Echocardiographic Demonstration of Abnormal Motion of the Interventricular Septum in Left Bundle Branch Block

By IAN G. MCDONALD, M.D., MELB., FRACP

SUMMARY
A characteristic abnormality of motion of the interventricular septum was recorded by echocardiography in 17 of 18 patients with left bundle branch block. Early and abrupt contraction of the septum occurs during the pre-ejection period before the delayed commencement of contraction of the posterior wall of the left ventricle. This abnormality can be explained by asynchronous contraction of the left ventricle with early activation and contraction of the septum but delay in activation and contraction of the left ventricular free wall due to a block in the left bundle branch or its peripheral branches.

Additional Indexing Words:
Left ventricle Ultrasound

SYSTOLIC contraction of the human left ventricle is normally an almost symmetrical process accompanied by small rotational movements of the chamber within the thorax. This pattern of contraction depends upon the normal rapid spread of myocardial activation so that the cavity is quickly surrounded by contracting myocardium during early systole. Experimental interruption of conduction through the left bundle branch not only delays left ventricular activation but also disturbs its sequence so that the normal symmetry of contraction might be disturbed by asynchronous movements of the walls of the chamber. Echocardiography has confirmed this supposition by demonstrating that abnormal abrupt early systolic contraction of the interventricular septum is characteristically found in patients with left bundle branch block.

Methods

Patients Studied
Twenty-one patients with left bundle branch block were studied by left ventricular echocardiography as part of a routine clinical assessment. Three were excluded from the study because the echocardiograms were of inadequate quality for detailed analysis. Clinical details of the remaining 18 patients are listed in table 1. In one subject (patient 16) full investigation, including cardiac catheterization with selective coronary angiography, revealed no abnormality apart from left bundle branch block. The contour of the left ventricular echoes in this group were compared with those of a group of 25 subjects with no clinical cardiovascular abnormality.

Echocardiography and Phonocardiography
Echocardiography was performed with a 1.27 cm 2.25 mHz transducer, and standard ultrasonoscope M-mode tracings (fig. 1) were made on a multichannel oscillographic recorder in 12 patients, and by Polaroid photography of the screen of the ultrasonoscope in six patients. Details of the technique of examination have been previously described in detail. Important precautions in obtaining a valid and reproducible left ventricular echocardiogram include (a) use of the mitral valve as a landmark to control the direction of the ultrasound beam through the left ventricle and (b) accepting for analysis only recordings showing simultaneous resolution of the left side of the interventricular septum and endocardial surface of the posterior left ventricular wall. In particular, care must be taken to distinguish the right and left sides of the interventricular septum and the endocardial and epicardial surfaces of the posterior left ventricular wall by careful

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†Eko-Kline 20, Smith Kline Instruments, Inc., Palo Alto, California.
‡Model DR 8, Electronics for Medicine, White Plains, New York.
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Table 1

Clinical Details, Time Intervals, Echocardiography

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<th>I-P</th>
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Abbreviations: I = onset of QRS; M = early systolic septal movement; P = peak of early systolic septal movement; LV = upstroke of the apexcardiogram; I-Car = Pre-ejection period; LVET = left ventricular ejection time; Dd = end-diastolic dimension; Ds = end-systolic dimension; CM = cardiomyopathy; AS = aortic stenosis; AR = aortic regurgitation; MS = mitral stenosis; AVP = aortic valve prosthesis; IHD = ischemic heart disease.

Adjustment of both gain and damping controls. Examples of echocardiograms in a normal subject and in a patient with left bundle branch block are shown in Figure 1; the range of appearances of left ventricular echoes found in patients with left bundle branch block is shown in Figure 2. The echocardiographic contours of septal motion were traced for all patients with left bundle branch block, and for comparison, in six unselected subjects from a control group (Fig 3). The left ventricular ultrasonic dimensions were measured at end-diastole (Dd) and end-systole (Ds).

For those studies performed using a multichannel recorder, the phonocardiogram, indirect carotid pulse, and electrocardiogram were recorded with the left ventricular echocardiogram. For the six patients in whom echocardiograms were recorded by direct Polaroid photography of the ultrasonicoscope, the electrocardiogram was the only reference tracing, and in four of them a phonocardiogram with an electrocardiogram and indirect carotid pulse was recorded immediately after the echocardiogram. Apexcardiography was attempted in all 16 patients in whom phonocardiography was performed but a technically satisfactory recording could be obtained in only 13. Transmission time for the pressure wave in the transducer used in recording the apexcardiogram and indirect carotid pulse tracing was 5 msec.

Left bundle branch block was defined as a QRS interval of 120 msec or more with a characteristic notched contour, particularly in leads I, aVL, and the left precordial leads; an absent Q wave; and an ST-segment and T wave of opposite polarity to the R wave. The duration of the QRS complex was measured on a standard 12 lead electrocardiogram to the nearest 10 msec. Other time intervals measured were between the initial deflection of the QRS complex (I) and a) the beginning of the early systolic septal movement (I-M); b) the peak of this movement (I-P); c) the upstroke of the apexcardiogram (I-LV); and d) the aortic component of the second heart sound (I-A2). The pre-ejection period (I-Car) was calculated by subtracting the left ventricular ejection time (LVET) from electromechanical systole (I-A2). These intervals were measured to the nearest 5 msec.

