motions due to electronic asynchrony between the right and left ventricles and to pathologic change in the myocardium[13,14]. However, evaluations using M-mode and Doppler echocardiography have not determined whether these mechanical alterations affect left ventricular systolic as well as diastolic functions. This study attempted to clarify the correlation between regional ventricular wall motion abnormalities and ventricular functions, especially early diastolic function.

Xiao *et al.*[14] suggested that subendocardial muscle fibers within the left ventricle were longitudinally directed. The earliest portion of the ventricular myocardium activated is the subendocardium of the septum and lateral wall at the mid-cavity level[15,16]. We consider that the locus and the prevalence of specific sites and patterns of contraction abnormalities in the interventricular septum are related closely to systolic and diastolic cardiac function. Since the most common abnormal cardiac wall motion types are the paradoxical and flat patterns, which manifest in various cardiac diseases including ischemic heart disease, cardiomyopathy, and CLBBB[3,12], we classified septal motion into 3 types; paradoxical, flat, and normal patterns. The systolic normal pattern was used as a control.

The most outstanding abnormal finding in diastolic interventricular septal motion in CLBBB is a protodiastolic notch, which may affect early diastolic filling[5,7]. Therefore, we analyzed this notch as a marker of protodiastolic interventricular septal motion. In this study, we used the notch to second heart sound interval as a parameter similar to isometric relaxation time because the shape and timing are easy to recognize. We found the interval of the second heart sound to the peak of notch coincided with the interval of the second heart sound to the onset of the early mitral filling velocity signal (unpublished data).

Modern noninvasive methods should provide more precise information regarding the mechanical events of myocardial wall motion in CLBBB. Two-dimensional echocardiography is the imaging technique most commonly used to assess the heart. This method is especially useful for observation of global wall motion. However, M-mode echocardiography is superior to two-dimensional echocardiography for precise time analysis or measurement of cardiac wall excursion. Timing of the onset of abnormal septal motion, particularly that of the protodiastolic notch, can be determined precisely by M-mode echocardiography. Global systolic functions, including ejection fraction and mean ventricular circumferential fiber shortening, are better assessed using two-dimensional echocardiography. However, the patients with CLBBB in this study showed localized abnormal interventricular septal motion, but no abnormality in other parts of the left ventricle. So, we considered that systolic function assessed by M-mode echocardiography was more accurate than that by two-dimensional echocardiography because we could select the correct timing and endocardial site using the ice-pick view of M-mode echocardiography. Several previous reports have described left ventricular systolic function including fractional shortening using M-mode echocardiography[6,8,12].

Pulsed Doppler echocardiography is also commonly used for the evaluation of diastolic function[7]. Early diastole is the most important time in the entire diastolic ventricular filling period. Interventricular septal motion in early diastole also affects rapid ventricular filling. The ascending limb of the protodiastolic notch relates closely to the rapid filling of the left ventricle, so we can assess early diastolic function in a similar way to that of the diastolic descent rate of the mitral valve. The second heart sound to notch interval is considered to hold the same significance as isometric relaxation time, because the peak of the notch coincides with the beginning of the early mitral filling velocity signal on pulsed Doppler echocardiography.

In this study, the flat pattern group showed a smaller mean ventricular circumferential fiber shortening and early diastolic notch amplitude, and a longer second heart sound to notch interval than the paradoxical pattern group. Moreover, the flat pattern group revealed a tendency towards slower early mitral filling velocity, but there was no significant difference with the paradoxical motion group. The reason might be that global diastolic wall motion was preserved except in the interventricular septum.

Previous reports showed that patients exhibiting the flat pattern had more severe myocardial disturbances than patients with the paradoxical pattern[3]. Therefore, patients with the flat pattern group may have more severe disturbances in both systolic and diastolic function. In our subjects, underlying heart diseases were mostly caused by the aging process, and all patients were in a hemodynamically stable condition. Therefore, the ejection fraction and mean ventricular circumferential fiber shortening of our subjects were not considered to be so bad. Moreover, other segments of the left ventricular wall except the interventricular septum showed no asynergy. We believe the general condition of patients with CLBBB in this study was due to the aging phenomenon. However, the present study has several limitations. First, we did not show cardiac catheterization data from patients in the study groups because only a few patients underwent cardiac catheterization. Thus, we could not exclude coronary artery disease completely. Second, the underlying histological finding of interventricular septum in our patients should be proven anatomically, but we have no such direct information.

In conclusion, we analyzed the correlation between the abnormal patterns of interventricular septal motion. The flat motion pattern indicated much more severe systolic and diastolic dysfunction than did the paradoxical motion pattern. We suggest that the combination of electrical and mechanical findings has proved the profound functional effects of these abnormalities, and this knowledge may open the way for more effective treatment[17].

要　約

完全左脚ブロック症例における心室中隔運動パターンと左室収縮能−拡張能との相関に関する検討

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完全左脚ブロック46例を用い，心室中隔異常運動の左室収縮能および拡張能に及ぼす影響を心エコー図法により検討した．収縮期運動は奇異性と平坦型に分類し，さらに拡張早期のnotchに注目し，これら心室中隔異常運動波形と駆出率，平均左室円周心筋短縮速度および拡張早期僧帽弁流入血流速(E)との相関を検討した．収縮期に正常中隔運動を示す群を対照とした．

駆出率は奇異性運動群(0.44 ± 0.13，$p < 0.02$)，平坦型群(0.38 ± 0.09，$p < 0.001$)ともに正常型群(0.54 ± 0.1)に比べ，有意に低値であった．平均左室円周心筋短縮速度は平坦型群が正常型に比べ，有意に低値であった(0.72 ± 0.19 vs 0.99 ± 0.23 circ/sec，$p < 0.002$)．

Notchの大きさは平坦型群が正常型群に比べ，有意に低値であった(2.3 ± 0.2 vs 4.8 ± 0.8 mm，$p < 0.0001$)．Notchの減速時間は奇異性運動群，平坦型群ともに正常型群に比べ，有意に遅延していた(37.3 ± 12.2，31.3 ± 8.1 vs 69.1 ± 2.5 cm/sec，$p < 0.0001$)．Eは平坦型群が他の2群より低値であった．

完全左脚ブロック症例における心室中隔収縮期平坦型運動群は，奇異性運動群に比べ，左室収縮能および拡張能の障害がより大きかった．

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