Histopathology of Heart Block Complicating
Acute Myocardial Infarction

Correlation with the His Bundle Electrogram

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SUMMARY
Histopathological studies of the conduction system were related to His bundle electrogram recordings in seven patients with acute myocardial infarction and atrioventricular (A-V) conduction disturbances. The three patients with inferior infarctions had normal width QRS complexes and delay or block of the impulses above the His bundle. Recent ischemic changes were present in the A-V node in two cases and in the distal conduction system in all three cases. In the four patients with antero-septal infarction and right bundle branch block (RBBB), either the H-V interval was prolonged or block was present below the H spike. The A-H interval was normal in each of these cases, and the A-V node was not affected by the recent infarction. The right bundle branch was involved in all four of these cases and two patients also had involvement of the left bundle branch. In general there was a good correlation between the sites of heart block as defined by the His bundle electrogram and the histopathological analysis of the cardiac conduction system.

Additional Indexing Words:
Coronary artery Sinoatrial node Atrioventricular conduction system

The technique of recording His bundle electrograms has been invaluable in the understanding of the pathophysiology of a variety of conduction defects. With the information from the His bundle electrogram atrioventricular conduction time can be separated into two components; the A-H interval, representing the atrioventricular (A-V) nodal conduction time, and the H-V interval, which reflects the time of conduction over the distal His bundle and peripheral conduction system. The majoritiy of published studies have dealt with clinical correlations between the electrocardiogram (ECG) and His bundle electrograms. There has been an occasional report of correlation of the His bundle electrogram with the structural changes of the cardiac conduction system, but to our knowledge, none of the association with acute myocardial infarction.

Here we relate the histopathological findings in the conduction systems of seven patients with heart block complicating acute myocardial infarction with His bundle electrograms performed in these same patients.

Materials and Methods

Patients
Since 1971 we have recorded His bundle electrograms in more than 25 patients with acute myocardial infarction while temporary transvenous pacemaker electrodes were being inserted for correction of a variety of conduction disturbances. The seven patients in this study (table 1) were all admitted with severe ischemic chest pain and clinically considered to have acute myocardial infarction. The diagnosis was later confirmed by electrocardiographic and/or serum enzyme studies in all the patients. Second degree heart block was present on admission in one patient (Case VII) and the atrioventricular (A-V) block developed later in another five cases (I, III, IV, V, VI). The remaining patient (Case II) was paced because of the development of right bundle branch block and left axis deviation associated with an anteroseptal infarction. A
### Table 1

**Clinical and His Bundle Electrogram Findings**

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex/Age</th>
<th>History</th>
<th>ECG</th>
<th>Clinical course</th>
<th>HB EG</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>M 60</td>
<td>Many ischemic episodes. Admitted with further chest pain. Developed RBBB and LAD. On the 5th day, developed CHB.</td>
<td>CHB rate 35/min. RBBB pattern. QRS 0.12 sec wide. Frontal axis -90°. Anterior infarct.</td>
<td>Pacing was commenced and he returned to SR (P-R 0.18 sec) on the 7th day. On the 16th day, he died suddenly in asystole.</td>
<td>CHB</td>
</tr>
<tr>
<td>II</td>
<td>M 57</td>
<td>Past history of anterior myocardial infarction. Readmitted with further chest pain.</td>
<td>SR. P-R 0.16 sec RBBB. QRS 0.16 sec wide. Frontal axis -60°. Old anterior infarct.</td>
<td>Pacing was commenced. The next day developed pulmonary edema. He remained in congestive failure and died on 10th day.</td>
<td>SR</td>
</tr>
<tr>
<td>III</td>
<td>M 57</td>
<td>Admitted with acute myocardial infarction and mild cardiac failure. Developed VF 5 hours after onset. Was then noted to be in CHB.</td>
<td>CHB. RBBB. QRS 0.14 sec wide. Axis -80°. Acute anterior infarction.</td>
<td>Pacing was commenced and he returned to SR (P-R 0.16 sec) on 6th day. On day 8 developed a loud systolic murmur and died in pulmonary edema.</td>
<td>SR</td>
</tr>
<tr>
<td>IV</td>
<td>M 51</td>
<td>Angina pectoris for 2 years. Admitted with severe chest pain and cardiac failure.</td>
<td>SR. P-R 0.14 sec RBBB. QRS 0.14 sec wide. Axis +90°. Old inferior infarction.</td>
<td>On the 2nd day developed CHB. Pacing was commenced and he returned to SR on the 7th day. On the 12th developed VF, cardiogenic shock, and died the next day.</td>
<td>CHB</td>
</tr>
<tr>
<td>V</td>
<td>M 64</td>
<td>Lateral infarction two years previously. Readmitted with acute inferior infarction and cardiac failure.</td>
<td>SR. P-R 0.24 sec QRS 0.09 sec wide. Axis -30°. Recent inferior infarction.</td>
<td>Developed CHB on day 3. After pacing returned to SR. (P-R 0.24 sec) Remained in cardiac failure and died suddenly on 7th day.</td>
<td>CHB</td>
</tr>
<tr>
<td>VI</td>
<td>M 52</td>
<td>Angina pectoris and inferior infarction 2 years previously. Readmitted with chest pain but no signs of cardiac failure.</td>
<td>SR. P-R 0.20 sec QRS 0.09 sec wide. Axis 0°. Old inferior infarction.</td>
<td>Developed Wenckebach block. Pacing was commenced but he died suddenly on the 4th day.</td>
<td>SR</td>
</tr>
<tr>
<td>VII</td>
<td>M 44</td>
<td>Admitted with acute inferior infarction. No cardiac failure.</td>
<td>SR. Wenckebach block. QRS 0.08 sec wide. Frontal axis +60°. Old anterior and recent inferior infarction.</td>
<td>Pacing was commenced. He reverted to SR. (P-R 0.22 sec) but on the 5th day died suddenly.</td>
<td>CHB</td>
</tr>
</tbody>
</table>

