Catheter Recording and Validation of Left Bundle-Branch Potentials in Intact Dogs

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SUMMARY
The left bundle-branch potential (LB), as well as His bundle (H) and atroventricular nodal (N) potentials, were recorded in intact dogs by using a tripolar electrode catheter positioned in the left ventricle. Simultaneous recordings of H and right bundle-branch (RB) activity from the right endocardial surface were also made. The LB potential was less rapid than the RB potential, but both occurred almost simultaneously after the H potential. Atrial premature stimulation was used to induce aberrant ventricular conduction (right or left bundle-branch block) and to verify the recorded bundle-branch potentials. During LBBB the LB potential became absent, while during RBBB the RB potential became absent, indicating blockage or delay of conduction. Incomplete LBBB showed a delay in the LB potential. Initial spontaneous activity in the left bundle branch or its Purkinje system was manifested by a premature beat which resembled a RBBB pattern electrocardiographically. Spontaneous activity in the right bundle branch or its terminal Purkinje system manifested as a LBBB pattern. The recording of bundle-branch potentials by this technic may enable investigators to study further the cardiac electrical phenomena in intact animals or in man.

Additional Indexing Words:
Aberrant intraventricular conduction
Cardiac catheterization
Left bundle-branch premature beat
Vagal stimulation
Atrial pacing
Bundle-branch block
His bundle premature beat
Right bundle-branch escape beat

The recording of electrical potentials from the specialized conducting tissues of the intact heart by the electrode catheter technic1,2 has enabled investigators to study more specific problems of impulse formation and conduction in animals and in man. Besides the His bundle potential, A-V nodal3,4 and right bundle-branch potentials3,5,6 have been obtained by use of this technic. In the present study the recording and validation of electrical potentials from the left bundle branch will be described.

Methods
Ten adult mongrel dogs were anesthetized with sodium pentobarbital (30 mg/kg) administered intravenously. All animals were in normal sinus rhythm with normal atroventricular conduction. The dogs were secured in the supine position. Tracheotomy was performed for artificial respiration. The right external jugular vein was exposed, and a bipolar electrode catheter was inserted and positioned fluoroscopically at the superior vena caval-right atrial junction for atrial pacing. A tripolar catheter was inserted percutaneously into the right femoral vein and positioned as previously described1,2 to record the His bundle and right bundle-branch potentials. The catheter electrodes were 2 mm long and 10 mm apart. The right common carotid artery was exposed for the insertion of a tripolar catheter which was positioned fluoroscopically just below the aortic valve, so that the electrodes were in contact with the septal surface (fig. 1). The right vagus nerve was isolated and sectioned. Two fine Teflon-coated stainless steel wires were inserted into the distal end of the vagus nerve for
Figure 1

Anteroposterior view of bipolar electrode catheters in the left ventricle (LV) and right ventricle (RV). The electrodes of the LV catheter are just beyond the aortic valve. Ao = ascending aorta; RA = right atrium.

electrical stimulation* (2-msec impulse duration, 500 cps). Right atrial pacing in the demand mode and premature atrial stimulation was accomplished using a battery powered pacemaker.†

For the recording of electrical potentials, the proximal electrodes of the cardiac catheter were connected to a distribution switch box‡ for the selection of bipolar leads. Each bipolar lead was connected to the a-c input of an ECG preamplifier, the filter frequencies of which were set at 40 and 500 Hz. A standard ECG lead or V1 precordial lead was simultaneously monitored and recorded. All records were made on a multichannel oscilloscopic photographic recorder§ at a paper speed of 200 mm/sec.

Results

Figure 1 is an anteroposterior view of the heart and illustrates the usual position of the right and left heart catheters. The distal pair of electrodes are positioned across the cuspid valve and record right bundle-branch potentials (RB). The proximal electrodes record His bundle (H) activity. The left heart catheter is positioned within the ventricular cavity just below the aortic valve and directed medially toward the high ventricular septum. The electrode catheters may be rotated slightly to obtain optimal recordings. In two dogs A-V nodal (N) and His bundle (H) potentials were obtained by positioning the left heart catheter in the sinus of the posterior cusp.

