Cardiodynamic Effects of Experimental Bundle-Branch Block in the Dog

By James R. Wennemark, M.D., David F. Blake, M.D., and Paul Kezdi, M.D.

There is disagreement as to whether bundle-branch block causes a delay in contraction of the homolateral (blocked) ventricle. Previous studies in animals and man have produced conflicting results. The majority of investigators have found that a delay in electrical activation of one of the ventricles, as occurs in bundle-branch block or an extrasystole originating in the contralateral ventricle, produces a delayed mechanical contraction of the ventricle. Others have concluded that no such electrical-mechanical relationship consistently occurs in man or the experimental animal. Many of the previous studies have used indirect methods for timing the mechanical events of the heart. Recently, however, there have been studies in man and in the experimental animal using simultaneous right and left intraventricular pressures as a method for determining the onset of isometric contraction of the respective chambers. Previous animal studies have not been performed, to our knowledge, with pressure measurements in the closed-chest animal with chronic bundle-branch block. The present study was undertaken to evaluate further electrical-mechanical relationships in the canine heart under these conditions.

Methods

The experiments were performed on medium-sized mongrel dogs under pentobarbital anesthesia (25 mg./Kg.). Simultaneous right and left cardiac catheterizations were performed by posterior percutaneous transthoracic approach using no. 18 thin-walled needles. The needle was used as an exploring electrode. The proximity of the atrium could be determined by the configuration of large bi-phasic P waves of the electrocardiogram. An atrial puncture was indicated by elevation of the P-R segment. Pressures were measured as nearly as possible in expiration through 12-inch lengths of PE 50 polyethylene catheter with Statham P23G strain gauges. Recordings were made on a photographic recorder (Electronics for Medicine, White Plains, New York) at paper speeds of 75 and 150 mm./sec. The two recording systems were tested and found to have simultaneous upstroke responses. The time delay of the impulse for this catheter system was not computed because the conclusions are derived from a comparison of observations made before and after block in each animal.

The conduction system was approached through an atrial incision during temporary cardiac inflow and outflow occlusions in the normothermic dog. The bundle branches of the canine heart can usually be seen with the naked eye. This is particularly true of the right bundle branch.

The chest was entered through a fourth intercostal incision. The pericardium was opened and the atrium exposed. Retracting sutures were placed in the atrial wall, and an area of the atrium was isolated in a Satinsky clamp. An atrial incision was made in this area. Inflow and outflow cardiac occlusions were performed by tightening adjustable plastic ligatures. The Satinsky clamp was removed and the heart was cleared of blood by constant suction. By retraction of the atrioventricular valve, the bundle branch could be visualized. A total occlusion time of two to three minutes can be used in the normothermic dog.

Two types of experiments were performed:

1. A control electrocardiogram was obtained. Simultaneous right and left cardiac catheterizations were performed by posterior percutaneous transthoracic approach using no. 18 thin-walled needles. The needle was used as an exploring electrode. The proximity of the atrium could be determined by the configuration of large bi-phasic P waves of the electrocardiogram. An atrial puncture was indicated by elevation of the P-R segment. Pressures were measured as nearly as possible in expiration through 12-inch lengths of PE 50 polyethylene catheter with Statham P23G strain gauges. Recordings were made on a photographic recorder (Electronics for Medicine, White Plains, New York) at paper speeds of 75 and 150 mm./sec. The two recording systems were tested and found to have simultaneous upstroke responses. The time delay of the impulse for this catheter system was not computed because the conclusions are derived from a comparison of observations made before and after block in each animal.

2. A suture was placed around the main bundle
TABLE 1

Asynchrony of Right and Left Ventricular Isometric Contraction and Interval Between Q and Right Ventricular Isometric Contraction Before and After Right Bundle-Branch Block

<table>
<thead>
<tr>
<th>Right ventricular delay before block</th>
<th>Mean ± Standard deviation</th>
<th>Right ventricular delay after block</th>
<th>Mean ± Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.010 to 0.020</td>
<td>0.030 ± 0.006</td>
<td></td>
</tr>
<tr>
<td>Delay due to block</td>
<td>0.010 ± 0.030</td>
<td>0.023 ± 0.005</td>
<td></td>
</tr>
<tr>
<td>Q-R interval before block</td>
<td>0.040 ± 0.050</td>
<td>0.042 ± 0.006</td>
<td></td>
</tr>
<tr>
<td>Q-R interval after block</td>
<td>0.060 ± 0.080</td>
<td>0.067 ± 0.007</td>
<td></td>
</tr>
</tbody>
</table>

*Time in seconds.
†Average of 18 animals.

