Studies Utilizing the Portable Electromagnetic Ballistocardiograph

III. The Ballistocardiogram in Bundle Branch Block

By Harry Mandelbaum, M.D., and Robert A. Mandelbaum, M.D.

Ballistocardiographic studies were done on 28 subjects with left bundle branch block and on 18 subjects with right bundle branch block. The influence of ventricular asynchronism, and the predominance of left or right ventricular disease, upon the derivation and interpretation of the ballistocardiogram, is discussed. The ballistocardiogram was found to be a valuable objective guide in the detection of subjects whose bundle branch block was not associated with significant heart disease. The ballistocardiogram also provided helpful confirmatory evidence of coronary artery or hypertensive heart disease when this was the suspected or certain diagnosis in subjects with bundle branch block.

The finding of bundle branch block in the electrocardiogram presents a clearly defined abnormality whose significance must be carefully evaluated by the clinician. When bundle branch block is discovered in a patient who has definite evidence of heart disease, many clinical studies have shown that the outlook for life expectancy is poor. In sharp contrast, are statistics which were obtained from medical observation of subjects who were not suspected of having heart disease, and in whom bundle branch block was an unexpected finding. In a 20 year observation period of life insurance applicants, Rosdtein and co-workers found that there was an excellent outlook as to life span in subjects with bundle branch block who showed no clinical evidence of heart disease; these constituted 50 per cent of the entire group, and the average age of discovery of bundle branch block was 48 years.

It may be assumed, therefore, that bundle branch block may be indicative of only a small scar in the conduction system of a person with a good life span expectancy, rather than always be regarded as a sign of advanced heart disease. The meaning of bundle branch block in each particular case is related only to the extent of the underlying myocardial disease. After demonstrating the existence of bundle branch block, the electrocardiogram can offer little assistance in determining the significance of the finding. A complete history together with the physical examination of the patient is, of course, the basic method for detecting heart disease. A reliable objective guide in determining the extent of disease, if present, in a case of bundle branch block, is the heart size as shown by roentgen examination. Studies of hospitalized patients, based upon duration of life and postmortem findings, have shown that cardiac enlargement in the presence of bundle branch block is a reliable criterion of extensive myocardial disease, and indicates a poor prognosis.

Since the ballistocardiogram has been shown to be valuable in estimating the extent of functional myocardial impairment in coronary artery and hypertensive heart disease, it is reasonable to expect that the ballistocardiogram will provide another objective means of evaluating the cardiac status of persons with bundle branch block.

Before application of the ballistocardiograph to the study of bundle branch block, the problem of ventricular asynchronism in bundle branch block and its possible relationship to the derivation of the ballistocardiogram must be clarified. Through the use of roentgenkymographic studies of the pulmonary arterial and aortic pulsations, and optical records of cardiac apex thrust, Wolffert and Braun-Menendez...
have adequately demonstrated asynchronism in the time of ventricular ejection in bundle branch block. With the electrokymogram, Ellinger\textsuperscript{13} has confirmed these findings and has calculated the maximum time of ventricular asynchronism to be .05 second in right bundle branch block and .07 second in left bundle branch block. Studies on humans,\textsuperscript{18} as well as on dogs,\textsuperscript{19} have demonstrated that some degree of ventricular asynchronism is the rule in the majority of normal hearts. In 33 of the normal young adults studied by Ellinger,\textsuperscript{18} the left ventricular ejection led by .01 to .03 second; in 21, the right ventricular ejection came first by .01 to .03 second; and in 14, synchronous ventricular ejection was present. Since normal ballistocardiograms were found in all of a group of young normal subjects,\textsuperscript{13} this degree of ventricular asynchronism up to .03 second does not apparently affect the ballistocardiogram.

What of the effect of the extremes of ventricular asynchronism which have been found to be up to .07 second? This degree of asynchronism, while not the rule in bundle branch block,\textsuperscript{17, 18} probably does not cause an appreciable effect on the ballistocardiographic pattern. Theoretically, extremes of ventricular asynchronism may cause the appearance of notched J waves.\textsuperscript{20} In our study of 46 cases of bundle branch block, the normal ballistocardiograms which were recorded revealed nothing unusual in their configuration although many were obtained from subjects who had extremes of QRS widening. This agrees with Starr's reports.\textsuperscript{20}

