EPIDEMIOLOGY

Right Bundle Branch Block: Long-Term Prognosis in Apparently Healthy Men

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The long-term cardiac prognosis of 24 clinically healthy men with complete right bundle branch block, identified from the 1,142 men constituting the population of the Baltimore Longitudinal Study on Aging, was assessed over a follow-up period averaging 8.4 years. When compared with a control group matched for age at which right bundle branch block appeared (mean ± standard deviation 64.0 ± 13.5 years), men with right bundle branch block showed no difference in the prevalence of antecedent coronary risk factors or obstructive lung disease. The incidence of angina pectoris, myocardial infarction, valvular heart disease, cardiomegaly, congestive heart failure, advanced heart block or cardiac death in these men did not differ from that of the control group over the observation period. Furthermore, at the latest follow-up study, maximal aerobic exercise tolerance and chronotropic response to maximal exercise were not impaired in men with right bundle branch block relative to control men (9.1 ± 2.2 versus 7.3 ± 3.0 minutes and 150.3 ± 23.5 versus 147.7 ± 20.7 beats/minute, respectively). However, axis deviation leftward of −30° was present in 46% of men with right bundle branch block but in only 15% of control subjects at latest follow-up (probability [p] < 0.01). Although the PR interval lengthened by 40 ms or more developed in only 6% of control subjects over the observation period, such prolongation occurred in 29% of men with right bundle branch block (p < 0.05). These results support the concept that right bundle branch block in these asymptomatic men is a manifestation of a primary abnormality of the cardiac conduction system but has no demonstrable adverse effect on long-term cardiac morbidity or mortality.

Since its electrocardiographic description more than 70 years ago (1), right bundle branch block has been the subject of numerous epidemiologic investigations. In many of these early studies (2–5), the subjects were derived from hospital-based populations with heart disease; consequently, the long-term cardiovascular morbidity and mortality rates of these patients with right bundle branch block were very high. It was eventually recognized, however, that right bundle branch block by no means constituted a homogeneous clinical disorder and that its prognosis depended on the nature and extent of underlying heart disease (6–8).

Given the increased use of the electrocardiogram as a screening tool in the general population, a question of practical concern is whether the presence of right bundle branch block in apparently healthy subjects increases their likelihood for subsequent cardiac events. Conflicting answers to this question are provided by epidemiologic studies in military (9,10) and community-based (11–13) groups. Investigations in military populations with right bundle branch block generally yielded low rates of coronary disease (9,10), probably reflecting the young age and highly selected nature of their subjects. In community-based studies, right bundle branch block was generally associated with a greater frequency of organic heart disease than in the military studies. Among the community studies, only the Framingham investigators (13) employed an age-matched control population; they found a 2.5-fold increase in coronary disease and nearly 4-fold increase in congestive heart failure in 53 men and women with right bundle branch block and no initial evidence of coronary disease over a 6-year follow-up period.

This study describes the long-term cardiac prognosis of apparently healthy men with right bundle branch block, either preexisting or newly developed, identified from the Baltimore Longitudinal Study on Aging, a community-

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dwelling population of 1,142 men (14). In addition to comparing the incidence of subsequent cardiac events with that in an age-matched control population, we have addressed several questions to further define the natural history and pathophysiology of this conduction disorder in subjects without other evidence of cardiac disease. Is the incidence of latent coronary artery disease greater in these subjects than in control men? Do these subjects demonstrate abnormal sinus node or atrioventricular node function, or disease in another fascicle suggesting a diffuse conduction system degeneration? Is their maximal aerobic capacity or chronotropic response to exercise lower than that of their age-matched normal cohorts?

Methods

Study patients. Since 1958, the Baltimore Longitudinal Study on Aging has enrolled some 1,142 men, who have been followed up biennially (annually if 70 years or older) with extensive noninvasive testing that includes a complete history and physical examination, chest X-ray films, 12 lead rest electrocardiogram, exercise stress testing and pulmonary function tests (14). During this 23 year period, 39 men with right bundle branch block on the rest electrocardiogram were identified. Of this group, 24 men, on initial presentation with right bundle branch block, had no evidence of associated cardiac disease, as defined by angina, myocardial infarction by history or electrocardiogram, cardiomegaly, valvular heart disease or congestive heart failure, and returned for at least one subsequent visit. These 24 men constitute the subject of this report.