**Abbreviations:** RBBB = right bundle branch block; LAD = left axis deviation; CHB = complete heart block; SR = sinus rhythm; VF = ventricular fibrillation; HB EG = His bundle electrogram.

brief history, clinical course, ECG, and His bundle electrogram findings of each patient are shown in table 1.

### His Bundle Electrogram

His bundle electrogram studies were performed under local anesthesia using a tripolar No. 7 USCI catheter introduced percutaneously from the right groin.\(^3\), \(^11\), \(^16\)-\(^18\) The catheter was positioned across the tricuspid valve under fluoroscopic control and manipulated to achieve the optimal recording of the His deflection. The signal was passed through a battery box to two phonocardiographic preamplifiers (frequency 25-100 cycles per second) and an ECG preamplifier. One or two surface ECG leads, chosen to show the clear onset of ventricular activity, were also used. The signals were observed on a Sanborn 764 eight channel oscilloscope.
and recorded on light sensitive paper at 100 msec on a Sanborn 560 recorder.

Following the recording of the His bundle electrogram, using the same femoral vein, a bipolar pacing catheter was positioned at the apex of the right ventricle.

Measurements were made of the A-H interval (from the onset of atrial activity on the His bundle electrogram to the first rapid deflection of the H spike) and H-V interval (from the first rapid deflection on the H spike to the earliest evidence of ventricular activity as seen on any of the surface or intracardiac recordings). At least five beats were measured and averaged. We have used the methods of measurement and normal values published by Narula.5,7 The normal values for A-H and H-V intervals are 50-120 msec and 35-45 msec, respectively. The drugs the patient had been receiving prior to the His bundle electrogram included digoxin (Cases I, II, VI) and thiazide diuretics and potassium chloride (Cases II, IV, VII). The serum potassium levels ranged between 3.8-5.3 mEq/liter (normal values 3.5-5.5 mEq/liter) at the time of the study.

Pathologic Studies

A complete autopsy was performed in all seven patients within four to 26 hours of death. The epicardial coronary arteries down to the size of 2 mm in external diameter were transected at 2-3 mm intervals. Calcified vessels were first dissected out in toto and decalcified before making the transection. Serial blocks were taken from each coronary artery for histological examination.

After the nature, size, and location of grossly discernible lesions in the opened heart were noted, multiple myocardial tissue blocks were sampled from both sides of the heart including apparently normal, scarred, and infarcted areas. The conduction system was studied by the techniques described by Lev19 including the sinoatrial (SA) node, the atroventricular (AV) node, the A-V (His) bundle and bundle branches through the level of the moderator band. All tissue blocks were fixed in formalin and embedded in paraffin. The sections were cut at 5-7μ thickness and stained with hematoxylin and eosin, Mallory-Heidenhain stain, and elastic-van Gieson stain.

