Left Anterior Arborization Block
Combined with Right Bundle Branch Block
in Canine and Primate Hearts

AN ELECTROCARDIOGRAPHIC STUDY

By Thomas B. Watt, Jr., M.D., Ph.D., Gerrit E. Freud, M.D.,
Dirk Durrer, M.D., and Raymond D. Pruitt, M.D., M.S. (Med.)

ABSTRACT

Interruption of anterior fibers of the left bundle branch system together with
right bundle branch block was accomplished experimentally in canine and
primate hearts. In both species the electrocardiographic effects included a major
alteration of the mean electrical axis to a superior and anterior direction. Epi-
cardial excitation was markedly delayed anteriorly, causing widening of the
QRS complex in standard electrocardiographic leads. Normal outward intra-
mural spread of excitation in anterior regions of the left ventricle was reversed
after left anterior arborization block alone. After addition of right bundle branch
block, intramural spread of excitation was again directed outwardly but was
markedly delayed in endocardial onset. Electrical effects of these blocks could
be "corrected" individually or in combination by introducing synchronized
electrical stimuli distal to each lesion. A scheme is proposed by which various
forms of intraventricular conduction disturbance can be defined in terms of
block of one or more divisions of a three-pronged system of rapid ventricular
excitation.

ADDITIONAL KEY WORDS intraventricular conduction disturbances
left axis deviation masquerading block QRS widening
bilateral bundle branch block epicardial excitation posterior precedence
transmural excitation synchronous endocardial stimulation dog
baboon

The electrocardiographic consequences of
complete block of either the left or the right
branches of the bundle of His are well es-
tablished, but speculation existed regarding
the significance of, subtotal interruption of
these conduction pathways (1). Recent ex-
perimental studies established the effect of
disturbances in anterior and posterior rami
of the left branch system in the canine heart
(2) and specifically confirmed the relationship
of left anterior arborization block to left axis
deviation in the primate (3). Several authors
(4-7) speculated on the electrical phenomena
which might derive from block of all the
right bundle branch together with only a por-
tion of the left bundle branch. However,
morphologic data essential to corroboration
were meager (8). The results described here
demonstrate the characteristic features attending
an anatomically verified combination of
left anterior arborization block and right bun-
dle branch block. Such features include not
only a unique form of complexes recorded
from standard electrocardiographic leads, but
also marked alterations of observed epicardial
and transmural patterns of excitation.

Methods

Studies on 24 mongrel dogs weighing about
15 kg and 10 baboons constitute the basis
Combined left anterior arborization block and right bundle branch block (LAAB + RBBB) in a dog results in both widened complexes and major alteration of axis. Lead designations are at left.

FIGURE 1

Results

The electrocardiographic consequences of left anterior arborization block followed by right bundle branch block in one dog are illustrated in Figure 1. The tracings before the block show that the ventricular complexes in leads II, III, and aVF included Q, R, and S deflections and that the mean electrical axis was semivertical in the frontal plane. Following left anterior arborization block alone, no major shift occurred in the mean frontal plane axis. After adding right bundle branch block to the existing left anterior arborization block, more evident alterations were present. The QRS interval increased from 0.05 to 0.09 sec, the electrical axis throughout ventricular excitation assumed a superior-left-anterior direction, and the mean electrical axis in the frontal plane shifted to $-70^\circ$. Figure 2 depicts results recorded from epicardial leads. In the control pattern of excitation, epicardial depolarization enveloped the heart from two relatively early centers of activity, one located near the anterior trabeculated zone of the right ventricle about halfway to the apex, and the other in a more lateral apical region. The last portion of the free wall to be depolarized was located posteriorly and basally. Excitation was complete in about 50 msec. Following left anterior arborization block alone, the focus of earliest right ventricular excitation was undisturbed, but the lateral apical focus shifted more apically with a marked delay in the spread of excitation into the lateral

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2Sernylan (Parke, Davis & Co.).
In the center is a drawing of the anterolateral aspect of the same canine heart as shown in Figure 2. Locations of 4 needle electrodes are indicated—one posterior at the end of the broken line from the left lower graph, and 3 anterior at the ends of the solid lines from the remaining graphs. See text for details of the graphs which depict timing of intrinsic deflections at several transmural levels.