Three patients with left bundle branch block were studied by left ventricular cineangiography. Two studies were performed in the right anterior oblique (RAO) projection only and one study (patient 7) in both left (LAO) and right anterior oblique projections. Since abnormal septal movement was detected in this study, movements of the left ventricular walls were studied in detail using methods previously described. Figure 4 shows single frames from both RAO and LAO left ventricular cineangiograms which correspond to end-diastole (beginning of the QRS complex), to the instant of maximum abnormal displacement of the septum during pre-ejection systole and to end-ejection (aortic component of the second heart sound). The left ventricular angiographic profile at end-diastole and at
Figure 1

(a) Left ventricular echocardiogram in a patient with cardiomyopathy and left bundle branch block showing echoes from the transducer face (T), chest wall (CW) right ventricle (RV), interventricular septum (S) and posterior left ventricular wall (PLV). The characteristic abnormal early systolic septal contraction (C) is shown. The beginning of this movement (M), its peak (P), and the septal notch (N) are also shown. The physiological reference tracings are the electrocardiogram (EKG), phonocardiogram (PHONO), and indirect carotid pulse tracing (CAR). The initial deflection of the electrocardiogram, the measurement of the left ventricular ejection time (LVET), and aortic component of the second sound (A2) are indicated.

(b) Left ventricular echocardiogram of a normal subject. The characteristic septal notch (N) is shown and the timing of the initial deflection of the electrocardiogram and aortic component of the second sound are also indicated. Time lines at intervals of 40 msec.

the peak of the abnormal septal movement were traced, using the bones of the thoracic cage as fixed reference points, then superimposed (fig. 5). In the LAO projection, the motion of the left side of the interventricular septum and endocardial surface of the posterior left ventricular wall were analyzed by measuring frame-by-frame displacement from a fixed reference point along the maximum left ventricular diameter in this projection, then correcting for X-ray magnification. The angiographic and echocardiographic contours of left ventricular wall motion could then be compared (fig. 6a). Similar tracings were made for comparison in a patient with pure mitral stenosis who did not have left bundle branch block (fig. 6b).

Results

Echocardiography

The echocardiographic contours of septal and posterior left ventricular wall motion in normal subjects have been previously described in detail. The contour of the posterior left ventricular wall echo resembled an inverted ventricular volume curve while septal motion was of smaller amplitude and the contour showed a characteristic notch in early diastole.

Patients with left bundle branch block exhibited a characteristic abnormality of septal motion (fig. 1,
Examples of left ventricular echocardiograms in patients with left bundle branch block. A to D show the abnormal early systolic contraction (C), but this is absent in E.
There was an abrupt movement of the interventricular septum away from the ultrasound transducer and toward the left ventricular long axis and posterior wall which commenced approximately 50 msec after the beginning of the QRS complex and reached its peak at 100 msec. From this peak, the subsequent movement in the reverse direction toward the ultrasound transducer usually continued into the ejection phase. The commonest contour during ejection (12 patients) was a shallow "paradoxical" pattern—the septal wall continued to move toward the ultrasound transducer and away from the posterior left ventricular wall. In a minority (five patients), there was a more complex pattern produced by a further movement away from the ultrasound transducer during part of ejection. The notching of the contour of the septal echo which is characteristically observed in normal subjects was less prominent and occasionally absent.
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Tracings of the cineangiographic profile of the left ventricle (LV) and aortic root (AO) at end-diastole (continuous line) and at the time of maximum displacement of the interventricular septum during its abnormal early systolic movement (dotted line) in the left anterior oblique (LAO) and right anterior oblique (RAO) projections.

The only exception to this description was encountered in a patient with a heterograft aortic valve prosthesis in whom left bundle branch block had occurred at the time of surgery and who had severe aortic regurgitation at the time of the echocardiogram. Septal movement was exaggerated in the fashion characteristic of severe left ventricular volume overload but the echocardiographic contour was not apparently affected by the presence of left bundle branch block.

In all patients with left bundle branch block, the contour of the left ventricular posterior wall echo appeared normal apart from delay in the commencement of its movement toward the ultrasound transducer due to prolongation of the pre-ejection phase of systole.

Discussion

Left Ventricular Contraction—Normal

The abnormal septal movement caused by left bundle branch block can best be explained by comparing the sequence of activation and contraction of the left ventricle with that normally observed. Detailed studies of the ventricular activation sequence obtained in the dog can be reasonably extrapolated to man by allowing for the species difference in the duration of the QRS complex. Thus rapid conduction through both left and right bundle branches initially produces rapid activation (within 10 msec) of subendocardial myocardium around both ventricular cavities which are almost completely surrounded in the middle portions of the ventricles. Invasion of the interventricular septum then occurs from both right and left sides and results in almost complete activation by 25 msec. Since the left ventricular cavity is surrounded so rapidly by activated myocardium there is little tendency for asymmetrical or localized movements of the left ventricular wall. In fact, left ventricular angiography reveals only a slight shortening of the left ventricular minor axes as blood is displaced from the cavity into the closing mitral valve cusps. Myocardial contraction is then truly isovolumic for a brief period prior to ejection so that the concentric force exerted by the left ventricular walls can cause no significant movement. With the onset of ejection, the activation process has been completed so that the left ventricular wall contracts in an approximately symmetrical fashion about the long axis of the chamber, and descent of the base is completed. Small rotational movements are observed early and late in systole and can be explained by the sequence of activation of the left ventricle which results in early contraction of endocardial layers of myocardium and late persistence of contraction in the epicardial layers which are obliquely orientated in the left ventricular wall. The latter movement is an anticlockwise twisting movement toward the anterior chest wall which is responsible for the characteristic notch in the septal echo of the left ventricular echocardiogram.

