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. Epicardial excitation was markedly delayed anteriorly, causing widening of the QRS complex in standard electrocardiographic leads. Normal outward intramural 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 established, but speculation existed regarding the significance of, subtotal interruption of these conduction pathways (1). Recent experimental 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 portion 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 bundle 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
of the present report. The dogs received pentobarbital (initially about 30 mg/kg intravenously). In the baboons, preliminary tranquillization with phencyclidine1 (2 to 3 mg/kg intramuscularly) preceded a lower dose of pentobarbital (initially 10 to 15 mg/kg intravenously). The heart was exposed by a midline sternal incision and supported in approximately normal position by a sling made from the pericardium. By the ligature technique (2), selected portions of the left bundle branch were blocked. Right bundle branch block was produced with a convex knife, the blade of which was about 2 mm long and 1 mm thick, introduced into the right ventricular cavity through the free wall of the ventricle.

Standard unipolar and bipolar extremity leads, unipolar chest leads, an esophageal (posterior) lead, and direct atraumatic epicardial leads were used for recording before left anterior arborization block, after left anterior arborization block alone, and after left anterior arborization block was combined with right bundle branch block. In several experiments the course of ventricular excitation was further studied by the recording of unipolar and bipolar complexes from points along multipolar needle electrodes (9) inserted into the myocardium at selected sites.

On completion of recordings, the extent and location of each septal laceration was determined.

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

---

1Sernylan (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.

In the most delayed zone, excitation occurred at about 80 msec. When right bundle branch block was superimposed, the apical focus remained unchanged, but the site of comparatively early right ventricular excitation was eliminated. Excitation of the entire right ventricular free wall was late and the pulmonary conus was latest (98 msec).

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
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 V₁ due to opening of the chest, but can be seen in lead V₆ (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 baboons 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.

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 pro-
ceeding along three pathways: (1) antero-
medial (the right bundle branch), (2) antero-
lateral (the anterior or superior ramifications
of the left bundle branch), and (3) posterior
or posterobasal (the posterior or inferior ram-
ifications of the left bundle branch). Intra-
ventricular conduction defects may involve
any one or combination of these three path-
ways. 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 antero-
lateral and posterior pathways.

2. Anterolateral block is equivalent to left
anterior arborization block, which in primates
results in immediate profound left axis de-
viation.

3. Posterior block is equivalent to left pos-
terior arborization block or "inferior intraven-
tricular block" of Pryor and Blount (9).

4. Anteromedial precedence is the conven-
tional left bundle branch block; rapid excita-
tion of the ventricles remains only over the
right bundle branch.

5. Anterolateral precedence is a left pos-
terior 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.

References

1. WATT, T. B., JR., AND PRUITT, R. D.: Cocaine-
induced incomplete bundle branch block in
dogs. Circulation Res. 15: 234, 1964. (For
further citations, see bibliography of this
article.)

2. WATT, T. B., JR., AND PRUITT, R. D.: Electro-
cardiographic findings associated with experi-
mental arborization block in dogs. Am. Heart

3. WATT, T. B., JR., MURAO, S., AND PRUITT, R. D.:
Left axis deviation induced experimentally in

4. WILSON, F. N., JOHNSTON, F. D., AND BARKER,
P. S.: Electrocardiograms of an unusual type
in right bundle-branch block. Am. Heart J.
9: 472, 1934.

5. RICHERMAN, J. L., AND WOLFF, L.: Left bundle
branch block masquerading as right bundle

6. LENEGRE, J.: Etiology and pathology of bi-
lateral bundle branch block in relation to
complete heart block. Progr. Cardiovascular

7. LEPESCHKIN, E.: Electrocardiographic diagnosis
of bilateral bundle branch block in relation to
heart block. Progr. Cardiovascular Diseases

8. WILSON, F. N., AND HERBST, G. R.: Experi-
mental study of incomplete bundle branch
block and of the refractory period of the
heart of the dog. Heart 8: 229, 1921, Expt. 32.

9. DURRER, D., AND VAN DER TWEEL, L. H.: Spread
of activation in the left ventricular wall of

10. PRYOR, R., AND BLOUNT, S. C., JR.: Clinical
significance of true left axis deviation. Am.
Left Anterior Arborization Block Combined with Right Bundle Branch Block in Canine and Primate Hearts: An Electrocardiographic Study
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
Copyright © 1968 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7330. Online ISSN: 1524-4571

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circres.ahajournals.org/content/22/1/57

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation Research can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation Research is online at:
http://circres.ahajournals.org/subscriptions/