Left Ventricular Approach for Recording His Bundle Potential in Man*

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The electrical potentials of the His bundle (HB) were recorded from the left ventricular endocardial surface in 28 patients ranging from 16 to 63 years of age. In 14 of the patients the left bundle branch (LB) potentials were also obtained. Placement of a bipolar electrode catheter tip toward the interventricular septum, right at and also 1 to 2 cm below the aortic valve, resulted in stable recordings of both potentials in successive cardiac cycles even at performing atrial or HB pacing from the right heart. The following intervals were measured in milliseconds (msec): P-A, A-H, H, H-V, LB, and LB-V. The average values in 12 patients (average age 26±7 years and average heart rate 90±16 beats per minute) with normal A-V conduction were as follows: P-A 28±7, A-H 76±16, H 19±3 and H-V 45±6 msec. The average values for LB and LB-V in 10 of these 12 patients were 15±3 and 25±3 msec respectively. Validation of the His bundle electrogram (HBE) from the left ventricular endocardial surface was based on simultaneous recordings of the intracardiac electrograms from both left and right sides of the heart in 18 patients. The individual average values for the intervals obtained from both sides of the heart in these patients were statistically not different, except that the H potential was slightly longer in duration from the left heart (P = 0.05). Among these, 16 showed simultaneous onset of the H potentials, and the LB-V and RB-V conduction times from comparable points were almost the same. Indications for the left sided electrophysiologic studies include the following situations: (a) inability to record H from the right side of the heart; (b) giant right atrium; and (c) possibly during atrial fibrillation.

The electrode catheter technique for recording electrical activity of the specialized conducting tissue in man during right heart catheterization, first introduced by Scherlag et al in 1969,1 has been a simple, useful means for the study of human A-V conduction in both health and disease. This allows impulse transmission from the atrium to the ventricle to be analyzed at its various levels and aids in localizing the site of conduction abnormality of various forms of heart block.2 Moreover, this technique has been used to study physiologic and pharmacologic effects on the conducting system and also to clarify various arrhythmias.3,4

Recently, recordings from the His bundle (HB) and left bundle branch (LBB) during left heart catheterization in man have also been reported.6,8 Narula et al8 obtained records of the HB potential in seven of their eight patients, using an arterial approach with an electrode catheter introduced retrograde into the root of the aorta and positioned above the aortic valve in the posterior cusp. In the remaining one patient, they obtained the potential of the HB from the left side just across (below) the aortic valve. Lau et al10 and Ettinger and his associates10 have accomplished recordings of the HB, AV nodal and LB potentials from the left ventricular endocardial surface during left heart catheterization in adult mongrel dogs. Nevertheless, there have been few reports dealing with catheter recordings of the HB potential from the left ventricle in man.11

The purpose of the present communication is to report recording and validation of electrical activities of the HB obtained from the left ventricular endocardial surface in 28 patients. The usefulness of the left ventricular approach for recording electrical potentials of the specialized conduction tissue is also discussed and emphasized.

Materials and Methods

A total of 28 patients (15 men and 13 women ranging from 16 to 63 years of age) were studied mostly during diagnostic right heart catheterization and retrograde arterial catheterization of the left ventricle. Auricular fibrillation was present in four patients; the remainder had sinus rhythm. In 5 of the 28 patients the study was carried out primarily for investigation of possible conduction disturbance. Informed consent was obtained in all patients. The patients were studied in the postabsorptive state and were premedicated with 100 mg of secobarbital (Seconal) per os together with 50 to 100 mg of meperidine hydrochloride (Demerol) intramuscularly 30 min-

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utes prior to the study.

Three 6F bipolar electrode catheters (each with ring electrodes 2 mm wide and 10 mm apart) were used. One catheter was percutaneously introduced into the right femoral vein and positioned across the septal leaflet of the tricuspid valve, and HB potentials from the right side were recorded as described by Scherlag et al. The second catheter was inserted into the right brachial artery and advanced retrograde into the outflow tract of the left ventricle along the right border of the ascending aorta. An attempt was made to keep the catheter between the right coronary cusp and noncoronary cusp for stability.