Definitions. *Right bundle branch block* was defined by the Minnesota Code criteria (7:2) of a limb lead QRS duration of 0.12 second or more with an R′ greater than R or an R peak duration of 0.06 second or more in either lead V_1 or V_2 (15). In men who developed right bundle branch block while under observation, the first visit was defined as the visit in which right bundle branch block was initially manifested. At each visit the presence of the following was ascertained:

Hypertension: blood pressure of 160/95 mm Hg or greater or an interim history of such an elevated pressure currently under treatment.

Hypercholesterolemia: a serum cholesterol level of more than 275 mg/100 ml.

Smoking history: a smoker was defined as a person who smoked 10 or more cigarettes per day for at least 5 years and was smoking at the onset of the study.

Diabetes: symptomatic fasting hyperglycemia requiring insulin or an oral hypoglycemic agent. Men with asymptomatic elevation of blood glucose outside standard deviations of the mean age-adjusted standards were not included in this definition.

Angina pectoris: ischemic chest pain fulfilling standard clinical criteria as evaluated by a staff cardiologist.

Myocardial infarction: a convincing history of infarction, usually verified by hospital records, or the presence of diagnostic Q waves (Minnesota Code 1:1 or 2:1),or both (15).

Valvular heart disease: valvular stenosis or insufficiency as evaluated by a staff cardiologist.

Cardiomegaly: a cardiothoracic ratio greater than 0.50 on a standard posteroanterior chest X-ray film.

Congestive heart failure: a convincing history of dyspnea, orthopnea or systemic venous congestion resolving with diuretic agents or digitalis therapy, or both, or the presence of similar clinical findings associated with radiographic evidence of pulmonary venous engorgement.

Chronic obstructive pulmonary disease: symptoms of chronic bronchitis or emphysema or physical, spirometric or radiographic signs of airway obstruction.

Sinus bradycardia: a heart rate of less than 60 beats/min.

First degree heart block: a PR interval of 0.22 second or more (Minnesota Code 6:3) (15).

Left axis deviation. an axis of the initial 0.08 second of the QRS complex of $-30°$ or less (Minnesota Code 2:1) (15).

Atrial fibrillation: irregular atrial activity faster than 350/min with an irregular ventricular response.

Positive exercise thallium scintigraphy (performed in a subset of study subjects and control subjects): a perfusion defect appearing during maximal treadmill exercise and improving with redistribution.

Positive electrocardiographic stress test: 1.0 mm or greater J point depression with flat or downsloping ST segment for 0.08 second after the J point (Minnesota Code 11:1) (15) on double Master two-step or treadmill exercise testing, present in inferior or anterolateral leads. The validity of the exercise electrocardiogram in right bundle branch block has been previously verified for these leads (16,17).

Cardiovascular death: any death in which the underlying cause as determined by autopsy or from the death certificate was disease of the heart or blood vessels.

In order to identify more subtle longitudinal cardiovascular differences between men with right bundle branch block and control subjects than the end points just listed, we also examined the following variables in both groups:

Blood pressure. determined from the mean of four readings for systolic and diastolic blood pressures taken on each visit and averaged over the entire number of visits for each man. The slopes of systolic and diastolic blood pressure changes over time were also calculated.

Heart size: determined by the cardiothoracic ratio on the most recent chest X-ray film.

Aerobic capacity: determined on the most recent visit by maximal treadmill exercise duration in minutes, utilizing a modified Balke protocol.

Maximal exercise heart rate: determined by the maximal heart rate attained during treadmill exercise on the most recent visit.

Rest heart rate, PR interval and QRS axis: determined on the initial and most recent visits from the standard electrocardiogram. Annualized rates of change were then calculated for each of these electrocardiographic variables.