Left Ventricular Contraction—Left Bundle Branch Block

When conduction through the left bundle is blocked experimentally, ventricular activation begins on the right side of the interventricular septum and invades this structure from right to left before activating the free wall of the left ventricle. On the other hand, there is evidence that in some clinical cases of left bundle branch block, the conduction delay may be more peripheral in these instances, the left side of the septum may be activated without delay so that activation of the remainder of the left ventricular myocardium may be slowed by "aborization block." However, either of these two abnormal sequences of activation could cause contraction of the right ventricle and interventricular septum before the left ventricular free wall. Again, experiments in the dog suggest that the septum in man would be partially activated by 30 msec and completely activated by 80 msec—before any significant activation of the left ventricular free wall had occurred. Hence, in contrast to the normally activated left ventricle, early septal contraction would be unopposed by...
forces generated by a contracting free wall and therefore would be expected to produce an inward (posterior) movement. Furthermore, the tendency of the interventricular septum to move "paradoxically" in an anterior direction toward the ultrasound transducer during early ejection could also be
ABNORMAL SEPTAL MOTION IN LBBB

explained by the delay in left ventricular wall activation allowing the right ventricle to draw the left ventricle anteriorly toward the chest wall. In the patient with severe aortic regurgitation who did not show abnormal septal motion, the hypertrophied left ventricle might have been contracting strongly enough to counteract this effect. However, it is not clear why abnormal early septal contraction was not seen in this subject.

There has been only one previous study of the motion of the left ventricular walls in left bundle branch block. Haft et al.\textsuperscript{10} found an abnormal contraction pattern only in patients with coronary arterial disease or cardiomyopathy and left ventricular failure, and attributed the abnormal motion to regional myocardial damage. In their remaining patients, asynchronous movements attributable solely to “late regional depolarization” were not observed. However, these findings are not in conflict with the present study since all of their left ventricular angiograms were recorded only in the right anterior oblique projection, in which motion of the interventricular septum cannot be seen. Furthermore, the abnormal septal motion demonstrated by echocardiography in the present study was found so consistently, both in an otherwise normal left ventricle and in a variety of disease states, that it could not reasonably be attributed to fortuitous local myocardial damage in all of them.

Interpretation of Echocardiograms

The demonstration of asynchronous left ventricular contraction in left bundle branch block has some practical implications for the interpretation of echocardiograms. A shallow paradoxical septal movement may occasionally be recorded in a normal subject particularly if the ultrasound beam passes too close to the mitral valve ring and records a complete or near complete echo from the anterior leaflet of the mitral valve. A more definite paradoxical motion of the septum has been described as a sign of right ventricular volume overload,\textsuperscript{11} since this is most commonly due to atrial septal defect which is rarely associated with left bundle branch block, confusion in interpretation is unlikely to occur. Anterosephal myocardial infarction may also cause paradoxical septal motion\textsuperscript{12} which obviously could not be attributed to ischemic damage in the presence of left bundle branch block. Following cardiac surgery, particularly if a sternal splitting incision has been used for aortic valve replacement, the interventricular septum frequently moves paradoxically.\textsuperscript{9} This might be due to retrosternal adhesions anchoring the right ventricle to the chest wall during systolic contraction and could have contributed to the paradoxical movement in the patients after aortic valve replacement. Finally, asymmetry of left ventricular contraction has been assumed in the choice of a model for estimation of left ventricular volume and stroke volume\textsuperscript{13, 14} and also for the assessment of myocardial function.\textsuperscript{15, 16} Such measurements may not be valid in the presence of left bundle branch block.

Acknowledgments

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References

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Figure 6

a) Contour of motion of the left side of the interventricular septum and endocardial surface of the posterior left ventricular wall measured from the LAO cineangiogram. The zero of the scale is the fixed reference point (R). The vertical lines indicate the initial deflection of the electrocardiogram (I) and the aortic component of the second sound (A2). On the right is the corresponding left ventricular echocardiogram. Echoes arising from mitral valve structures, probably chordae tendineae (MVC), are distinguished from those arising from the endocardial surface of the posterior left ventricular wall (PLV). Note the similarity of the contour of septal motion detected by cineangiography and echocardiography. b) Motion of the left ventricular walls demonstrated by cineangiography and echocardiography as in a) for a patient with pure mitral stenosis and no left bundle branch block. LS = left side of septum. See fig. 1 for other abbreviations.

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