Results

His Bundle Electrogram Recordings

Two of the patients with inferior infarction were in complete heart block with block below the His bundle recording site, and the third patient was in 2:1 block. The A-H interval was prolonged (150 msec) in the one patient in whom it could be measured (Case VI, fig. 3). The H-V intervals measured 55, 50 (Case VII, fig. 4), and 45 msec.

Autopsy Findings

The findings are summarized in table 2.

In all cases the heart weight exceeded 400 g and there was hypertrophy and dilatation of all chambers, particularly the left ventricle.

The coronary distribution was right preponderant in all but two patients (Cases IV, V). Significant coronary artery disease, defined as greater than 75% atherosclerotic luminal narrowing, affected three vessels in five patients and two vessels in two patients (Case I, II). Coronary thrombi were found in one or more epicardial vessels in every patient and in general they corresponded with the location of the infarcts.

The histological ages of the infarcts indicated that all patients had survived for at least one week following the onset of irreversible myocardial

![Figure 1](https://circ.ahajournals.org/)

*Figure 1*

His bundle electrogram (HBE) in Case I. Each A wave is followed by an H spike. There is distal (Mobitz II) block. A-H interval is 86 msec.

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ischemia. It was also evident that the infarcts in some patients appeared histologically older than were implied by the symptomatology (tables 1 and 2). Evidence of previous ischemic damage to the myocardium (fibrous scars) was present in all patients. The location of infarcts was antero-septal in four patients (Cases I, II, III, IV), postero-septal in two patients (Cases V, VI), and antero-septo-posterior in one patient (Case VII). In every case, the estimated size of the infarct had exceeded 50% of the total left ventricular muscle.

The histopathology of the conduction system was tabulated (table 2) and shown graphically in figures 5 and 6.

Fibrosis and fatty changes of the SA and A-V nodal fibers were evident in all patients. There was no thrombotic occlusion of the SA node or A-V node artery though intimal fibrosis of varying degrees was seen in Cases I and VI.

Ischemic necrosis of the A-V nodal fibers was not seen in any of the four patients with anterior infarction, but was found in two of the three patients (Case VI and VII) with posterior infarction. In one

<table>
<thead>
<tr>
<th>HBE</th>
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<tbody>
<tr>
<td>A-H = 75 m. sec.</td>
<td>H-V = 100 m. sec.</td>
<td></td>
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<tr>
<td>H 69</td>
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</table>

Figure 2

His bundle electrogram (HBE) recorded during sinus rhythm in Case III. A-H interval is 75 msec (normal) and H-V interval is 100 msec.

(Case VII), the proximal half of the A-V node was infarcted, and in the other (Case VI) microinfarcts were scattered throughout the A-V node (fig. 7). Histological evidence of infarction of the distal bundle branches was seen in all seven patients, associated with extensive (full-thickness) infarction of the ventricular septum in every case (fig. 8). Infarction of the His bundle was seen in one patient (Case I, fig. 9).

<table>
<thead>
<tr>
<th>EGG</th>
<th>EGG</th>
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<td>H-V = 45</td>
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<td>H 99</td>
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</table>

Figure 4

His bundle electrogram during complete heart block in Case VII. H-V interval is 45 msec.
### Table 2