Beside the asynchronism of ejection time, functional ventricular asynchronism due to predominant left or right ventricular disease has been shown to be present in most cases of bundle branch block associated with myocardial disease.\textsuperscript{5} Yater\textsuperscript{21} has demonstrated that while both bundles are usually involved by disease, cases of bundle branch block associated with coronary artery or hypertensive heart disease reveal pathologically that the left ventricle is predominantly scarred and hypertrophied. In a similar fashion, the right ventricle is predominantly diseased when mitral valve or pulmonary disease is present.\textsuperscript{5, 21} The asymmetric weakening of the force of ejection, especially when the left ventricle is predominantly diseased, will result in markedly abnormal ballistocardiograms. Starr\textsuperscript{22} has shown that the HIJK complex actually records cardiac ejection velocity rather than cardiac output, and results from a summation of the forces produced by the right and left ventricle. In his cadaver experiments, Starr has demonstrated that the normal HIJK complex of the ballistocardiogram occurs when the maximum velocity of blood ejection is attained early in systole. The double-peaked systolic complexes which have been attributed to asynchronism of ejection time\textsuperscript{20, 22} probably result from the lag in ejection force from the diseased ventricle.

**Ballistocardiographic Studies in Subjects with Bundle Branch Block**

The use of the ballistocardiograph proved valuable in confirming the clinical impression of the presence or absence of heart disease in our 46 cases of bundle branch block, who were observed for periods of 12 to 24 months. All of our subjects were ambulatory and comparatively well at the time of the initial ballistocardiographic evaluation. The electrocardiographic diagnosis of bundle branch block was dependent entirely upon the present accepted criteria\textsuperscript{9} as applied to the precordial leads. No cases of Wolff-Parkinson-White pattern were included. The direct portable electromagnetic ballistocardiograph\textsuperscript{22} was used in all instances. As a rule, the abnormalities of the ballistocardiogram in patients with bundle branch block associated with hypertensive or coronary artery heart disease were found to be similar to those previously described in these conditions.\textsuperscript{11, 12} Abnormalities were classified utilizing the nomenclature of Brown.\textsuperscript{11} Low II waves were often found in normal tracings.\textsuperscript{24}

**Left Bundle Branch Block.** There were 28 cases of left bundle branch block: 16 were males; 12 were females. All but nine were over 50 years of age. Of eight subjects who had survived a previous myocardial infarction, satisfactory ballistocardiographic recovery to normal or grade I was recorded in two. Coronary artery disease without an episode of proven myocardial infarction was the clinical diagnosis in five subjects. All five demonstratedballistocardiographic abnormality suggestive of ex-
tensive myocardial disease. In 10 subjects with hypertension but without angina pectoris, four

record found. In the 23 subjects with coronary artery and hypertensive heart disease, x-ray

TABLE 1.—Ballistocardiographic Evaluation of 28 Subjects with Left Bundle Branch Block and 18 Subjects with Right Bundle Branch Block

<table>
<thead>
<tr>
<th>Ballistocardiogram</th>
<th>Electrocardiogram</th>
<th>No. of Patients</th>
<th>Per Cent</th>
<th>Sex</th>
<th>Age</th>
<th>Cardiac Diagnosis</th>
<th>Heart Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal at rest and</td>
<td>Left BBB—3</td>
<td>10</td>
<td>22</td>
<td>M—6</td>
<td>31–40–1</td>
<td>Normotension with no evidence of heart disease—6</td>
<td>Normal—10</td>
</tr>
<tr>
<td>after exercise</td>
<td>Right BBB—7</td>
<td></td>
<td></td>
<td>F—4</td>
<td>41–50–3</td>
<td>Hypertension with no evidence of heart disease—2</td>
<td>Enlarged—0</td>
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<td></td>
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<td></td>
<td></td>
<td>51–60–5</td>
<td>Healed myocardial infarct—2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61–70–1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal abnormal-</td>
<td>Left BBB—7</td>
<td>10</td>
<td>22</td>
<td>M—3</td>
<td>41–50–3</td>
<td>Normotension with no evidence of heart disease—2</td>
<td>Normal—8</td>
</tr>
<tr>
<td>ities at rest or</td>
<td>Right BBB—3</td>
<td></td>
<td></td>
<td>F—7</td>
<td>51–60–4</td>
<td>Hypertension with no evidence of heart disease—4</td>
<td>Enlarged—2</td>
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<tr>
<td>after exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61–70–3</td>
<td>Coronary artery disease with no definite infarction—1</td>
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<tr>
<td>(Grade I)</td>
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<td>Healed myocardial infarct—1</td>
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<td></td>
<td>Rheumatic valvular disease—1</td>
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<td></td>
<td></td>
<td></td>
<td>Lutembacher, digitalized—1</td>
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<tr>
<td>Moderate abnormal-</td>
<td>Left BBB—7</td>
<td>7</td>
<td>15</td>
<td>M—6</td>
<td>31–40–1</td>
<td>Hypertension with no evidence of heart disease—1</td>
<td>Normal—7</td>
</tr>
<tr>
<td>ities at rest or</td>
<td>Right BBB—0</td>
<td></td>
<td></td>
<td>F—1</td>
<td>41–50–2</td>
<td>Myocarditis healed—1</td>
<td>Enlarged—0</td>
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<tr>
<td>after exercise</td>
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<td></td>
<td></td>
<td></td>
<td>51–60–1</td>
<td>Coronary artery disease with no definite infarction—3</td>
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<tr>
<td>(Grade II)</td>
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<td></td>
<td></td>
<td>61–70–3</td>
<td>Healed myocardial infarct—2</td>
<td></td>
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<tr>
<td>Marked abnormal-</td>
<td>Left BBB—11</td>
<td>19</td>
<td>41</td>
<td>M—13</td>
<td>41–50–4</td>
<td>Hypertension with no evidence of heart disease—1</td>
<td>Normal—8</td>
</tr>
<tr>
<td>ities at rest or</td>
<td>Right BBB—8</td>
<td></td>
<td></td>
<td>F—6</td>
<td>51–60–7</td>
<td>Hypertensive heart disease—5</td>
<td>Enlarged—11</td>
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<tr>
<td>after exercise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61–70–6</td>
<td>Coronary artery disease with no definite infarction—7</td>
<td></td>
</tr>
<tr>
<td>(Grade III or IV)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>71–80–2</td>
<td>Healed myocardial infarct—8</td>
<td></td>
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</tbody>
</table>

