A Phonocardiographic Study of Right Bundle Branch Block, with Special Reference to the Second Heart Sound

Masahiko Okuni, M.D.* and Alexander S. Nadas, M.D.

SUMMARY

The second heart sounds in 29 cases with right bundle branch block, mainly surgically induced, were studied.

Three general types of the second sound were classified.

Eleven cases revealed wide splitting of the second sound (0.05 sec. or more), and 14 cases showed narrow splitting less than 0.05 sec.), while 4 cases showed a single 2nd heart sound throughout the respiratory cycle.

Ten cases revealed a respiratory change in the splitting, and 14 cases showed fixed splitting.

The cases with a widely split 2nd sound revealed fixed splitting except in 2 cases. Among the cases with narrow splitting, 8 cases (57%) showed respiratory change.

All cases with a QRS duration of 0.14 sec. or more revealed fixed splitting.

A Valsalva maneuver was performed in 18 cases with RBBB. Five cases showed a widening of the split 2nd sound immediately following the release of Valsalva maneuver and then the IIA-IIP interval decreased, but in only 2 cases did the IIA-IIP interval merge into single sound. In 13 cases the IIA-IIP interval remained unchanged throughout the Valsalva maneuver.

No correlation was found between splitting of the second heart sound and the type of vectorcardiogram in RBBB.

The mechanism of these observations was discussed.

Additional Indexing Words:
Second heart sound Valsalva maneuver

RIGHT bundle branch block (RBBB) has been considered one of the frequent causes of wide splitting of the second heart sound.11–3) The mechanism of second sound splitting has been regarded as related to the

From the Department of Pediatrics, Harvard Medical School and the Sharon Cardiovascular Unit of the Children's Hospital Medical Center, Boston, Mass., U.S.A.

Supported in part by Grant HE-10436-02 from the National Heart Institute of the National Institutes of Health, Bethesda, Md., U.S.A.

* Present Address: Department of Pediatrics, Nihon University Medical School, Itabashi-ku, Tokyo.

Received for publication January 7, 1970.
delayed contraction of one of the ventricles, usually the right ventricle.

Recently Testelli reported that the duration of the right ventricular pressure curve in transient right bundle branch block is shortened because the upstroke of the curve is delayed, in spite of a normal downstroke time.

These results implied that the second heart sound in patients with right bundle branch block does not necessarily split in every case.

The present report is based upon an analysis of the second heart sound of 29 patients with RBBB.

**Material and Methods**

This study includes all patients seen at the Children’s Hospital Medical Center at Boston between 1966 and 1967 in whom RBBB was recorded by electrocardiogram. Twenty-nine cases with RBBB were studied. The definition of RBBB is as follows; QRS duration of 0.10 sec. or more with a positive late deflection in lead V1 and a negative late deflection in lead I. In cases with QRS duration of less than 0.12 sec. a terminal delay of the ventricular loop in at least 2 planes of vectorcardiogram was confirmed.

These were 22 males and 7 females included in the study. The age of the patients ranged from 4 to 38 years (average 15 years). The basic cardiac defect of each patient is listed in Table I.

<table>
<thead>
<tr>
<th>Table I. Original Congenital Heart Defect of the Cases with RBBB</th>
</tr>
</thead>
<tbody>
<tr>
<td>postoperative VSD</td>
</tr>
<tr>
<td>postoperative VSD+PS</td>
</tr>
<tr>
<td>postoperative PS</td>
</tr>
<tr>
<td>Ebstein's disease</td>
</tr>
<tr>
<td>TAPVD</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

VSD: ventricular septal defect, PS: pulmonic stenosis
TAPVD: total anomalous pulmonary venous drainage

Except for 2 cases cardiac operations were done in the Children’s Hospital Medical Center, Boston, Mass. before November, 1964. Nine cases had a small residual left to right shunt at the ventricular level, 4 cases a mild residual pulmonic stenosis, 3 cases mild pulmonic stenosis with a ventricular septal defect and 1 case had a mild pulmonic regurgitation. Phonocardiograms were recorded by means of a 4 channel photographic recorder made by Sanborn Company (model 550M). Phonocardiogram from 2 sites together with electrocardiogram and with respiration, carotid pulse, jugular venous pulse or apex cardiogram were recorded simultaneously.