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Control group. To determine whether these abnormalities occurred more frequently in asymptomatic subjects with right bundle branch block than in normal subjects, we derived a control group by age-matching each subject with right bundle branch block (using the age at initial presentation with right bundle branch block) with the two normal men whose history numbers were closest to that of the index case. Normality was defined by the absence of cardiac disease, as outlined for right bundle branch block subjects, and by the absence of any intraventricular conduction delay on electrocardiogram. All control subjects were successfully matched to within 2 years of their respective right bundle branch block index cases.

Statistical methods. The group means for continuous variables were compared for right bundle branch block and control subjects using the unpaired or paired *t* test as appropriate; discrete variables were compared by Fisher's exact test. The slope of longitudinal blood pressure change in a given subject was calculated by least squares linear regression analysis. A probability (p) value of ≤ 0.05 was considered significant for all analyses. Data are presented as mean values ± standard deviation.

Results

Age at onset of right bundle branch block. Thirty-nine men (3.4%) of 1,142 were found to have complete right bundle branch block. Eleven of the 39 had preexisting cardiac disease and another 4 were lost to follow-up after their initial visit, leaying 24 men with complete right bundle branch block without evidence of heart disease for whom follow-up information was available. Seven of these men developed right bundle branch block during the course of the Baltimore Longitudinal Study on Aging and the remaining 17 presented with this conduction disturbance. Their mean age on presentation with, or development of, right bundle branch block was 64.0 ± 13.5 years (range 33.6 to 90.5) (Table 1). The mean age of the seven men who developed right bundle branch block while under observation was 61.1 ± 8.0 years and did not differ from that of men with preexisting right bundle branch block. The mean age of the 48 control men at the onset of study was 64.2 ± 12.8 years (range 32.8 to 88.6). Follow-up duration averaged 8.4 ± 6.4 years (range 1.0 to 20.4).

Risk factors and pulmonary disease. The prevalence of antecedent coronary risk factors and obstructive pulmonary disease did not differ significantly between the two groups. Smoking was the most common risk factor in both right bundle branch block and control groups, occurring in 42 and 38% of subjects, respectively. The frequency of hypertension was 21 and 19% in the respective groups. Clinical chronic obstructive pulmonary disease was seen in 13% of men with right bundle branch block and 17% of control subjects; the mean forced expiratory volume (FEV_1) in 1 second of 76.2 ± 6.8% in subjects with right bundle branch block was also similar to the control value of 73.3 ± 9.2%. Hypercholesterolemia and diabetes were present, respectively, in 4 and 4% of men with right bundle branch block and in 12 and 4% of control subjects.

New cardiac events or abnormalities. The incidence of new cardiac events or abnormalities (angina, myocardial infarction, valvular heart disease, cardiomegaly, congestive heart failure, complete heart block or cardiac death) over the 8 year observation period was not significantly different between the right bundle branch block and control groups. Only 5 men (21%) with right bundle branch block and 10 control subjects (21%) experienced any event or abnormality. Clinical coronary disease, manifested by angina pectoris or myocardial infarction, developed in 17% of men with right bundle branch block and 13% of control subjects. Valvular heart disease, cardiomegaly and congestive heart failure occurred, respectively, in 8, 8 and 4% of men with right bundle branch block and 4, 6 and 0% of control subjects. Within the right bundle branch block group, cardiac morbidity-mortality was not related to QRS axis, QRS duration or PR interval on initial presentation with right bundle branch block group were from cardiac disease: one from an acute myocardial infarction in a 73 year old man who had developed angina during the observation period, the other from congestive heart failure complicating a sigmoid volvulus in a 78 year old man without prior heart disease. Of the 14 deaths in the control group, 4 resulted from cardiac causes, all acute myocardial infarctions, 2 of which occurred in men who did not manifest clinical heart disease while alive.

Latent coronary heart disease. The presence of latent coronary heart disease (as defined by an ischemic ST segment response to either a double Master two-step or graded treadmill exercise test) was sought in 15 (62%) patients with right bundle branch block and 43 (90%) control subjects during the observation period. (The smaller percent of subjects with right bundle branch block performing exercise reflects the belief during the early years of the study that right bundle branch block precluded accurate interpretation of the exercise electrocardiogram with the consequence that stress testing was not routinely performed.) Three subjects with right bundle branch block (20% of those exercised) and 12 control subjects (28%) were positive for ischemia by Minnesota Code 11:1. Eight men with right bundle branch block, chosen consecutively from those still active in the study, underwent thallium scanning in conjunction with maximal treadmill exercise. One man with right bundle branch block who developed coronary heart disease during follow-up and three control subjects, all of whom were asymptomatic, demonstrated perfusion defects with exercise suggestive of coronary artery disease.

