Right Bundle-Branch Block. Hemodynamic, Vectorcardiographic and Electrocardiographic Observations

By Eugene Braunwald, M.D., Ephraim Donoso, M.D., Samuel O. Sapin, M.D., and Arthur Grishman, M.D.

The time intervals between the onset of ventricular depolarization and of right ventricular contraction were studied in 36 patients, by means of cardiac catheterization, and were correlated with their vectorcardiograms and electrocardiograms. The onset of right ventricular contraction was delayed in six subjects without heart disease but with the electrocardiographic picture of right bundle-branch block. The onset of right ventricular contraction was found to be normal in 10 of 15 patients with right ventricular hypertrophy with the electrocardiographic picture of right bundle-branch block. This indicates that this electrocardiographic configuration is not necessarily accompanied by delayed right ventricular contraction.

In 1932, Wilson and collaborators described the electrocardiographic patterns associated with bundle branch block experimentally produced in the dog. These classic studies have formed the basis for the electrocardiographic criteria employed in the diagnosis of bundle branch block in man. It was the purpose of this investigation to examine the validity of these electrocardiographic criteria for the diagnosis of right bundle branch block, and also to evaluate the usefulness of the spatial vectorcardiogram in determining the presence of right bundle branch block.

The simultaneous recording of the electrocardiogram with the right ventricular-pressure pulse makes possible the accurate measurement of the time interval between the onset of ventricular depolarization and the onset of right ventricular contraction. Right bundle branch block, or other disturbances in right ventricular conduction, produce a delay in right ventricular depolarization and should be accompanied by a corresponding delay in the onset of right ventricular contraction and therefore in prolongation of the time interval between the onset of the QRS complex and the onset of the rise in the right ventricular-pressure pulse. In this study both the scalar electrocardiogram and the spatial vectorcardiogram were correlated with this time interval in 3 groups of patients.

Material

The 36 patients studied were all on the ward or private services of The Mount Sinai Hospital, New York. Group 1 consisted of 15 patients with clinical evidence of right ventricular hypertrophy, confirmed in each instance by the demonstration at the time of cardiac catheterization of a lesion that imposes a hemodynamic burden exclusively or predominantly on the right ventricle. These patients ranged in age from 3 to 34 years. Seven patients had pulmonic stenosis with normal aortic root, 5 had the tetralogy of Fallot, 1 had rheumatic mitral stenosis, 1 had an interatrial septal defect, and 1 had an Eisenmenger's complex. All 15 patients had electrocardiograms that satisfied the recently described criteria for right ventricular hypertrophy.* None had an RSR' configuration in right precordial leads.

Group 2 consisted of 6 persons ranging in age from 16 to 28 years with no evidence of heart disease that could be elicited by clinical examination or cardiac catheterization. The electrocardiograms of these patients were characterized by an RSR' pattern in the right precordial leads with a QRS duration ranging from 0.10 to 0.13 second.

Group 3 consisted of 15 patients with clinical evidence of unilateral right ventricular hypertrophy, confirmed in each instance by the demonstration, at the time of cardiac catheterization, of a lesion that imposes a hemodynamic burden on the right ventricle alone. All had the so-called right bundle-

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branch-block pattern in the electrocardiogram. The 10 patients in group 3A ranged in age from 4 to 50 years. Four patients had pulmonic stenosis with normal aortic root, 4 had interatrial septal defects, 1 had a truncus arteriosus (confirmed at postmortem examination), while 1 patient had the tetralogy of Fallot. These patients all had an RSR' configuration in right precordial leads with a QRS duration ranging from 0.08 to 0.12 second.

Group 3B consisted of 5 patients ranging in age from 16 to 64 years. Four of these patients had interatrial septal defects, while 1 had marked pulmonary hypertension during life and idiopathic nonspecific myocarditis with right ventricular hypertrophy at postmortem examination. These 5 patients also had an RSR' pattern in right precordial leads, with a QRS duration ranging from 0.10 to 0.14 second.

METHODS

Strain-gage pressure transducers (Statham P23A) were employed in conjunction with a single gun, multichannel oscilloscopic photographic recorder, in which errors of parallax are eliminated. Standard lead II of the electrocardiogram was recorded simultaneously with the right ventricular-pressure pulse in all instances. The paper speed of the recorder was 50 mm. per sec. Measurements of the time interval between the onset of QRS in lead II and the onset of the rise in the right ventricular-pressure curve were averaged for 2 respiratory cycles. The delay in the transmission of a pressure pulse through the catheter-strain-gage system has been measured and found to be close to 0.005 sec. This value was subtracted from all measured intervals between electrical and mechanical events. Only records were utilized in this study in which both the onset of the QRS and of the pressure rise in the right ventricular-pressure pulse were clear.