Respiration was recorded by thermister and carotid wave was recorded with plastic cup and pickup connected by rubber tube (Sanborn model 374) to serve as a reference tracing for the identification of the second heart sound.
The Valsalva maneuver was performed and the phonocardiogram was recorded during the strain period and following release of Valsalva strain. Patients were asked to perform the Valsalva maneuver by expiring forcibly into a mouthpiece connected to a pressure gauge. They were asked to maintain a pressure of 40 mm Hg for about 10 sec. and to remain very still after releasing this strain.

A vectorcardiogram was recorded in Frank system by a vectorcardiographic machine of Sanborn Company. The loops were photographed from the oscilloscope.

**RESULTS**

1. Splitting of the second heart sound in RBBB (Table II)

Among 29 cases of RBBB, 25 cases (86%) showed a splitting of the second heart sound during respiration, and 4 cases did not.

Among the cases with a split second heart sound, 11 cases showed splitting

<table>
<thead>
<tr>
<th>Table II. Splitting of the Second Heart Sound in RBBB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a)</strong> widely split (0.05 sec. or more)</td>
</tr>
<tr>
<td>fixed splitting</td>
</tr>
<tr>
<td>with respiratory movement</td>
</tr>
<tr>
<td>undetermined</td>
</tr>
<tr>
<td><strong>b)</strong> narrowly split</td>
</tr>
<tr>
<td>fixed splitting</td>
</tr>
<tr>
<td>with respiratory movement</td>
</tr>
<tr>
<td><strong>c)</strong> single throughout a respiratory cycle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table III. Respiratory Variation and Residual Defect in RBBB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a)</strong> fixed splitting</td>
</tr>
<tr>
<td>without residual defect</td>
</tr>
<tr>
<td>with residual defect</td>
</tr>
<tr>
<td>VSD</td>
</tr>
<tr>
<td>VSD+PS</td>
</tr>
<tr>
<td>VSD+PAH</td>
</tr>
<tr>
<td>Ebstein's disease</td>
</tr>
<tr>
<td><strong>b)</strong> single without respiratory change</td>
</tr>
<tr>
<td>without residual defect</td>
</tr>
<tr>
<td>with residual defect (VSD+PS)</td>
</tr>
<tr>
<td><strong>c)</strong> with respiratory change</td>
</tr>
<tr>
<td>without residual defect</td>
</tr>
<tr>
<td>with residual defect</td>
</tr>
<tr>
<td>VSD</td>
</tr>
<tr>
<td>pulmonary regurgitation</td>
</tr>
<tr>
<td>PS</td>
</tr>
<tr>
<td>TAPVD</td>
</tr>
</tbody>
</table>

(abbreviation: cf. Table I)
of 0.05 sec. or more, and 14 cases showed splitting less than 0.06 sec. at expiration.

Since the second sound rarely split 0.05 sec. or more in the pediatric field\(^2\) a splitting of 0.05 sec. or more was classified as wide splitting.

Among the 4 cases with single IIS throughout respiratory cycle, 3 cases were operated for tetralogy of Fallot, in which 1 case had no residual defect and 1 case had soft systolic murmur and another case showed a systolic ejection murmur by residual pulmonic stenosis. Another case of single IIS had residual pulmonic stenosis. Another case of single IIS was operated for pulmonic stenosis without residual defect.

2. Respiratory movement of the split second heart sound (Table III)

Ten cases revealed a respiratory movement of the split second heart sound, whereas 18 cases, including 4 cases with the single second heart sound, showed no demonstrable respiratory movement, that is, a majority of the cases with RBBB showed a fixed splitting of the second heart sound. In these cases, respiratory change of Q-IIA as well as Q-IIP interval was minimal, less than 0.01 sec. Almost all cases, except 2 cases, with a widely split second sound showed fixed splitting of the second heart sound (Fig. 1). All cases with QRS

---

**Fig. 1.** Original defect and splitting of IIS.
duration of 0.14 sec. or more showed fixed splitting (Fig. 2). Four cases showed a single second heart sound throughout a respiratory cycle, while 2 cases with a single second heart sound at expiration showed a split second sound at inspiration.

No particular relationship was found between the presence of a residual defect or the type of the residual defect and the splitting of the second heart sound.

3. Original defect and the splitting of the second heart sound

The relationship between the original cardiac defect and the splitting of the second heart sound is shown in Fig. 1.

No particular correlation was found between the original defect and second sound split. Some cases had a residual defect at the time of this study, although they were very much improved when compared with their preoperative status.

4. Respiratory variation and residual defect in RBBB

As shown in Table III, 18 cases had residual or original congenital cardiac defects. Among the cases with fixed splitting of the second heart sound 7 cases had residual defects of pulmonic stenosis and/or small ventricular septal
5. QRS duration and the splitting of the second heart sound

As shown in Fig. 2, some correlation was found between the QRS duration and IIA-IIP interval with the exceptions of 3 cases with very wide splitting of the second sound and 6 cases with single IIS.