Figure 2 illustrates simultaneous recordings of H potentials from the right and left endocardial surfaces. The recording of N activity by the left heart catheter and a right bundle-branch potential (RB) by the right heart catheter are also shown. The N and RB potentials possess characteristics of contour and sequence like those previously described.8,4,7 The N potential is a slow notched wave which is contiguous with the

*Grass Medical Instruments, Quincy, Massachusetts.
†Medtronic, Inc., Minneapolis, Minnesota.
‡Electronics for Medicine, Inc., White Plains, New York.
atrial electrogram (A) and extends to the bundle of His deflection.

Figure 3 illustrates the simultaneous recording of left bundle-branch (LB) potentials by the left heart catheter and H and RB potentials recorded by the right heart catheter. The timing of these recordings is such that the H potential is followed by the LB and RB potentials. The LB potential is often less rapid than the RB potential. As illustrated in this figure, both H and RB potentials may often be recorded from the same pair of electrodes. At other times, the distal pair of electrodes recorded the RB potential from the right ventricular cavity, while the proximal pair recorded primarily H activity. The sequence of RB and LB recordings, which may vary approximately 5 msec, depended largely upon the location of the recording electrodes along the bundle branches.

Increasing the heart rate by atrial pacing (fig. 4) or slowing the heart rate by vagal stimulation (fig. 5) did not change the sequence of these potentials.

To validate the LB and RB potential recordings, premature atrial stimulation, as described by Cohen and associates, was utilized to produce aberrant intraventricular conduction.

In figure 6 an atrial premature stimulus resulted in normal ventricular depolarization. The H, LB, and RB sequence is unchanged from that of the control beat when the right atrium was prematurely stimulated. When alternate right and left bundle-branch block patterns were produced by prematurely stimulating the right atrium at a shorter coupling interval, there was a change in the sequence of the recorded potentials. In figure 7 beat 2 has a complete LBBB pattern. No LB potential is recorded for this beat, and this indicates a blockade or delay of conduction in
Atrial pacing at a rate faster than the sinus rate does not change the sequence or characteristics of the recorded potentials. Same animal as in figure 3.

In three dogs junctional premature beats were noted. Of interest were those premature beats which resulted in either a right or left bundle-branch block pattern. In figure 9 the first beat is a normal sinus beat. The H, LB, and RB potentials are in sequence and are all recorded prior to the onset of ventricular depolarization. The second beat is a premature His bundle beat which manifests a RBBB pattern. The H deflection precedes the onset of ventricular depolarization. The interval between the H deflection and the onset of ventricular depolarization (V) is the same as the H-V interval of the sinus beat. The LB potential follows the H deflection and also precedes the onset of ventricular depolarization. Absence of the RB potential indicates either conduction delay or block in the right bundle branch.

In figure 10 the second beat has a right bundle-branch block pattern in lead V₁ similar to that seen in figure 9. However, in figure 10 the electrographic recordings reveal a change of sequence to an LB, H, and RB. The LB potential precedes the onset of ventricular depolarization and is opposite in polarity compared with that of the control beat. The H potential occurs almost simultaneously with
VAGAL STIMULATION

V1

LB

RB

H

Figure 5

Electrical stimulation of the severed right cervical vagus nerve sufficient to slow the heart rate does not change the sequence or character of the recorded potentials. Same animal as in figures 3 and 4.

Ventricular depolarization, while the RB potential is recorded after the onset of ventricular depolarization. This sequence of events suggests that the premature beat arose in the left bundle branch or its Purkinje system and was retrogradely conducted to the bundle of His and anterogradely down the right bundle branch; the resultant QRS complex of this "left bundle-branch premature beat" has an RBBB pattern.

Escape beats are frequently seen during vagal stimulation when complete sino-atrial and atrioventricular nodal block is produced. In figure 11 such an escape beat was produced (panel B) with an incomplete left bundle-branch block pattern. The RB potential, which is unchanged in polarity compared with the control beat (panel A), precedes the onset of ventricular depolarization, and is followed by the H and LB potentials. The latter is inscribed just after the onset of ventricular depolarization. This sequence suggests that the escape beat arose in the right bundle...
Premature atrial stimulation at a shorter coupling interval than in figure 6 produces alternate left bundle-branch block (beat 2) and right bundle-branch block (beat 4) as shown in precordial lead V1. Beats 1 and 3 are control beats. During left bundle-branch block, the LB potential is absent, while during right bundle-branch block the RB potential is absent. Same animal as in figure 6.

branch and was conducted retrogradely to the bundle of His and antegradely down the left bundle branch; the resultant QRS complex of this “right bundle-branch escape beat” has an incomplete left bundle-branch block pattern similar to beat 5 in figure 8.