**Pathological Findings**

<table>
<thead>
<tr>
<th>Case</th>
<th>Heart wt (g)</th>
<th>Coronary arteries</th>
<th>Myocardium</th>
<th>SA node</th>
<th>A-V node</th>
<th>His bundle and bundle branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>525</td>
<td>Right preponderant.</td>
<td>Recent (3 wk) antero-septal infarct in the basal half of LV; multifocal scars elsewhere; apical aneurysmal dilatation.</td>
<td>Intimal thickening of SA node artery; fibrosis &amp; fatty replacement of nodal tissue.</td>
<td>Intimal thickening of A-V node artery; fibrosis, &amp; fatty replacement of nodal tissue.</td>
<td>Fibrosis &amp; atrophy of proximal His bundle fibers. Capillary proliferation &amp; inflammatory infiltrate at His bundle bifurcation. Infarction of both bundle branches. (fig. 9)</td>
</tr>
<tr>
<td>III</td>
<td>510</td>
<td>Right preponderant.</td>
<td>Recent (10-14 day) antero-septal infarct from apex to base LV; multifocal scars RV.</td>
<td>Essentially normal.</td>
<td>Essentially normal.</td>
<td>Fibrosis of distal His bundle and of left bundle branch. Infarction of right bundle branch. (fig. 8)</td>
</tr>
<tr>
<td>IV</td>
<td>630</td>
<td>Left preponderant.</td>
<td>Recent (2 wk) antero-septal infarct in basal half of LV; apical aneurysmal dilatation; multifocal scars in both ventricles.</td>
<td>Fibrosis &amp; atrophy of nodal tissue.</td>
<td>Fibrosis of nodal tissue.</td>
<td>Essentially normal His bundle; fibrosis of left bundle branch; infarction of distal right bundle.</td>
</tr>
<tr>
<td>V</td>
<td>590</td>
<td>Left preponderant.</td>
<td>Recent (1 wk) in septal &amp; posterior walls of LV, extending from apex to the base of heart.</td>
<td>Marked fibrosis &amp; fatty replacement of nodal tissue.</td>
<td>Fibrosis of nodal tissue.</td>
<td>Fibrosis of His bundle and proximal bundle branches. Infarction of distal segments of both bundle branches.</td>
</tr>
<tr>
<td>VI</td>
<td>415</td>
<td>Right preponderant.</td>
<td>Recent (2 wk) posteroseptal wall of LV with extension to posterior half of lateral wall.</td>
<td>Thickening of SA node artery; diffuse fibrosis of nodal tissue.</td>
<td>Fibrosis of nodal tissue and micro-infarcts.</td>
<td>Fibrosis &amp; atrophy of His bundle and right bundle branch fibers; infarction of distal segments of left bundle.</td>
</tr>
<tr>
<td>VII</td>
<td>495</td>
<td>Right preponderant.</td>
<td>Recent (10-14 day) infarct of LV sparing the lateral wall.</td>
<td>Essentially normal.</td>
<td>Infarction of the proximal nodal fibers. (fig. 7)</td>
<td>Fibrosis &amp; atrophy of His bundle and proximal segments of both bundle branches. Infarction of distal parts of both bundle branches.</td>
</tr>
</tbody>
</table>

**Abbreviations:** LAD = left anterior descending; LCA = left circumflex artery; RCA = right coronary artery; LV = left ventricle; RV = right ventricle; significant disease = more than 75% luminal narrowing; A-V = atrioventricular; SA = sinoatrial.
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CASE

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<tr>
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<tr>
<td>I</td>
<td>AH 86</td>
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<td></td>
<td>HV –</td>
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<tr>
<td>II</td>
<td>AH 90</td>
<td></td>
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<td></td>
<td>HV 50</td>
<td></td>
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<tr>
<td>III</td>
<td>AH 75</td>
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<tr>
<td></td>
<td>HV 100</td>
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</tr>
<tr>
<td>IV</td>
<td>AH 65</td>
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<td>HV –</td>
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</table>

**Figure 5**

Graphic demonstration of correlation of His bundle electrogram and histopathologic findings in anterior infarction. A-H and H-V intervals in milliseconds. (a) coronary arteries; (b) ventricular map through the midsection of the heart; infarction implies acute infarction. (c) schematic drawing of the atrioventricular conduction system of the heart, major divisions of left bundle branch are represented by two pairs of fascicles.

**CASE**

<table>
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<tr>
<td>V</td>
<td>AH –</td>
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<tr>
<td></td>
<td>HV 55</td>
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<td>VI</td>
<td>AH 150</td>
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<td></td>
<td>HV 50</td>
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<tr>
<td>VII</td>
<td>AH –</td>
<td></td>
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<tr>
<td></td>
<td>HV 45</td>
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</tr>
</tbody>
</table>

**Figure 6**

Graphic correlation of His bundle electrogram and histopathologic findings in posterior infarction. A-H and H-V intervals in milliseconds. (a) coronary arteries; (b) ventricular map through the midsection of the heart; infarction implies acute infarction; (c) schematic drawing of the atrioventricular conduction system of the heart, major divisions of left bundle branch are represented by two pairs of fascicles.

**Discussion**

Correlative studies of His bundle electrograms and conduction system histopathology have been reported in three patients with chronic advanced or

**Figure 7**

Case VII. Top: Infarction of the A-V node; CFB = Central Fibrous Body. (Hematoxylin and eosin, × 40). Bottom: Higher magnification of the boxed area showing the darkly stained and shrunken A-V node fibers and the inflammatory infiltrate. (Hematoxylin and eosin, × 100).
complete A-V block.\textsuperscript{10, 15} None, to our knowledge, have been reported in patients with acute myocardial infarction and conduction defects because of the problems of performing His bundle electrograms in patients with acute infarctions and the reluctance of pathologists to undertake the tedious histopathologic study of the conduction system. Further, there have been very few studies using His bundle electrograms of second or third degree conduction defects in acute myocardial infarction.\textsuperscript{6, 11, 12}