Observations derived from multipolar needle electrodes introduced into the myocardium are presented in Figure 3 in which the pertinent electrode sites are identified. In each graph, the numbers on the vertical scale represent serial electrode positions every 2 mm along the shaft of the transmural needle—0 being near the tip of the needle and 10 near its base. Point 10 of each illustration is from the electrode nearest the epicardial level; the lowest number from which an intrinsic deflection could be recorded is from the electrode nearest the endocardium. The lower left graph portrays data derived from a needle placed in the left ventricular wall at a posterior site where excitation was altered neither by left anterior arborization block nor by right bundle branch block. Note that excitation began almost simultaneously at points 8, 7, and 6, occurring at 22, 23, and 26 msec, respectively, after onset of a measurable potential in the left ventricular cavity; excitation then spread slowly toward the epicardium: reaching point 9 at 28 msec and point 10 at 40 msec.

A needle electrode within the free wall of the right ventricle (upper left graph) recorded no appreciable delay following left anterior arborization block alone. However, with the production of right bundle branch block, the excitation time increased at subendocardial point 5 from 25 msec with left anterior arborization block alone to 51 msec following combined block. At epicardial point 10, the excitation time was 18 msec before and 78 msec after the added right bundle branch block. The direction of excitation was changed from nearly tangential spread before right bundle branch block to overtly outward spread afterward.

The results from those needle placements at which left anterior arborization block produced greatest changes in excitation times are shown in the right upper and lower panels.
Timing of intrinsic deflection at each transmural level of a needle electrode placed into the anterior myocardium of the left ventricle of a dog. Details are similar to those of the graphs in Figure 3. Note reversal in direction of radial spread from outward to inward after left anterior arborization block alone, changing again to a predominantly outward but delayed excitation after combined block.

of Figure 3. The sites of needle placement were along the left side of the anterior descending coronary artery. In the control, the course of excitation was clearly from endocardium to epicardium at both sites. Following left anterior arborization block, excitation arrived last at point 7 in the upper panel and at point 8 in the lower panel, indicating a spread of excitation to intramural levels from both the endocardium and the epicardium. After production of right bundle branch block, the outward spread from the endocardium was little affected, but the inward spread from the epicardium was eliminated. This suggests that in left anterior arborization block the epicardium of the anterior portion of the left ventricle derives its excitation from a right ventricular focus. A still better example of this phenomenon from another dog is presented in Figure 4, which is a graph similar in composition to those in Figure 3. The intramural needle was introduced into the anterolateral wall of the left ventricle near the interventricular sulcus, somewhat closer to the base than the apex. The earliest excitation before producing either lesion was at point 4 (11 msec) with nearly simultaneous excitation of points 3, 2, and 1. An outward spread to the epicardium is inferred from an excitation time of 27 msec at point 10. Following left anterior arborization block, excitation at point 10 was unchanged, but now excitation of that point, which had been latest, occurred earlier than at any other transmural point. After added right bundle branch block, point 1 remained excited at 65 msec, point 4 again became the earliest point of excitation at 59 msec, and excitation at point 10 was delayed to 81 msec.

In the two canine experiments represented by Figures 1 through 4, studies were conducted to show the consequences of artificial stimulation beyond the lesions that produced the combined block. A signal taken from the right atrium was utilized for timing a stimulating device so that two electrical impulses could be introduced, one beyond each respective lesion, at the instant excitation would have arrived at each site were it not for the lacerations. Both stimuli were bipolar and located at the endocardial level of the appropriate multipolar needle electrodes. Each

Effect in a dog of stimulation distal to lesions producing left anterior arborization block and right bundle branch block. First column is similar to last column of Figure 1 and represents combined block before stimulation. Second and third columns demonstrate the results of imposing an appropriately delayed stimulus from the right atrium onto endocardial sites distal to lesions producing left anterior arborization block (residual RBBB) and right bundle branch block (residual LAAB), respectively. Last column shows the effect of imposing stimuli at both sites concurrently—an essentially "normal" electrocardiogram.
Typical electrocardiographic patterns of combined left anterior arborization block plus right bundle branch block in the dog (left) and in the baboon (right). Leads are as indicated. Right-hand strip for each animal includes approximately perpendicular leads I, aVF, and V₆ at a paper speed of 200 mm/sec. Other strips are recorded at a paper speed of 50 mm/sec. Mean electrical axis is markedly superior and anterior. Right bundle branch block is not evident in lead V₆ due to opening of the chest, but can be seen in lead V₅ (esophageal) which clearly reflects expected reciprocal alterations posteriorly.

stimulus could be independently delayed by a precise interval following the right atrial synchronizing signal, and these delays were chosen empirically to return the electrocardiogram to a pattern as close as possible to that observed before the block. Figure 5 shows the consequences of this procedure. Stimulation distal to the site of left anterior arborization block produced some shortening of the QRS complex and a pattern like that of right bundle branch block alone. Stimulation distal to the site of right bundle branch block produced a pattern not readily distinguishable from left anterior arborization block alone (compare for the same dog column 3 of Figure 5 [LAAB] with column 2 of Figure 1 [LAAB]). Stimulation distal to the sites of both left anterior arborization block and right bundle branch block, utilizing the predetermined timing delays employed when stimulating each respective site alone, resulted in a nearly normal electrocardiogram (compare for the same dog column 4 of Figure 5 [Normal] with column 1 of Figure 1 [Control]). With this double stimulation, the ventricle that had been contracting sluggishly regained a vigorous pumping action.