6. Vectorcardiogram and the splitting of the second heart sound

Vectorcardiograms in 20 cases of RBBB were studied. Fourteen cases showed the Type I of Baydar, 4 cases had the Type II and 2 cases with Type III.

No significant correlation was found between the type of vectorcardiogram and the splitting of the second heart sound (Fig. 3).

7. Valsalva maneuver and the second heart sound

The Valsalva maneuver caused a significant change in the splitting of the second heart sound in some of 18 patients with RBBB (Fig. 4), but had no effect on the splitting of the second heart sound in 13 cases (72%) including 2 cases with single second heart sound.
Among 18 cases of the authors' series, 5 cases revealed the initial widening and later narrowing of the second sound, but in only 2 cases the second sound merged into a single sound. Thirteen cases demonstrated almost constant splitting throughout the Valsalva maneuver. Two cases in which the second heart sound fused had a residual defect. Among 5 cases with initial widening and later narrowing of the second sound 3 cases had a residual defect. Among 13 cases with no response to a Valsalva maneuver 6 cases had residual defects, and 11 cases revealed fixed splitting. No relationship between the response to Valsalva maneuver and residual defects could be recognized.

**DISCUSSION**

Splitting of the second sound with delay of the pulmonary component has been considered as an important auscultatory and phonocardiographic sign in RBBB. McKusik\(^3\) described splitting of the second heart sound in expiration and inspiratory increase of the IIA-IIP interval and no splitting of the first sound in RBBB. Shafter\(^1\) studied 2 cases of RBBB without congestive heart failure and noted that both earlier movement of IIA and later
movement of IIP contributed to the inspiratory increase in splitting of the second sound in RBBB. Haber and Leatham\textsuperscript{21} described splitting of heart sounds from ventricular asynchrony in bundle branch block, ventricular ectopic beats and artificial pacing.

In the present study the authors classified 3 types of second heart sounds in RBBB, that is, widely split, narrowly split and single throughout a respiratory cycle. In a further analysis of the influence of respiratory variation the authors found 2 groups, with respiratory movement and with fixed splitting. Hemodynamic and pathological considerations are necessary for the evaluation of these results.

As for the hemodynamic changes in RBBB, several authors\textsuperscript{7-9} described a delay in the onset of right ventricular contraction but some exceptional cases are also described.\textsuperscript{8} Goldblatt et al.\textsuperscript{8} stated that the delay in the onset of right ventricular contraction is accompanied by prolongation of right ventricular ejection and is responsible for the wide splitting of the first and second heart sound. Peñaloza\textsuperscript{10} found a significant delay in right ventricular systole in advanced degree of RBBB which was produced in the normal human heart.

The results of Testelli,\textsuperscript{4} however, is somewhat different. He found that the duration of right ventricular pressure curve in transient RBBB in man is shortened because the upstroke is delayed while the downstroke is not. This result may explain the narrow splitting of IIS in RBBB of the authors’ series.

Single second sound has been reported as an infrequent phenomenon in RBBB. Ovaretz et al.\textsuperscript{11} found only 1 case with single second sound in 20 patients with RBBB, and no case with single second sound was found among 11 cases of Perloff et al.\textsuperscript{13} with RBBB, while the authors found 4 cases with single second sound among 29 cases with RBBB. Segall et al.\textsuperscript{13} found that in about 20 per cent of cases with bundle branch block with satisfactory electrophonocardiogram splitting was absent in the supine position, though in the sitting position it was detected by clinical auscultation.

For the explanation of single second sound, following 3 reasons are considered: simultaneous occurrence of IIA and IIP, rudimentary IIP with some IIA-IIP interval and broad IIS. Segall et al.\textsuperscript{13} described that IIP became inaudible in about 30 per cent of cases when the posture was changed from sitting to dorsal recumbent; electrophonocardiograms were recorded only in this latter posture.

Among 4 cases with single IIS in the authors’ series, 1 case of post-op. pulmonic stenosis with ventricular septal defect had residual pulmonic stenosis which may have very small IIP. A case of post-op. pulmonic stenosis with ventricular septal defect had soft regurgitant systolic murmur and another case without residual defect showed broad IIS up to 0.04 sec. of duration which
may include IIA and IIP. One case of post-op. pulmonic stenosis had no residual defect. All cases with single IIS had pulmonic stenosis before the operation, therefore malformed pulmonic valves may cause this phenomenon even after the surgical repair. In addition, in all cases with single IIS, R-IIS interval did not show any respiratory change, that is, R-IIS intervals were roughly constant, although in almost all cases of RBBB with fixed splitting respiratory change of R-IIS interval was minimal.