Beats 1, 2, and 4 are control sinus beats. The first premature atrial stimulus results in blockade below the His bundle. The second premature stimulus produces a delay in the left bundle branch and blockade or further delay in the right bundle branch, resulting in a RBBB pattern (beat 3). Beat 5 shows an incomplete LBBB pattern, with a slight delay in the inscription of the LB potential. Same animal as in figures 6 and 7.

Figure 7

Figure 8
The second beat is a His bundle premature beat; it also shows a right bundle-branch block pattern in precordial lead V1. The RB potential is absent.

Discussion

A variety of technics have been used to obtain recordings from various portions of the specialized conducting system of the heart. Burchell and co-workers11 used a plunge-needle technic to record the electrical activity of the right bundle-branch-Purkinje system. Alanis and co-workers12 first recorded the electrical activity of the bundle of His in 1958. Hoffman and co-workers13 obtained recordings from plaque electrodes sewn over different parts of the conducting system. Sodi-Pollares and associates8 used needle electrodes to record the electrical activity of the right and left bundle branches in the in situ dog heart preparation.

An electrode catheter technic has been used to record the electrical activity of the bundle of His in the intact dog heart and in man.1, 2 This same catheter technic has been used to record A-V nodal3, 4 and right bundle-branch potentials.5, 6 In this report the use of the electrode catheter technic has been extended to the recording of left bundle-branch potentials.

In this study validation of the left bundle-branch potentials was based on (1) the location and position of the electrode catheter, (2) the morphologic characteristics of the LB potential, and (3) the sequential changes in the H, RB, and LB relationships during induced and spontaneous aberrant ventricular depolarization. The associated and expected changes in the sequence of recordings during aberrant beats of both right and left bundle-branch block patterns proved to be a simple method of validation. However, in this study the absence of an RB potential during RBBB or an LB potential during LBBB did not indicate whether conduction was delayed or completely blocked. If only delay in conduction occurred, it is conceivable that the appropriate bundle-branch potential was inscribed within the ventricular electrogram and, thereby, masked.

While it is well documented that spontaneous activity (automaticity) occurs within the peripheral Purkinje network, relatively little is known concerning similar activity in the bundle branches.14 The premature beats in figures 9 and 10, showing both a RBBB pattern and absence of preceding atrial depolarization, and the escape beats like the one in figure 11B, and similar to beat 5 of
Figure 11

Panel A shows a control sinus beat. The bottom electrogram shows a combination of the H and RB potentials. In panel B, during vagal stimulation, an escape beat shows an incomplete LBBB pattern as manifested in lead V1. However, the sequence of the recorded potentials is RB to H to LB. The polarity of the RB potential is unchanged compared with that of the control beat. The LB potential is inscribed after the onset of ventricular depolarization.

Figure 8 showing an incomplete LBBB pattern were differentiated only by LB and RB potential recordings. One type of RBBB was produced by blockade or delay of conduction in the right bundle branch (fig. 9), another (fig. 10) by spontaneous activity in the left bundle branch or its terminal Purkinje network. The incomplete LBBB shown in figure 11 was produced by spontaneous activity in the right bundle branch or its terminal Purkinje network, while that in figure 8 was due to delay of conduction in the left bundle branch. The latter, however, was preceded by atrial depolarization.

The inconsistent lack of change of the polarity of the potentials from either bundle branch during spontaneous activity does not enable us to indicate with certainty whether automaticity occurred in the bundle branch or whether conduction in the bundle branch was retrograde from the Purkinje system. If automaticity were present in the bundle branch, the recording electrodes may have been either proximal or distal to the focus of origin, or the poles of the electrodes may have been at a right angle to the direction of conduction.

The recording and validation of the bundle-branch potentials described in this report may enable investigators to study further the electrical phenomena of cardiac conductive tissue in the intact animal or in man.

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