had ballistocardiograms approaching normal. In no case in which heart disease was detected clinically was a normal ballistocardiographic evidence of ventricular enlargement was found in 7 of the 17 cases in which the ballistocardiogram detected serious myocardial damage.
Of the five other cases of left bundle branch block, two were studied because of pain in the left chest, which was not typical of angina pectoris. All studies of cardiac function in these two patients were normal, and the basal and exercise ballistocardiograms were normal. The final diagnosis in one was radiculitis, and, in the other, gall bladder dyspepsia. One subject was studied as part of a routine preoperative checkup. Another, an elderly man, requested a complete investigation because of weakness and weight loss. The fifth case gave a childhood history of a protracted illness following scarlet fever complicated by myocarditis; no valvular disease was detected.

In only 3 of the 28 subjects were the resting and postexercise ballistocardiograms normal. Two of these subjects had no clinical evidence of heart disease; the other had recovered from a myocardial infarction. In seven subjects, the ballistocardiograms were normal or grade I at rest, and not worse than grade I after exercise. Ten subjects, therefore, or 35.7 per cent of the entire group with left bundle branch block, showed ballistocardiograms which were normal or only slightly abnormal. Of these, 8 were 50 years of age or over. These good ballistocardiographic records correlated well, in each case, with the clinical impression that the patient had good myocardial function in spite of findings of left bundle branch block in the electrocardiogram.

Right Bundle Branch Block. Eighteen cases of right bundle branch block were observed from 12 to 24 months. There were 12 males and six females. Fifteen of the subjects were 50 years of age or older. Eight subjects had markedly abnormal ballistocardiograms. Two of these eight had survived a myocardial infarct after his initial study. X-ray studies revealed ventricular enlargement in four of these eight cases. One subject, age 35, who had suffered myocardial infarction two years previous to the present study, demonstrated a normal ballistocardiogram, indicating excellent myocardial function. Six other subjects, none of whom showed any evidence of heart disease, although hypertension was noted in two, had normal ballistocardiograms at rest and after exercise. Three subjects had ballistocardiograms which demonstrated only minimal abnormality; one of these three had essential hypertension; the other two were digitalized patients with compensated valvular heart disease. Ten subjects, or 56 per cent of the entire group with right bundle branch block, had ballistocardiograms which suggested good myocardial function. Six of the 10 were over 55. The good ballistocardiographic records confirmed our impression that no serious heart disease was present in each of these cases, with the exception of the two subjects with compensated valvular heart disease.

In comparing the findings from the right and left bundle branch block groups, the striking observation was that the incidence of coronary artery and hypertensive heart disease was about as frequent in both. All of the serious ballistocardiographic abnormalities were noted in association with these degenerative diseases. Though it is undoubtedly true that the left ventricle bore the brunt of the disease in these cases of right bundle branch block with degenerative heart disease, the right bundle, as has been previously noted, apparently had sufficient involvement to dominate the electrocardiographic pattern. Two cases of valvular disease were found in the right bundle branch block group. In both cases, repeated attacks of congestive heart failure necessitated the establishment of compensation by digitalis, mercurials and sodium restriction. Reestablishment of compensation accounted for the minimal ballistocardiographic abnormalities. Some degree of essential hypertension was noted as the only abnormal finding in the majority of patients in both groups whose ballistocardiograms showed grade I abnormality.