As for the relationship between QRS duration and IIA-IIP interval, Sakamoto et al.\textsuperscript{14} reported a not so very close parabolic relationship, but they also found that very wide IIA-IIP interval had no apparent correlation to QRS duration. In the authors' series, QRS duration and IIA-IIP interval showed some correlation except for cases with single second sound and with very wide split interval. Two cases, other than 4 cases with single IIS throughout respiratory cycle, showed single IIS at expiration, one of which had residual ventricular septal defect and another was post-op. pulmonic stenosis. Among the 3 cases with extremely wide IIS, 2 cases were post-op. ventricular septal defect and pulmonic stenosis, in which 1 case had residual ventricular septal defect, and another case had Ebstein's anomaly.

The explanation of the mechanism of fixed splitting of the second heart sound in RBBB is also somewhat difficult. Fixed splitting of the second sound has been described in atrial septal defect, pulmonic stenosis, left or right bundle branch block\textsuperscript{10,12} with or without right ventricular failure, congestive heart failure and idiopathic dilatation of the pulmonary artery.\textsuperscript{15} According to Perloff, fixed splitting is caused by diastolic hypervolemia of the right heart. Aygen and Braunwald\textsuperscript{16} have described the reciprocal flow changes responsible for fixed splitting in atrial septal defect. In the author's series 14 cases showed split second heart sound without respiratory movement. These cases did not have atrial septal defect or clinical evidence of heart failure. Also, in these cases very little respiratory movement of Q-IIA or Q-IIP interval was observed, usually less than 0.01 sec. As for the type of cardiac defect present there was no significant difference between the group with fixed splitting and the group with respiratory movement of the second heart sound. It is of interest to note that all cases with a QRS duration of 0.14 sec. or more demonstrated fixed splitting.

The effect of Valsalva maneuver on splitting of the second heart sound has been reported by various authors.\textsuperscript{16,17} Recently van der Hauwaert\textsuperscript{17} described a wide splitting of the second heart sound in normal persons following release of the Valsalva maneuver. The first or the second beat immediately after this release showed a wide splitting of average 82 msec., but the IIA-IIP interval gradually decreased and in almost all cases the second sound merged
into a single sound, usually between the fifth and eighth cardiac cycle following release. This observation is explained by the hemodynamic changes that follow a Valsalva maneuver.\(^{18}\) Immediately after the release, increased venous return to the right atrium and ventricle cause an increase in right ventricular stroke volume and a prolongation of the right ventricular ejection time. The increased stroke volume moves through the lungs to left ventricle and causes a prolonged left ventricular ejection time. These phenomena are reflected in the Q-IIA and Q-IIP interval. At first a short Q-IIA and prolonged Q-IIP are observed causing a wide splitting of the second sound but subsequent shortening of the Q-IIP and prolongation of the Q-IIA interval result in narrowing of the IIA-IIP interval until the 2 second sound components fuse. In patients with atrial septal defect, however, he noted only minor change. Aygen and Braunwald\(^{18}\) also described the minimal effect of the Valsalva maneuver on the second sound in atrial septal defect.

As for the response to the Valsalva maneuver on the second sound in RBBB, a majority of the cases did not show the normal response. Since the response to the Valsalva maneuver did not correlate with the presence or absence of residual cardiac defect, it is suggested that the failure to respond to the Valsalva maneuver in RBBB is caused by RBBB in itself.

The mechanism for the high incidence of both fixed splitting of IIS and failure to respond to the Valsalva maneuver in RBBB is speculated that the right ventricle in the cases with RBBB does not respond sensitively to the induced hypervolemia in the right ventricle or increased output of the right ventricle in RBBB does not reflect to the further prolongation of ejection time. Further study is considered to be necessary to explain for these results of observations.

Many vectorcardiographic studies of right bundle branch block have been published. Bayder\(^{6}\) divided the vectorcardiographic variants of RBBB into three types. By his criteria most cases of RBBB with right ventricular enlargement belonged to type II or type III. The authors' results did not show any relationship between the vectorcardiographic type of RBBB and splitting of the second sound.

**Acknowledgement**

The authors are grateful to the technical assistance of Miss Sarrah L. Dalton.

**References**