TABLE 2

Asynchrony of Right and Left Ventricular Isometric Contraction with Delay of Right Ventricle Before and Delay of Left Ventricle After Left Bundle-Branch Block

<table>
<thead>
<tr>
<th>Right ventricular delay before block</th>
<th>Mean ± Standard deviation</th>
<th>Left ventricular delay after block</th>
<th>Mean ± Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.000 to 0.015</td>
<td>0.030 ± 0.008</td>
<td></td>
</tr>
<tr>
<td>Delay due to block</td>
<td>0.000 ± 0.030</td>
<td>0.021 ± 0.009</td>
<td></td>
</tr>
<tr>
<td>Q-L interval before block</td>
<td>0.025 to 0.040</td>
<td>0.032 ± 0.005</td>
<td></td>
</tr>
<tr>
<td>Q-L interval after block</td>
<td>0.040 ± 0.070</td>
<td>0.055 ± 0.010</td>
<td></td>
</tr>
</tbody>
</table>

*Average of 20 animals. Note also increased interval between Q and left ventricular isometric contraction after block.

Electrical-mechanical relationships were similarly studied in animals with complete heart block due to bilateral bundle-branch block. Two animals with QRS complexes resembling right bundle-branch block were included in the previous right bundle-branch block group, and 3 animals with QRS complexes resembling left bundle-branch block were included in the left bundle-branch block group. The results were similar in all cases. Thus, delayed electrical activation of the right ventricle was studied in 18 animals and delayed left ventricular activation was studied in 20 animals.

The pressure tracings of each experiment were analyzed for the relative time of onset of right and left ventricular isometric contraction and for the Q-ventricular upstroke (onset of QRS complex to onset of isometric ventricular contraction) inter-

Results

Tables 1 and 2 summarize the results of the right bundle-branch block group and the left bundle-branch block group of experiments. As the first line of each table indicates, there was usually a slight asynchrony in the control tracings, the onset of right ventricular isometric contraction following that of the left. In only one instance in the control tracings did the onset of right ventricular contraction precede the onset of left ventricular contraction. Right bundle-branch block produced a delay in the onset of right ventricular isometric contraction in all experiments. The mean value of the delay was 0.023 second, with a standard deviation of ± 0.005 second. Left bundle-branch block produced a delay in the onset of left ventricular isometric contraction in all but one experiment. The mean value of the delay was 0.021 second, with a standard deviation of ± 0.009 second. Following left bundle-branch block, the onset of left ventricular isometric contraction became either synchronous with, or followed the onset of, right ventricular isometric contraction. The change in the Q-ventricular upstroke inter-

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Simultaneous right and left ventricular pressure curves before and after right bundle-branch block produced by tension on suture encircling the right bundle. Note the delay of right ventricular isometric contraction and the change in contour of right ventricular pressure curve after block (time, 0.02 second).

val closely followed the change in the relative time of onset of contraction of the ventricles. The measured intervals found in the animals after bundle-branch block, as compared with the control measurements, were significant at less than the 0.01 level in both bundle-branch groups.

Figure 1 is taken from the second type of experiment and illustrates the effect of right bundle-branch block on the mechanical events of the heart. Bundle-branch block can be seen to appear when tension is applied to the suture encircling the right bundle branch. Note the delay in onset of right ventricular isometric contraction when right bundle-branch block is present. In addition to the delayed onset of right ventricular isometric contraction, there is a change in contour of the right intraventricular pressure curve. The complexes with bundle-branch block become "tened" with a peak in the midportion of the curve. Sufficient control of the pressure curves was attained only in the second type experiment to discern this change. It was seen in six of the nine animals in this group and was reproducible in these animals. No similar change in contour of the left intraventricular pressure curves could be detected with left bundle-branch block.