The period of observation of the cases herein reported averaged more than 15 months. Excepting the two patients with valvular disease, all of the subjects whose ballistocardiograms were normal or slightly abnormal have done well. Four, whose activities had been previously restricted because of the electrocardiographic
findings of bundle branch block, have returned to their usual occupations.

**Conclusion**

The ballistocardiographic evaluation of 28 subjects with left bundle branch block, and 18 with right bundle branch block, has demonstrated the value of ballistocardiography in the clinical appraisal of the patient who is found to have bundle branch block. A markedly abnormal ballistocardiogram served as further proof of advanced myocardial impairment when the diagnosis of coronary artery or hypertensive heart disease was considered likely. In the absence of confirmatory evidence of heart disease, the abnormal ballistocardiogram served as a valuable guide in cases in which coronary artery disease was suspected.

In 58 per cent of the cases with markedly abnormal ballistocardiograms, teleoroentgenograms failed to show enlargement of the heart.

The finding of a normal ballistocardiogram in the presence of bundle branch block in subjects over 50 years of age provided the only objective means at the disposal of the clinician to assure himself as well as the patient of a well functioning heart despite the abnormal electrocardiogram.

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**ILLUSTRATIVE CASES**

**Left Bundle Branch Block**

*Case 1, Figure 1.* M. H., female, age 60; normotensive. The patient was subject to recurrent attacks of dyspepsia due to gall bladder dyskinesia. In May, 1950, her husband died of cancer of the lung. Shortly thereafter, she developed chest pain. She consulted a physician who discovered left bundle branch block. She was ordered to bed and digitalis and sedatives were prescribed. Finding no relief, she discontinued all medication after two weeks.

She was examined August 6, 1950; she weighed 127 pounds; the B.M.R. was plus 11 per cent; the blood pressure was 130/80. Examination of the heart and lungs revealed nothing abnormal. X-ray of the chest showed a normal cardiac silhouette. Spondylitis and scoliosis of the cervidorsal spine were found.

Ballistocardiogram: (a) basal; normal for age 60; (b) exercise test*; normal response, with increased amplitude of complexes.† H waves are low.

Electrocardiogram: (Lead I; Lead III; V1; V6) characteristic of left bundle branch block.

With reassurance that no serious heart disease was present, this patient has done well with no

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* Exercise test: Unless otherwise stated, the patient performed ten trips on the two-step platform.
† The upper channel in each figure represents the ballistocardiogram; the lower channel, the concomitant tracing taken from the left radial pulse. The J wave is recorded at the apex of the radial pulse.
limitation of activity. Chest pain disappeared after orthopedic care of the spondylitis and scoliosis.

Case 2, Figure 2, B. S., female, age 50. This patient had hyperthyroidism in 1946 and was treated successfully with x-ray therapy. There has been no recurrence since. She has suffered repeated attacks of dyspepsia in the last few years. X-rays examinations of the stomach, intestines and gall bladder were reported as negative. In July, 1950, after eating a very heavy meal, she noted the occurrence of sharp pain over the left breast area which lasted ten minutes. Relief was obtained by belching. There has been no recurrence since. She visited her doctor the next day and in the course of a complete examination, the electrocardiogram showed left bundle branch block. It was felt advisable to put her to bed. However, after two weeks, she insisted that she was not ill and requested consultation by a cardiologist. He felt that it was wisest to have her spend another two weeks in bed.

Mrs. B. S. was examined in October, 1950. There were no subjective complaints. Her weight was 125 pounds; the blood pressure was 125/75 and the B.M.R. was plus 6 per cent. Examination of the heart, lungs and abdomen was negative. Teleorontgenogram showed the heart to be of normal size and form. Electrocardiogram: (V₁) showed left bundle branch block.

Ballistocardiogram: (a) basal; normal complexes; (b) exercise test; grade I respiratory variation. Short HIJ may be noted in the second complex. H waves are low in amplitude in (a) and (b).

These ballistocardiograms of a normal record at rest with grade I abnormality after moderate exercise we have learned to correlate with minimal functional myocardial impairment, carrying a good prognosis. We assured this patient that in her instance the finding of bundle branch block did not indicate serious heart disease. With no restriction of activity, she has done well since.