Spatial vectorcardiograms were obtained by means of the cube method of electrode placement and were photographed from the screen of a Technicon or Sanborn oscilloscope. Electrocardiograms were recorded on a 3-channel, direct-writing Technicon recorder at a paper speed of 50 mm. per second.

RESULTS

Group 1

In this group of 15 patients with right ventricular hypertrophy, the electrocardiograms presented the pattern of right ventricular hypertrophy. The spatial vectorcardiograms showed the configuration of right ventricular hypertrophy without conduction disturbance, which has recently been described in detail. The QRS loop was situated anterior to the isoelectric point and was inscribed in a clockwise direction in the horizontal plane. No abnormal slowing was noted in the inscription of the terminal portion of the QRS loop. The intervals between the onset of ventricular depolarization and of right ventricular contraction in these patients ranged from 0.045 to 0.075 second (table 1). These time intervals are within the range recently found in normal subjects. Thus, in this first group of patients with clinical, electrocardiographic and vectorcardiographic evidence of right ventricular hypertrophy, the onset of right ventricular contraction was not delayed, and significant right ventricular conduction disturbance therefore did not exist.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Pts.</th>
<th>ECG</th>
<th>Range of QRS duration (sec.)</th>
<th>VCG</th>
<th>Q-RV (range sec.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>RVH</td>
<td>0.06-0.09</td>
<td>RVH</td>
<td>0.045-0.075</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>RSR'</td>
<td>0.10-0.12</td>
<td>RVCD</td>
<td>0.100-0.120</td>
</tr>
<tr>
<td>3A</td>
<td>10</td>
<td>RSR'</td>
<td>0.08-0.12</td>
<td>RVH</td>
<td>0.050-0.075</td>
</tr>
<tr>
<td>3B</td>
<td>5</td>
<td>RSR'</td>
<td>0.10-0.14 RVH + RVCD</td>
<td></td>
<td>0.095-0.120</td>
</tr>
</tbody>
</table>

RVH = Right ventricular hypertrophy.

RSR' = Electrocardiographic configuration of RSR' in right precordial leads.

RVCD = Vectorcardiographic configuration of right ventricular-conduction disturbance.

Q-RV = Time interval (sec.) between onset of QRS and of right ventricular-pressure rise.

**Group 2**

These six subjects without evidence of heart disease had electrocardiograms presenting an RSR' pattern in right precordial leads with a QRS duration ranging from 0.10 to 0.13 second (fig. 1A). Spatial vectorcardiograms were obtained in three of these patients; all three had a similar configuration that indicated a conduction delay (fig. 1B). The major portion of the QRS loop resembled that seen in normal persons. However, a distinct terminal appendage to the QRS loop was present. This
RIGHT BUNDLE BRANCH BLOCK

FIG. 1A. Electrocardiogram of a 16 year old boy without evidence of heart disease, taken at a paper speed of 50 mm. per second.

FIG. 1B. Spatial vectorcardiogram of the subject whose electrocardiogram is illustrated in figure 1A. The first portion of the QRS loop is directed to the left, inscribed in a counterclockwise direction in the horizontal plane, and resembles that seen in normal subjects. The terminal portion of the QRS loop is inscribed slowly, and is directed to the right, superiorly, and anteriorly. H, horizontal plane; S, sagittal plane; F, frontal plane.

FIG. 1C. Right ventricular-pressure pulse and lead I of the subject whose electrocardiogram and vectorcardiogram are illustrated in figures 1A and 1B. The arrows indicate the onset of QRS and of right ventricular contraction, which are separated by an abnormally long interval.

appendage was directed anteriorly and to the right of the isoelectric point and was inscribed very slowly (fig. 1B). In all six patients in this group the onset of right ventricular contraction was abnormally delayed, as evidenced by a prolongation of the time interval between the onset of QRS and the onset of right ventricular contraction to 0.10 second or longer (fig. 1C). These time intervals exceed those observed in normal persons. In these patients the electrocardiograms and vectorcardiograms both suggested the presence of right bundle branch block, and this was confirmed by the demonstration of an abnormal delay in the onset of right ventricular contraction.