In an earlier account (3), electrocardiographic consequences of left anterior arborization block in dog and baboon were compared. In contrast to the dog, major axis shift to the left occurred in the baboon after left anterior arborization block alone. After the addition of right bundle branch block, however, the QRS interval was widened in both dog and baboon, and both developed a markedly superior and anterior mean spatial axis (Figure 6). That the spread of epicardial excitation is similar in the two species at all stages of such an experiment is evident from a comparison of Figure 7 (a baboon) with Figure 2 (a dog). Figure 8 shows the pos-
Anterolateral sketch of a primate heart to show spread of epicardial excitation at each stage of the experiment. Compare with Figure 2 for corresponding results in a dog. Shading represents timing of intrinsic deflection in milliseconds after onset of QRS.

Posterior sketch of a baboon's heart (same experiment as in Figure 6) to show stepwise elimination of earliest excitation first from a lateral (leftward) focus in left anterior arborization block, then from a medial (rightward) focus in left anterior arborization block plus right bundle branch block. In this last stage, note the shaded bands representing both lateral and medial accession from a true posterobasal zone of earliest electrical activity.

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Figure 7

We have compiled the foregoing illustrations from 3 of the 24 dogs and from 2 of the 10 baboons studied in these experiments. Though individual animals showed minor variations, none yielded major conflicting data.

Discussion

Wilson, Johnston, and Barker (4) in 1934 presented three cases illustrating gradations of the phenomenon of left axis deviation combined with right bundle branch block. These they termed an "unusual type in right bundle-branch block." They proposed that the features in these electrocardiograms that were different from ordinary right bundle branch block resulted from some "additional factor," and suggested that one such factor might be a "lesion of some of the subdivisions of the left bundle-branch." Examples of similar electrocardiograms were identified by them in earlier publications of Mahaim in 1931 and Pardee in 1933. In Mahaim's account, an anteroseptal infarct was described which "showed lesions interrupting the right branch and the anterior subdivisions of the left."

Richman and Wolff (5) in 1954 reviewed several reports of tracings in which "precordial leads . . . were characteristic of right bundle branch block . . . (while) limb leads . . . were suggestive of left bundle branch block." These "paradoxical" tracings were regarded as left bundle branch block "masquerading" as right bundle branch block. In 1964 Lenegre (6) and Lepeschkin (7) under the heading of "bilateral bundle branch block" described still other instances of human tracings showing left axis deviation plus right bundle branch block. Though Lepeschkin's tabulation of pathologic defects showed a variety of lesions, he concluded that his "type VI" block...
was a combination of complete block of the right bundle branch and block of the anterior subdivision of the left bundle branch.

We propose that rapid spread of excitation into the ventricle may be regarded as proceeding along three pathways: (1) anteromedial (the right bundle branch), (2) anterolateral (the anterior or superior ramifications of the left bundle branch), and (3) posterior or posterobasal (the posterior or inferior ramifications of the left bundle branch). Intra-ventricular conduction defects may involve any one or combination of these three pathways. Six variations are possible; they are as follows:

1. **Anteromedial block** is the conventional right bundle branch block; rapid excitation of the ventricle is retained over both anterolateral and posterior pathways.

2. **Anterolateral block** is equivalent to left anterior arborization block, which in primates results in immediate profound left axis deviation.

3. **Posterior block** is equivalent to left posterior arborization block or "inferior intraventricular block" of Pryor and Blount (9).

4. **Anteromedial precedence** is the conventional left bundle branch block; rapid excitation of the ventricles remains only over the right bundle branch.

5. **Anterolateral precedence** is a left posterior arborization block combined with right bundle branch block, thus allowing rapid excitation only over anterolateral pathways.

6. **Posterior precedence** is a left anterior arborization block combined with right bundle branch block (reported herein) allowing rapid excitation only over posterior pathways and resulting in extreme left axis deviation in both dogs and primates.

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THOMAS B. WATT, Jr., GERRIT E. FREUD, DIRK DURRER and RAYMAND D. PRUITT

Circ Res. 1968;22:57-64
doi: 10.1161/01.RES.22.1.57

Circulation Research is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7330. Online ISSN: 1524-4571

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