Figure 2 illustrates the delayed onset of left ventricular isometric contraction with left bundle-block. The onset of left ventricular isometric contraction precedes that of right ventricular isometric contraction in the control curves. Following left bundle-branch block, the onset of right ventricular isometric contraction precedes that of left ventricular isometric contraction. Often, if there was moderate or marked asynchrony in the control tracing, with left ventricular isometric contraction preceding right ventricular isometric contraction, the change with left bundle-branch block would be manifested by synchronous contraction or only slight asynchrony with right ventricular isometric contraction preceding left ventricular isometric contraction.

Precise interruption of the main bundle branch under direct vision, always produced the electrocardiogram of complete bundle-branch block. Interruption of the contra-lateral bundle branch was carried out in two animals with right bundle-branch block and in two animals with left bundle-branch block. This always produced complete heart block.

Discussion

Asynchronism in experimental bundle-branch block has been previously studied using simultaneous right and left intraventricular pressure to evaluate the mechanical events. These studies have been acute experiments in the opened-chest animal. Altamura et al., Frau and Porta, and Folli et al. demonstrated that bundle-branch block causes a delayed onset of contraction of the homolateral ventricle in the canine heart. However, Samet et al. were not able to substantiate this. They frequently found a delay in ventricular contraction of the blocked ventricle. However, because of a marked variation in the time of onset of right and left ventricular contraction in the controls, this was not thought to be statistically significant. They concluded that no consistent delay of mechanical events occurs in bundle-branch block.

The mechanical events of the heart, as measured by the techniques of the present
experiments, were very stable. In only one animal did the onset of right ventricular isometric contraction precede that of left ventricular isometric contraction in the control curves. Some asynchrony in the onset of isometric ventricular contraction, left preceding right, was usually found in the control tracings. This has been found by others in animals and in man.

These experiments have demonstrated that a delay in the onset of isometric contraction of the homolateral ventricle does occur in experimental bundle-branch block. This is not surprising in view of the fact that each ventricle has its own functionally separate specialized conduction system and that each ventricular muscle mass is normally activated separately. The muscular wall of each ventricle contains fasciculi which have some degree of anatomical separation. Particularly the deep bulbospiral muscle fibers, one of the main contractile components of the left ventricle, are anatomically confined to the left ventricle.

The maximum dissociation of right and left ventricular contraction that occurs in bundle-branch block is limited by the transmission time of the activation impulse through the cardiac muscle between the uninvolved portion of the septum and the free wall of the blocked ventricle. Electrical activation of the free wall of the homolateral ventricle in canine bundle-branch block is delayed approximately 0.04 seconds. On this basis, a delay of 0.04 seconds in the onset of isometric contraction of the blocked ventricle might be expected. The average delay found in our experiments was approximately 0.02 seconds, which is somewhat less than that found by other investigators. We do not have an explanation for this discrepancy between theoretical and actual delay found. However, many unknown factors are probably involved in the formation of effective measurable ventricular contraction, as related to the underlying electrical phenomenon.

The finding of a change in contour of the right intraventricular pressure curve with right bundle-branch block in many of our cases was unexpected. This might be explained as a manifestation of abnormal depolarization of the free right ventricular wall in right bundle-branch block. There is evidence that the spread is largely tangential. However, one would then expect a similar finding in the pressure curves of the left ventricle in left bundle-branch block. Perhaps a better explanation is that the formation of the right intraventricular pressure curve is significantly influenced by contraction of the comparatively massive left ventricle. A change in the synchrony of right and left ventricular contraction with right bundle-branch block might alter the temporal relationship of this effect and produce a change in the dynamics of the right intraventricular pressure curve. However, the comparatively weak contraction of the right ventricle would have little effect on the intraventricular pressure dynamics of the powerful left ventricle in left bundle-branch block.

Summary

Electrical-mechanical relationships of the canine heart were studied using simultaneous right and left intraventricular pressures. In the control tracings, there was usually some asynchrony in the onset of ventricular iso-
metric contraction with the right ventricle following the left ventricle. Right bundle-branch block and left bundle-branch block produced a delay in the onset of isometric contraction of the homolateral ventricle. A change in contour of the right intraventricular curve was frequently seen with right bundle-branch block.

References

Errata
Vol. IX, page 1217, line 14 of Methods: deflect should be changed to reflect.
Vol. IX, page 1220, table 1, dog no. 10, line on norepinephrine: PVR of 26.3 should be 19.3, the difference of +8.9 should be +5.4.
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