Group 3A

In this group of 10 patients with clinical and cardiac catheterization evidence of unilateral right ventricular hypertrophy the electrocardiograms showed so-called incomplete right bundle branch block, namely, an RSR' configuration in right precordial leads with a QRS duration ranging from 0.08 to 0.12 sec. The vectorcardiograms, however, gave no evidence of conduction disturbance, and presented a configuration essentially similar to that noted in group 1, i.e., evidence of right ventricular hypertrophy. The time intervals between the onset of ventricular depolarization and of right ventricular contraction were within normal limits (table 1), further suggesting that significant right ventricular conduction disturbance did not exist, despite the electrocardiographic configuration.

Group 3B

These five patients with clinical and cardiac catheterization evidence of unilateral right ventricular hypertrophy also had electro-
cardiograms with an RSR' configuration in right precordial leads, the QRS duration ranging from 0.10 to 0.14 second (fig. 2A). The vectorcardiograms showed right ventricular hypertrophy, and, in addition, presented evidence of conduction disturbance. The terminal portion of the QRS loop was situated anteriorly and to the right of the isoelectric point and its inscription was distinctly slowed (fig. 2B). The time interval between the onset of the QRS complex and of right ventricular contraction was abnormally prolonged (table 1) to 0.095 to 0.120 sec., confirming the presence of right ventricular-conduction disturbance.

**Comment**

Previous investigations have attempted to prove the presence of bundle-branch block in man by demonstrating a prolonged time interval between the onset of ventricular depolarization and the onset of ventricular ejection. With the exception of the observations in Courand's laboratory these investigations have utilized indirect techniques, such as the electrokymogram,\(^9\) the roentgenkymogram,\(^10\) and the carotid\(^10, 12, 13\) or subclavian pulse\(^14, 15\) to indicate the onset of ventricular ejection. These studies have provided conflicting results, and the accuracy of some of the indirect methods has been questioned.\(^16, 18\) Furthermore, these techniques have yielded only the time interval between ventricular depolarization and ejection, and therefore include the variable period of isometric contraction.

Using the cardiac-catheter technic the time interval between electrical and mechanical events in the human heart can be established with greater accuracy than was possible in the studies employing indirect techniques. The interval between the onset of the QRS complex and the onset of the rise in right ventricular pressure is very closely related to the true time interval separating electrical and mechanical events in the right ventricle. It should be pointed out, however, that both ventricular depolarization and ventricular contraction undoubtedly commence slightly earlier than the electrocardiographic and right ventricular-pressure records indicate. Both the electrical and the mechanical processes must already be active and involve a significant portion of the myocardium before sufficient electrical potential and mechanical pressure, respectively, have been generated to produce visible deflections of the recordings. Experimental studies,\(^19\) however, indicate that the interval between the onset of the earliest fractionate contraction in the ventricles and the onset of rise in intraventricular pressure is short indeed.

Since only right ventricular pressures were recorded in this study, the presence of abnormally asynchronous ventricular contraction could not be demonstrated. However, the time interval between the onset of ventricular depolarization and of right ventricular contraction determined in our patients could be compared with the same interval obtained in a group of normal subjects.\(^6\) When this interval definitely exceeded that noted in the normal subjects, right bundle-branch block or significant right ventricular-conduction disturbance existed. On the other hand, a significant right ventricular-conduction disturbance could be excluded when this time interval fell within the normal range.

Right ventricular-conduction disturbances, as manifested by an abnormal delay in the onset of right ventricular contraction, were always found to be accompanied by the electrocardiographic pattern that has been designated\(^1\) as “right bundle branch block.” However, the reverse was not always found to be the case. Ten out of 15 patients with right ventricular hypertrophy and the electrocardiographic...
pattern of right bundle branch block failed to show delayed onset of right ventricular contraction. The spatial vectorcardiogram appears more reliable than the scalar electrocardiogram in detecting the presence of right ventricular-conduction disturbance. An anteriorly directed, abnormally, slowly inscribed, terminal phase of the QRS loop was observed in all patients with delayed onset of right ventricular contraction, but this vectorcardiographic pattern was absent in all patients with a normal onset of right ventricular contraction. The vectorcardiogram appears to be of particular value in patients whose electrocardiograms show an RSR’ pattern in right precordial leads. It effectively separates these patients into 3 distinct categories: (1) those with right ventricular-conduction disturbance without right ventricular hypertrophy, (2) those with right ventricular hypertrophy without right ventricular-conduction disturbance, and (3) those with right ventricular-conduction disturbance in the presence of right ventricular hypertrophy.