HB potential was recorded by a technique similar to that used in canines by Lau et al. The catheter tip was positioned just below the aortic valve, directed toward medially and slightly posteriorly. Upon gentle adjustment a bipolar His bundle electrogram (HBE) was obtained from the left ventricle. The LB potential was recorded when the electrodes were positioned 1 to 2 cm below the valve along the ventricular septum. An additional bipolar catheter was positioned against the lateral wall of the right atrium near the superior vena cava and pacing was accomplished using a battery powered pacemaker (Nihon Kohden, MDP-2). The same bipolar catheter used for HB recording was then connected to the external pacemaker for HB pacing. The bundle of His was paced at different heart rates above the control levels and an atrial bipolar catheter was used to record the atrial activity during the pacing. Electrical potentials were recorded using an 8-channel oscilloscopic photographic recorder (Electronics for Medicine, DR-8) at frequency settings of 40 to 500 Hz on the ECG amplifier, at paper speeds of 100 and 200 mm/sec. A standard ECG (lead 2) was simultaneously monitored and recorded.

The following measurements were made in milliseconds:
1. P-A interval: the interval between the onset of the P wave (P) and the major rapid deflection of the A wave (A).
2. A-H interval: the interval from the first rapid deflection of the A wave (A) to the first rapid deflection of the His deflection (H).
3. H duration.
4. H-V interval: the interval from the first rapid H deflection to the earliest recordable onset of ventricular depolarization in the HBE (V) and/or lead 2 ECG (R or Q).
5. RB and LB duration.
6. RB-V and LB-V intervals: the intervals between the first rapid right or left bundle potentials (RB or LB) and the earliest ventricular depolarization of the HBE (V) and/or lead 2 ECG (R or Q).
7. PI-R interval: the interval from the pacemaker impulse to the earliest ventricular depolarization seen on the standard ECG lead 2 during HB pacing.

RESULTS

HBEs from the left ventricular endocardial surface were obtained in all 28 patients. Of these, 20 had simultaneous recording of the HB potential from the right side of the heart. In the remaining
FIGURE 3. Simultaneous recordings of His potentials (HBE) from both sides of the heart. The time of onset of His bundle activities (H) is almost simultaneous. The amplitude of H recorded from the left ventricle (bottom tracing) is much greater than that obtained from the right heart (top tracing). A difference of 5 msec between H-V times from both sides of the heart is probably non-significant.

eight, the HBEs were obtained from the left ventricle alone. In two of these eight patients, the recordings from the right heart were not successful, one because of the presence of relative tricuspid insufficiency secondary to severe pulmonary hypertension, and the other because of a large atrial septal defect with hyperdynamic right ventricle.

Figure 1 illustrates a bipolar HBE recorded from the left ventricular endocardial surface in a patient with primary pulmonary hypertension. The HB potential appears as a rapid biphasic or triphasic wave occurring between the atrial and ventricular electrograms. Biplane spot films to illustrate catheter position during recordings of the HB potential from the left ventricle in this patient are shown in Figure 2 (A and B). The catheter tip is noted right below the aortic valve, medial and slightly posterior to the tip of another HB recording catheter in the right heart.

The HB potentials recorded from both sides of the heart were similar in shape, but a somewhat longer duration was noted in those recorded from the left ventricle. Figure 3 illustrates simultaneous recordings of HB potentials from the right and left endocardial surfaces. The amplitude of the potential recorded from the left ventricle was often much greater than that obtained from the right heart. This was noted in 12 of 20 patients in whom simultaneous recordings from both sides of the heart were carried out. The mean values of the A-V conduction intervals, including A-H, H-V times and H duration measured from HBEs which were recorded simultaneously from both sides of the heart in 18 patients (excluding two patients with auricular fibrillation), are shown in Table 1. There was no statistical difference between both sides of the heart in A-H and H-V times. The H duration was, however, longer in that recorded from the left ventricle than that from the right (P = 0.05). The time of onset of H deflection from both sides was simultaneous in 16 cases. Of the remaining two cases, the onset of H deflection from the left side was 5 and 10 msec earlier than that from the right side.