Electrocardiographic abnormalities. Electrocardiographic conduction abnormalities in right bundle branch block and control subjects on both initial and most recent visits are compared in Table 1. The most striking finding

Table 1. Electrocardiographic Findings on Initial and Most Recent Visits

	Men With Right Bundle Branch Block (n = 24)			Control Group (n = 48)		
	Initial	Recent	Δ	Initial	Recent	Δ
Sinus bradycardia (%)	25	25		10	16	
Rest heart rate (beats/min)	68.0 ± 10.7	65.3* ± 8.6	−2.7 ± 9.0	71.3 ± 8.8	71.1 ± 12.2	−0.1 ± 10.5
First degree AV block (%)	4	13		4	6	
PR interval (ms)	164.2 ± 25.7	190.4 ± 59.8	+26.3† ± 42.8	164.9 ± 10.0	174.6 ± 19.6	9.6‡ ± 14.0
Left axis deviation (%)	21	46§		8	15	
QRS axis (°)	2.8 ± 41.8	−9.8 ± 52.5	−12.6¶ ± 23.5	19.1 ± 31.5	11.8 ± 35.5	−7.3† ± 17.2

The percentages represent prevalence. Continuous variables are expressed as mean values ± standard deviation. Δ indicates longitudinal change in the continuous variables.
* <0.05 versus control. † <0.01 longitudinal change within group. ‡ <0.001 longitudinal change within group. § <0.01 versus control. ¶ <0.05 longitudinal change within group.
AV = atrioventricular.

was the increased frequency of left axis deviation of −30° or less in the former group on the most recent visit. In 6 of the 11 subjects with right bundle branch block and 3 of the 7 control subjects who eventually demonstrated left axis deviation, this abnormality became manifest during the observation period. Whereas no control subject displayed a QRS axis leftward of −50° on any electrocardiogram, three men with right bundle branch block showed an axis between −60° and −80° on initial presentation with right bundle branch block and two additional men developed this finding over the observation period. First degree atrioventricular block was uncommon in both groups; no subject developed a QRS axis rightward of +90°, had high degree atrioventricular block or required a pacemaker during the follow-up period.

Cardiac conduction system. In an attempt to identify subtle differences in the cardiac conduction system between right bundle branch block and control subjects, we compared heart rate at rest, PR interval and frontal plane QRS axis between groups on both initial and final visits (Table 1). Heart rate at rest was slower in the men with right bundle branch block than in control subjects on the final visit but this difference was small. PR interval was nearly identical in the two groups on the first visit and increased with age in both groups. The magnitude of this longitudinal PR interval prolongation was three times as great in right bundle branch block subjects as in control over the observation period (26.3 versus 9.6 ms, $p = 0.08$). Because 40 ms is probably the smallest increment in PR interval that can be reliably detected on a standard electrocardiogram by visual analysis, we identified the men in each group in whom such PR interval prolongation occurred over the observation period. Seven (29%) men with right bundle branch block and three (6%) control subjects developed PR interval prolongation of 40 ms or greater between initial and most recent visits ($p < 0.05$). Although the mean QRS axis of men with right bundle branch block was leftward of that of control subjects on both visits and moved further leftward at nearly twice the rate of control subjects, none of these differences was statistically significant. In both groups of men, significant leftward shifts in QRS axis were observed over time.

Blood pressure. In order to detect subtle differences in long-term blood pressure trends between the right bundle branch block and control groups, we averaged the systolic and diastolic blood pressures (four readings per visit) over the entire number of visits for each subject. Average systolic blood pressure was 131.5 ± 15.9 mm Hg in the group with right bundle branch block and 130.0 ± 16.6 mm Hg in the control group. Corresponding diastolic readings were 78.7 ± 7.0 and 78.6 ± 8.1 mm Hg. Neither reading was significantly different between the two groups. The slope of the systolic and diastolic blood pressures versus time over the 8.4 year observation period also did not differ between the right bundle branch block and control groups (0.83 ± 1.61 versus 1.21 ± 2.38 mm Hg per year for systolic blood pressure and 0.32 ± 0.89 versus −0.07 ± 1.60 mm Hg per year for diastolic blood pressure, respectively).