It has recently been noted that following cardiac surgery on patients with pulmonic stenosis and interatrial septal defect the electrocardiographic picture of so-called “incomplete right bundle branch block” has emerged from that of right ventricular hypertrophy. These observations further suggest that in patients with congenital heart disease and anatomic right ventricular hypertrophy, the electrocardiographic configuration of “right bundle branch block” does not always represent a conduction disturbance, but may reflect the presence of right ventricular hypertrophy. In the present study, no significant conduction disturbance could be demonstrated by the measurement of the time intervals between electrical and mechanical cardiac events in 10 of 15 patients with congenital heart disease, right ventricular hypertrophy, and the electrocardiographic pattern of right bundle branch block.

**Summary**

1. The time intervals between the onset of ventricular depolarization and of right ventricular contraction were obtained by cardiac catheterization in 36 patients, and were correlated with the spatial vectorcardiogram and the electrocardiogram.

2. In 15 patients with clinical, electrocardiographic and vectorcardiographic evidence of right ventricular hypertrophy, the onset of right ventricular contraction followed the onset of the QRS complex by normal intervals (0.045–0.075 sec.), indicating that significant right ventricular conduction disturbance did not exist.

3. In six subjects without heart disease, whose electrocardiograms and vectorcardiograms showed right bundle branch block, the electric-mechanical intervals were prolonged (0.095–0.110 sec.), confirming the presence of conduction disturbance.

4. In 15 patients with clinical evidence of right ventricular hypertrophy the electrocardiograms showed right bundle-branch block. In 10 of these the vectorcardiograms showed right ventricular hypertrophy without conduction disturbance, and this interpretation was confirmed by a normal electrical-mechanical interval. Thus, right ventricular contraction was not delayed in spite of the electrocardiographic configuration of right bundle branch block. In five such patients, however, the vectorcardiograms gave evidence of right ventricular hypertrophy and conduction disturbance, and the onset of right ventricular contraction followed the onset of the QRS complex by abnormally long intervals.

5. The spatial vectorcardiogram is useful in detecting the presence of right ventricular conduction disturbance.

**Acknowledgment**

The cardiac catheterizations were performed in conjunction with the other members of the cardiac catheterization team under the direction of Dr. Alvin J. Gordon.

**Summario in Interlingua**

1. Le intervalllos de tempore inter le declaration del dispolarisation ventricular e le contraction dextero-ventricular eseva obtenite per catheterisation cardiac in 36 patientes. Illos eseva correlateatione con le vectocardiogramma spatial e le electrocardiogramma.
2. In 15 pacientes con clínica, electrocardiográfica, e vectocardiográfica evidencia de hypertrophia dextero-ventricular, le declaración del contraction dextero-ventricular se queva le declaración del complexo QRS per intervallos normal (0,045 a 0,075 segundas). Isto indicava que un significativo disturbance del conduction dextero-ventricular non eseva presente.

3. In 6 subjectos sin morbo cardiac sed con electrocardiogrammas e vectocardiogrammas indicative de bloco de branca dextere, le intervallos electro-mechanic eseva prolongate (0,095 a 0,110 segundas) e confirmava assi le presentia de un disturbance del conduction.

4. In 15 pacientes con evidencia clinica de hypertrophia dextero-ventricular, le electrocardiogrammas indicava bloco de branca dextere. In 10 de iste casos le vectocardiogrammas indicava hypertrophia dextero-ventricular sin disturbance del conduction, e iste interpretation eseva confirmata per un normal intervallo electro-mechanic. Assi, le contraction dextero-ventricular non eseva retardata in despecto del configuration electrocardiographic indicative de bloco de branca dextere. In 5 tal pacientes, del altere latere, le vectocardiogrammas indicava hypertrophia dextero-ventricular e disturbance del conduction, e le declaration del contraction dextero-ventricular sequeva le declaration del complexo QRS per anormalmente longe intervallos.

5. Le vectocardiogramma es utile in le detection del presentia de un disturbance del conduction dextero-ventricular.

REFERENCES


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