The recording of HB potential from the left ventricle could also be accomplished in patients with aortic insufficiency. With little movement of the

Table 1—Comparison of Conducting Intervals (mean ± 1SD) in Simultaneously Recorded HBEs from Both Sides of the Heart (18 cases*)

<table>
<thead>
<tr>
<th>Site of HBE recording</th>
<th>Heart rate (beat/min)</th>
<th>A-H (msec)</th>
<th>H (msec)</th>
<th>H-V (msec)</th>
<th>B (msec)</th>
<th>B-V (msec)</th>
<th>Onset of H potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV</td>
<td>82 ± 10</td>
<td>81 ± 18</td>
<td>20 ± 2</td>
<td>48 ± 9</td>
<td>13 ± 3</td>
<td>25 ± 4</td>
<td>Simultaneous in 16 of 18** cases</td>
</tr>
<tr>
<td>LV</td>
<td></td>
<td>78 ± 16</td>
<td>22 ± 4</td>
<td>48 ± 10</td>
<td>15 ± 4</td>
<td>24 ± 2</td>
<td></td>
</tr>
</tbody>
</table>

Probability P = 0.6 P = 0.05 P = 0.9 P = 0.4 P = 0.7

* Two other patients with auricular fibrillation were excluded.
**In two patients, the onset of H potential recorded from the left ventricular endocardial surface was 5 and 10 msec earlier than that from the right ventricular endocardial surface.
SD = standard deviation; HBE = His bundle electrogram; min = minute; msec = millisecond; RV = right ventricle; LV = left ventricle; B = bundle branch.
Atrial Pacing

HBE (LV)

ECG - II

ATRIAL PACING (145/min)

Figure 5. The effect of atrial pacing on atioventricular conduction at a pacing rate of 145 beats/min shows progressive lengthening of A-H intervals with stable H spikes and constant H-V intervals until block occurs at the A-V junction. PI = pacing impulse.

catheter position in the left ventricular endocardial surface, however, potentials of LB and proximal LB could be recorded together with H deflection in a series of tracings. This has happened on only one occasion in a patient with combined valvular lesions (aortic insufficiency and mitral stenosis) and auricular fibrillation (Fig 4). The individual potentials can be identified by their timing relationships without difficulty, but simultaneous recording of HBE from the right side might have been preferable for more definitive validation.

Atrial Pacing

To validate the HB potential recordings, atrial pacing was carried out in ten patients. Effect of atrial pacing on the relationships of HB activity recorded from the left ventricular endocardial surface to atrial and ventricular activities in a patient who had rate-dependent second degree A-V block, is illustrated in Figure 5. Increasing the heart rate with atrial pacing resulted in a progressive lengthening of the A-H interval, but constant H-V time. Second degree A-V block of Wenckebach type occurred at a rate of 145 beats/minute. In all patients the HB spikes obtained from the left ventricle remained stable throughout the pacing.

HB Pacing

HB pacing from the ventricular electrode catheter of either side was carried out in 11 patients. The pacing artifacts at the time of HB pacing almost always overlapped the H deflections recorded from the opposite side, and the time interval between pacing impulse and V wave, most of the time, was identical to H-V interval before pacing (Table 2).

Left Bundle Electrogram (LBE)

LB potentials were obtained in 14 patients. It consisted of a rapid biphasic or triphasic deflection. In six patients in whom both right and left bundle potentials were recorded, the time durations of the bundles and the intervals from their onset to the earliest ventricular activities were not statistically different (Table 1).