Heart size. The heart size of the men with right bundle branch block and control subjects on the most recent chest X-ray film was compared. Films were available on 20 of the 26 men with right bundle branch block and their 40 corresponding control subjects. Two men in each group (10 and 5%, respectively) manifested a cardiothoracic ratio of more than 0.50; the largest ratio was 0.55. Mean cardiothoracic ratio also did not differ significantly between the two groups (0.45 ± 0.05 in men with right bundle branch block versus 0.43 ± 0.04 in control subjects).

Exercise performance. Maximal treadmill exercise performance on most recent examination was assessed in clinically healthy men with right bundle branch block and control subjects with a modified Balke protocol used in our laboratory since 1975. Subjects walked at a constant speed

of 3.5 mph and the incline was increased by 3% every 2 minutes, starting from the horizontal. The mean age of the 12 exercising men with right bundle branch block (69.6 ± 8.9 years) was nearly identical to that of the 20 control men (70.6 ± 9.5 years). Neither exercise duration (9.1 ± 2.2 versus 7.3 ± 3.0 minutes) nor maximal heart rate (150.3 ± 23.5 versus 147.2 ± 20.7 beats/min) differed significantly between the respective groups.

Discussion

Previous studies. Most early investigations of right bundle branch block (2–5,8) presaged a rather bleak prognosis for patients with this electrocardiographic finding primarily because the involved study groups derived from hospital wards and clinics. Even in early series (4,5,7), however, it became apparent that the outlook for a patient with right bundle branch block was by no means uniform but was strongly influenced by the patient's overall cardiac status. Reusch and Vivas (7), for example, observed a mortality rate of 32% in individuals with right bundle branch block accompanying heart disease compared with an 8% mortality rate in those with right bundle branch block and no cardiac disorder.

More recently, several epidemiologic studies have described various clinical characteristics of subjects with right bundle branch block (9–13). In a cross-sectional study of a retirement community (12), right bundle branch block with left axis deviation of less than −30° was associated with a high prevalence of cardiovascular disease but "uncomplicated" right bundle branch block was not. In a large military population (10), right bundle branch block occurred in 0.16% of apparently healthy men and was twice as common past the age of 40 years. No increase in coronary risk factors existed in these subjects. Rotman and Triebwasser (9) followed up 394 Air Force personnel with right bundle branch block for an average of 10.8 years and found that coronary heart disease developed in only 6%, reflecting the young age (mean 36 years) and highly selected character of this group.

Because neither persons in retirement communities nor highly screened military personnel can be considered representative of the general population, right bundle branch block occurring in these subjects also may not be truly representative. The community-based studies of Tecumseh and Framingham probably better approximate an unselected population. In the former investigation (11), right bundle branch block was seen primarily in elderly subjects and was associated with the appropriately high prevalence of coronary risk factors expected in this age group, but no follow-up information was provided. Data from 70 men and women with newly acquired right bundle branch block in the Framingham study (13) indicate an increased incidence of coronary disease, congestive heart failure and cardiovascular disease mortality over a mean follow-up period of 6 years compared with that in age-matched control subjects. A QRS duration of greater than 130 ms and a QRS axis left of −45° identified subgroups with a high cardiovascular risk. However, the 20 subjects who were free from associated cardiovascular abnormality at the onset of right bundle branch block had an overall favorable prognosis.

Does right bundle branch block presage subsequent cardiovascular disease and mortality? The present investigation addresses the issue whether right bundle branch block of itself increases the likelihood of subsequent cardiac events in asymptomatic subjects. In our Baltimore Longitudinal Study on Aging population, over two-thirds of all men with right bundle branch block presented without associated cardiac disease. As the number of elderly Americans continues to increase dramatically (18) and the electrocardiogram is routinely performed in large numbers of these older persons, it may be anticipated that a substantial number of clinically healthy persons with right bundle branch block will be identified. Thus, our 24 asymptomatic men with right bundle branch block, most of whom presented with this conduction abnormality on their first examination, represent a not uncommon clinical problem.