Case 3, Figure 3, J. S., female, age 42. Hypertension and albuminuria complicated her second pregnancy in 1938. She was well until 1946 when recurrent headaches led her to seek medical advice at the Hypertension and Nephritis Clinic of The Jewish Hospital of Brooklyn. In 1946, her blood pressure ranged from 180/100 to 200/110. The heart was of normal size and the electrocardiogram showed left ventricular hypertrophy. In 1949, the eye grounds were grade II. The heart was of normal size. The electrocardiogram was typical of left ventricular "strain pattern." In 1951, her blood pressure ranged between 160/90 and 190/100. She had no complaints. The cardiac silhouette showed the characteristic form of left ventricular hypertrophy; the total diameter was not increased.

Ballistocardiogram: (a) basal; short HIJ, deep K pattern; (b) exercise test; good myocardial response as shown by increased amplitude of complexes and less shortening of the HIJ. H waves are low.

Electrocardiogram: (Lead I; Lead III; V₁; V₆) characteristic of left bundle branch block.

The resting ballistocardiogram, in this instance, demonstrates the diminished HIJ with deep K pattern, which we see in almost every case of hypertension in which there is left heart involvement. The good response to exercise indicates adequate myocardial function and correlates well with the fact that this patient had no cardiac complaints, and that the x-ray showed no evidence of an enlarged heart. The ballistocardiographic findings here more clearly reflected her clinical state than did the successive progressive changes in the electrocardiograms.

![Figure 3](http://circ.ahajournals.org/)

*Fig. 3.* Ballistocardiograms and electrocardiograms of case 3. See text.

Right Bundle Branch Block

Case 4, J. G., male, age 42. Because of the death of an associate, this patient requested a complete checkup. He had no complaints. His weight was 178 pounds. The blood pressure was 140/80 and the basal metabolic rate was minus 9 per cent. Examination of the heart and lungs showed nothing abnormal. Teleorontgenogram was negative. The electrocardiogram showed the characteristic findings of right bundle branch block. The ballistocardiogram was normal at rest and after exercise.

Because the physical examination revealed nothing abnormal and because the ballistocardiograms, at rest and after exercise, were normal, the patient was not told of the electrocardiographic abnormality.

Case 5, Figure 4, M. I., male, aged 60. Asymptomatic hypertension has been present for at least 10 years. His blood pressure ranged between 160/100 and 220/115. Since May, 1951, he developed angina on effort. Paroxysmal nocturnal dyspnea has occurred several times in the last 12 months.

October 6, 1951, his weight was 170 pounds; blood
pressure was 205/115; and the basal metabolic rate was minus 9 per cent. Examination of the heart revealed a grade II systolic murmur at the apex and a split second sound. $A_2$ was greater than $P_2$. X-ray examination showed the heart to be enlarged in its transverse diameter, and the aorta to be tortuous and prominent.

Ballistocardiogram: (a) basal; fused HIJ waves are common; note prominence of L waves; (b) exercise test (eight trips); the amplitude is not increased; fused HIJ waves and tall L waves dominate the tracing. After eight weeks of digitalis therapy, (c) basal; resembles "u"; (d) exercise test (eight trips) marked improvement noted in amplitude of HIJ complexes.

Electrocardiogram: (Lead I; Lead III; $V_1$; $V_6$) demonstrated right bundle branch block.

The grade II basal and grade III exercise ballistocardiograms confirmed the clinical impression that serious heart disease was present. No further episodes of dyspnea occurred after institution of digitalis therapy and salt restriction.

Case 6, Figure 5. L. W., male, aged 51. Hypertension has been present for several years. He has noticed angina pectoris on effort and after heavy meals during the last two years.

November 16, 1950, he weighed 171 pounds; the blood pressure was 210/130; basal metabolic rate was plus 14 per cent. A grade II aortic systolic murmur was noted; roentgenogram showed the heart to be enlarged to the left with a prominent aortic arch.

Ballistocardiogram: (a) basal; the low amplitude and lack of definitiveness permits classification of grade IV; (b) exercise test (seven trips); grade III.

Fig. 4. Ballistocardiograms and electrocardiograms of case 5. See text.

Fig. 5. Ballistocardiograms and electrocardiograms of case 6. See text.

The markedly abnormal ballistocardiograms indicate that the bundle branch block in this 51 year old male is associated with advanced myocardial disease.

Electrocardiogram: (Lead I; Lead III; $V_1$; $V_6$) showed the characteristics of right bundle branch block.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Dr. William Dock for his invaluable assistance in the preparation of this paper.

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Circulation. 1952;6:578-585
doi: 10.1161/01.CIR.6.4.578

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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