A-V Conduction Intervals in Man
(with normal A-V conduction obtained from the left ventricle)

Recordings of HBE by the left ventricular ap-

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Pacing Rate (beat/min.)</th>
<th>PI-R (or Q) Time (msec)</th>
<th>H-V Time (msec)</th>
<th>Retrograde conduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>140 (RV)</td>
<td>46 (RV)</td>
<td>43 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>100 (RV)</td>
<td>42 (RV)</td>
<td>41 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>100 (RV)</td>
<td>45 (RV)</td>
<td>43 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>4</td>
<td>100 (RV)</td>
<td>52 (RV)</td>
<td>55 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>5</td>
<td>80 (RV)</td>
<td>36 (RV)</td>
<td>36 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>6</td>
<td>100 (RV)</td>
<td>38 (RV)</td>
<td>38 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>7</td>
<td>100 (LV)</td>
<td>46 (LV)</td>
<td>46 (LV)</td>
<td>no</td>
</tr>
<tr>
<td>8</td>
<td>100 (RV)</td>
<td>52 (RV)</td>
<td>50 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>9</td>
<td>110 (LV)</td>
<td>55 (LV)</td>
<td>56 (LV)</td>
<td>yes</td>
</tr>
<tr>
<td>10</td>
<td>100 (RV)</td>
<td>55 (RV)</td>
<td>53 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>11</td>
<td>80 (RV)</td>
<td>49 (RV)</td>
<td>50 (RV)</td>
<td>no</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>46.9 ± 6.4</td>
<td>46.5 ± 6.8</td>
<td></td>
<td>t = -0.16, P = 0.9</td>
</tr>
</tbody>
</table>

RV = right ventricle; LV = left ventricle; SD = standard deviation; min = minute; msec = millisecond.
and between the noncoronary cusp and right coronary cusp, the right below the aortic valve of His (or A-V bundle) is composed of a nonbranching portion and a branching portion enclosed by the central fibrous trigon. The penetrating part of the former is further divided into penetrating and nonpenetrating parts. The penetrating part of the nonbranching portion is enclosed by the central fibrous body. The nonbranching portion of the common stem passes through the right fibrous trigon to reach the top of the interventricular septum along the posterior and inferior margin of the membranous portion where it begins to bifurcate. From this anatomic standpoint, it is conceivable that the HB potential can be recorded when the catheter electrode is positioned adjacent to the membranous septum (right below the aortic valve and between the noncoronary cusp and right coronary cusp).

There have been only a few reports in which the HB potential is recorded from the left ventricular endocardial surface. This is probably because of the lack of indications for this procedure, and right heart approach is the procedure of choice. It is interesting, however, to accomplish such recordings as will add to our experience and extend our understanding of cardiac electrophysiology. In the present study, utilizing a bipolar electrode catheter placed in the subaortic region (with the tip directed medially and slightly posteriorly), we have recorded potentials that, we believe, represent depolarization of the HB in a total of 28 patients.

The reasons for accepting these as the HB activation are:

1. The electrograms were obtained from the high ventricular septum with catheter electrode positioned right below the aortic valve.
2. The HB deflections which were recorded simultaneously from both sides of the heart in 18 patients, disclosed almost simultaneous activation, except in two patients, and the measured H-V intervals were statistically not different in both sides of the heart. The onset of the H potential recorded from the left ventricular endocardial surface was never found to be later than that from the right ventricular route. In two occasions the former occurred 5 and 10 msec earlier, respectively.
3. HB pacing from the left side of the heart in two patients showed overlap of the pacing artifacts in the recorded H deflections from the right side of the heart.
4. The H potential recorded from the left ventricle was followed by LB, and/or RB obtained from the right and the sequence was normal in patients with normal A-V conduction.