Our most pertinent finding is that cardiovascular morbidity and mortality are not increased in asymptomatic men with right bundle branch block. This reinforces the conclusions from previous studies (4–7) that it is not the right bundle branch block but the underlying heart disease that determines prognosis. The similar prevalence of coronary risk factors in men with right bundle branch block and control subjects, as well as the similar frequency with which an ischemic ST segment or abnormal thallium scintigraphic response to exercise occurred, argues against an increase in asymptomatic coronary disease in these subjects with right bundle branch block. Further evidence for the benign nature of this condition is provided by the close agreement of cardiothoracic ratios between men with right bundle branch block and control subjects at latest follow-up examination. The nearly identical blood pressures averaged over the duration of the study would appear to eliminate even preclinical hypertension as an etiologic factor for right bundle branch block in these men.

Consistent with our demonstration that cardiovascular morbidity and mortality are not increased in men with asymptomatic right bundle branch block is our finding that no impairment of aerobic exercise performance was seen over long-term follow-up. The normal heart rate response to maximal exercise suggests that chronotropic reserve is not diminished in these men despite a mild decrease in rest heart rate compared with that of age-matched control subjects.

At first glance, our cardiovascular morbidity and mortality results appear to be at odds with those of the Framingham study. However, certain salient differences in study design and patient characteristics may account for this disparity. Individuals with preexisting right bundle branch block, excluded from the Framingham series but constituting 71%

of ours, may well have a more favorable prognosis than those who develop the conduction defect later in life. Second, our series contained no women; in the Framingham study, women with right bundle branch block had twice the prevalence of cardiomegaly and congestive heart failure as did men. Finally, the 20 subjects from Framingham who were free of antecedent or coincident cardiovascular abnormalities, as were the majority of our men, had much lower cardiac morbidity and mortality rates than the other subjects, 75% remaining free from any abnormality during the follow-up period.

Etiology of associated abnormal left axis deviation. Although aging itself is associated with a leftward shift of the QRS axis (19), the high prevalence of axis deviation leftward of $-30°$ in our subjects with right bundle branch block cannot be explained by advanced age alone because such axis deviation was seen significantly less often in the age-matched control subjects. Because the cause of right bundle branch block in these men is not immediately obvious, an attractive hypothesis is that the right bundle branch block, as well as the associated left axis deviation, reflects isolated fibrosis of the conduction system. Pathologic studies have demonstrated a variable degree of calcification of the left side of the cardiac skeleton with advancing age (20,21). The longitudinal leftward shift of QRS axis and prolongation of PR interval in both right bundle branch block and control groups may reflect the universality of these age-related changes in the conduction system. However, the greater tendency toward left axis deviation in men with right bundle branch block, coupled with their increased incidence of PR interval prolongation and slower rest heart rate on latest follow-up electrocardiogram in comparison with the control group, lends support to an acceleration of these primary aging changes in the conduction system of these apparently healthy men with right bundle branch block.

Limitations of study. As with any epidemiologic investigation, certain limitations exist in our study. The Baltimore Longitudinal Study on Aging population evaluated here consisted primarily of upper middle class white subjects and included no women. The relatively small series studied reflects the low prevalence of right bundle branch block in the general population. Although no statistical differences existed between the right bundle branch block and control groups with respect to the development of cardiac events, it is possible that differences might appear if a large enough population was studied over a longer period of time.

Implications. We have found no long-term increase in cardiovascular morbidity or mortality in asymptomatic men with right bundle branch block when compared with age-matched control subjects. Similarly, we could detect no increase in their prevalence of coronary risk factors or latent coronary disease and no impairment of maximal aerobic performance. The increased occurrence of left axis deviation and PR interval prolongation in these men supports the concept that right bundle branch block is a manifestation of a more general abnormality of the cardiac conduction system in men without other evidence of heart disease.

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