The technique of His bundle electrography has however been widely used for the study of chronic second and third degree A-V block.\textsuperscript{2, 5, 8, 11, 13, 14, 20} In Wenkebach or Mobitz I block or in complete heart block with normal width (less than 0.10 sec) QRS complexes, the conduction delay is generally above the His bundle recording site. In Mobitz II
block, characterized by a constant P-R interval and dropped beats, or in complete heart block with wide (greater than 0.10 sec) QRS complexes, the block is generally below the His bundle recording site. Mobitz I block with wide QRS complexes may be seen with block either in the A-V or in the distal conduction system.

Complete heart block complicating acute myocardial infarction usually occurs in one of two patterns.21,22 Patients with inferior infarction usual-
ly have normal width QRS complexes associated with A-V node ischemia or dysfunction, while in those with anterior infarction, the conduction defect usually follows bilateral bundle branch damage due to massive septal infarction. The resulting QRS complexes are wide.72-24

Among our seven patients, the four patients with anterior infarction had wide QRS complexes and block below the His bundle recording site, while the three patients with inferior infarction had normal width QRS complexes and delay or block above the His bundle recording site. These seven patients form part of a larger clinical study of 20 patients with acute myocardial infarction and heart block who were studied by recording His bundle electrograms.25 Other clinical studies have also been reported by Rosen et al.6 and Arcebal et al.11 but none of these three studies have included autopsy data. By pooling the data of the latter studies,5, 11, 25 it can be seen that His bundle electrogram studies are helpful in predicting the site of the block in patients with inferior infarction and wide QRS complexes, but do not improve on the predictions from standard ECG data in the patients with inferior infarction and normal width QRS complexes, or in patients with anterior infarction and wide QRS complexes.

In our study, the four cases with anterior infarction had either block below the H spike or H-V prolongation, findings that indicate distal conduction system damage. At necropsy, recent extensive damage was confirmed in all the cases. Thus all had recent infarction in the right bundle branch and two of the four had similar changes in the fibers of the left bundle branches. However, it should be noted that the diffuse fibrosis and atrophy of the origins of the left bundle branches is a feature commonly seen with increasing age.26 The A-H interval was normal in the four cases, and none showed recent involvement of the A-V node.

Among the three patients with posterior infarction, complete block was present above the His bundle recording site in two and the A-H interval greatly prolonged in the third patient. These recordings indicate functional insufficiency of the A-V node in all three cases. At autopsy, two had definite histological evidence of recent A-V nodal infarction. We have accepted 45 msec as the upper limit of normal of the H-V interval,7 but other workers6 have accepted up to 55 msec. Scherlag et al. have reviewed the problems inherent in measuring the H-V interval and concluded that "the difference in reported normal values for the H-V time may be due, at least in part, to the various methods employed to measure the H-V time."27

Accepting 45 msec for the upper limit of the H-V interval, minor prolongation of the interval was present in two of the patients with inferior infarction, both of whom had evidence of moderate, recent involvement of the distal conduction system. Involvement of the distal conduction system has usually been considered to be uncommon in patients with inferior infarction.24, 28 In another study25 we have found that among 15 patients with inferior infarction and A-V conduction disturbances, fatalities appear to be confined to the group with H-V intervals over 45 msec. This data again may represent septic infarction with involvement of the distal conduction system.

Autopsy studies of patients with acute myocardial infarction and heart block have all shown similar results.21, 22, 24, 28, 29 Massive septic infarction with damage to both the bundle branches was found in patients with isolated antero-septal infarctions.24, 29 Patients with posterior infarctions usually had histologically normal conducting systems. Small foci of necrosis were sometimes found in the A-V node or more commonly the bundle branches, but those areas were considered tiny in relation to the size of the conducting system.24 Massive A-V node necrosis has been described associated with A-V node artery thrombosis29 but is uncommon.

While A-V block in anterior infarction generally follows bilateral bundle branch destruction,5-29 the mechanisms of the conduction defects associated with posterior infarction are in dispute. In the majority of cases necrosis of the A-V node is not found and other mechanisms may be involved.5, 22, 25, 28 The A-V node may be ischemic but survives because of its relatively low oxygen requirements compared to those of the contractile systems.30 Release of potassium from the surrounding infarcted tissue or of lysosomal enzymes from the polymorphonuclear leucocyte infiltrate may also play some part.22

References


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