The left ventricular approach for recording H potentials was not difficult and was without complications. In all patients, the performed arteriotomy did not cause diminished pulse in the peripheral artery. An HBE could usually be recorded within five minutes after insertion of the electrode catheter into the left ventricle through the aortic valve. With the catheter between the right coronary cusp and noncoronary cusp (keeping the catheter toward the medial side of the ascending aorta), stable recordings could be obtained even on atrial pacing from either atrium and HB pacing could also be obtained from the left ventricle. In all the cases thus far studied in our laboratory, HB recordings have been obtained in all but one patient with proven severe aortic regurgitation. In contrast, Scherlag’s method has failed to record HB potentials in two out of 28 patients. These failures of recording from the right ventricular approach were obtained in 12 adult patients (average age 26±7 years) with normal A-V conduction, i.e., normal P-R interval (0.12 to 0.20 sec), normal mean frontal QRS axis (0° to +110°), normal QRS duration (<0.10 sec) and a normal QRS morphology on conventional ECGs. Tables 3 and 4 show the mean values and ranges (±1 SD). The average P-A time A-H time, H duration and H-V time for heart rate of 90±16 beats/min were 28±7, 76±16, 19±3 and 45±6 msec respectively. In 10 of these 12 patients, the LB potentials were also recorded. The LB duration averaged 15±3 msec. The average value for the LB-V interval was 25±3 msec.

### Table 3—A-V Conduction Intervals (mean ± ISD) in Man with Normal A-V Conduction (HBEs from the left ventricle in 12 cases)

<table>
<thead>
<tr>
<th>Age (beat/min)</th>
<th>Heart rate</th>
<th>Conduction time (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td>P-A</td>
</tr>
<tr>
<td>26±7</td>
<td>90±16</td>
<td>28±7</td>
</tr>
</tbody>
</table>

SD = standard deviation; HBE = His bundle electrogram; msec = millisecond; min = minute.

### Table 4—Values of Intraventricular Conduction Intervals (mean ± ISD) in Man with Normal Intraventricular Conduction (LBEs in 10 cases)

<table>
<thead>
<tr>
<th>Age (beat/min)</th>
<th>Heart rate</th>
<th>Conduction time (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LB</td>
</tr>
<tr>
<td>27±7</td>
<td>93±15</td>
<td>15±3</td>
</tr>
</tbody>
</table>

SD = standard deviation; LBE = left bundle electrogram; min = minute; msec = millisecond.
heart have been encountered in one patient with secundum atrial septal defect with large left-to-right shunt and in other with the relative tricuspid valvular insufficiency secondary to severe pulmonary hypertension in our series. Similar failure to record in secundum atrial septal defect with large left-to-right shunt has been reported.16

Wolff et al11 have recently stated that to record the H potential from the right side of the heart in endocardial cushion defect, it is necessary to position the catheter more posteriorly, and the recording can only be accomplished in the subaortic region in L-transposition of the great arteries. In these patients, because of the aforementioned diseases or some other tricuspid valve lesions, such as tricuspid valve stenosis, Ebstein’s anomaly of the tricuspid valve, and tricuspid atresia, and on patients from whom HBE cannot be obtained from the right side of the heart, the left ventricular approach might be useful, following failure of recording from the aortic root as described by Narula et al.6

Moreover, the left ventricular approach for recording HBE yields H deflections much more conspicuous than those recorded from the right one. This superiority has been encountered in 12 of 20 patients and this approach for recording HB potentials is considered to be more appropriate in patients with auricular fibrillation. However, the left ventricular approach necessitates arteriotomy which might be associated with more morbidity than right heart procedure, and for that reason left sided electrophysiologic studies should be carried out with caution.

CONCLUSION

The time intervals for normal A-V conduction in man as measured from HBE recorded from the left ventricular approach were similar to those obtained from the right side. The values (mean ± 1SD) for right ventricular approach in our 26 cases with average age of 24±8 years and heart rate of 86±15 beats/minute were: PA = 27±6, A-H = 74±11, H = 19±2 and H-V = 44±6 msec.17 The duration of H deflection was, however, slightly longer in HBE recorded from the left ventricle than that obtained from the right side of the heart in simultaneously recorded patients (P = 0.05).

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