Electrophysiologic and Histologic Correlations in Chronic Complete Atrioventricular Block

SHIN-ICHIRO OHKAWA, M.D., MASAYA SUGIURA, M.D., YUJI ITOH, M.D., KOUEI KITANO, M.D., KEISUKE HIROAKA, M.D., KEIJI UEDA, M.D., AND MOTOTAKA MURAKAMI, M.D.

SUMMARY Electrophysiologic studies using the His bundle electrogram (HBE) and histologic studies of serial sections of the conduction system were correlated in two groups of deceased patients. Group 1 consisted of five patients with chronic complete atrioventricular block (CAVB) who had narrow QRS complexes and AH block (block proximal to the His bundle deflection). Group 2 consisted of four patients with chronic CAVB who had wide QRS complexes and HV block (block distal to the His bundle deflection).

In group 1, the sites of the main lesion were not located in the approaches to the atrioventricular (AV) node or the AV node, but were found in the penetrating portion of the His bundle in one patient and in the branching portion of the His bundle in three patients. In the remaining patient, the main site of block could not be demonstrated histologically in the AV conduction system, but marked fibrosis of the approaches to the sinoatrial node and surrounding atrial muscle was found. In all patients of group 2, the site of the main lesion was located in the bilateral bundle branches, and thus was compatible with so-called trifascicular block.

This correlation study between the His bundle electrogram and histologic findings of the AV conduction system showed that in some cases, CAVB presenting as AH block on the HBE can be associated with a lesion in the branching portion of the His bundle (distal His), and that CAVB presenting as HV block on the HBE is associated with a bilateral lesion of the bundle branches.

HIS BUNDLE ELECTROCARDIOGRAPHY (HBE) has made it possible to interpret various types of conduction disturbances more accurately. However, few electrophysiologic and histologic studies have been performed. In this study, we correlated the electrophysiologic and histologic findings in patients with chronic complete atrioventricular block (CAVB) and compared the findings in patients who had block proximal to the His bundle deflection (AH block) with findings in patients who had block distal to the His bundle deflection (HV block).

Materials and Methods

Nine patients (four men and five women) with CAVB were studied. All patients underwent HBE and postmortem pathologic examination and were classified into two groups. Group 1 consisted of five patients with a narrow QRS complex (less than 0.12 second). Group 2 consisted of four patients with a wide QRS complex (at least 0.12 second). The average age was 78.8 years in group 1 and 72.0 years in group 2.

A bipolar electrode was directed into the right side of the heart and HBE was performed according to Scherlag's method on a direct-writing recorder (Nihonkoden rectigraph RGI 3004, electronic amplifier AVB-2) with a time constant of 3 msec and paper speed of 50–100 mm/sec or (case 1) recorded on a switched-beam, multichannel oscilloscope (Electronics for Medicine DR-12) and photographed at a paper speed of 50–100 mm/sec. Analysis of these recordings was enhanced through use of a four-channel tape system. The PA interval was measured from the onset of the P wave to the first rapid deflection of the atrial electrogram. The AH interval was measured from the first rapid deflection of the atrial electrogram to the first high-frequency component of the His bundle electrogram. The HV interval was measured from the first high-frequency component of the His bundle electrogram to the earliest QRS deflection...
recorded on the surface electrogram. The normal values (mean ± 2 SD) for the PA, AH and HV intervals in our laboratory are 31 ± 8.0 msec, 112 ± 13 msec and 43 ± 7.0 msec, respectively.

The heart was examined grossly, and narrowing of coronary arteries was checked by serial section of the major coronary arteries at 5-mm intervals. The extent of narrowing was graded from 5 to 0: 5 = complete occlusion, 4 = 75% stenosis, 3 = 50% stenosis, 2 = 25% stenosis and 1 = minimal stenosis. A stenotic index was obtained as the sum of the largest count in each major coronary artery. The histologic study of the conduction system was done as previously reported according to Lev’s method. Serial sections 6 mm thick were made of the conduction system, and every tenth section was retained and stained with hematoxylin-eosin, elastic van Gieson, periodic acid Schiff or toluidine blue. We used the nomenclature of the conduction system recommended by Lev. The His bundle was divided into the penetrating portion and then the branching portion. The branching portion of the His bundle, beginning at about the point where it emerges from the central fibrous body, sends forth the posterior fascicles of the left bundle branch until the His bundle bifurcates into the right bundle branch and the anterior fascicle of the left bundle branch. The right bundle branch was subdivided into three portions, designated as the first, second and third portions. The first portion extends from the bifurcation to the proximal region of the trabecula septomarginalis. The second portion extends usually in an intramycardial course to the distal region to the trabecula septomarginalis followed by the third portion, which runs in a subendocardial layer, terminating in the base of the anterolateral papillary muscle. The severity of lesions in the conduction system was expressed as previously reported. In the sinoatrial node (SAN) the number of conduction cells was expressed as a percentage of normal. The degree of lesions in the approaches to the SAN, internodal tracts and the approaches to the AV node was expressed as normal (N), mild (+), moderate (++) and severe (+++). Lesions in the AV conduction system were classified into five degrees: 5 = complete interruption of conducting cells; 4 = 75% destruction; 3 = 50% destruction; 2 = 25% destruction; 1 = 10% destruction; and 0 = no change. Because of the fanlike distribution of fibers in the left bundle branch, the severity of lesions was determined from the average score of all serial sections of this structure.

Results

Clinical Findings (table 1)

The findings by HBE demonstrated AH block in all group 1 patients, with PA intervals and HV intervals

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Clinical diagnoses</th>
<th>Syncope</th>
<th>Duration of CAVB</th>
<th>QRS duration (sec)</th>
<th>QRS pattern</th>
<th>PA (msec)</th>
<th>HBE AH (msec)</th>
<th>HV (msec)</th>
<th>Cause of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (AH block)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>77</td>
<td>F</td>
<td>CHF, CAVB, pneumonia</td>
<td>+</td>
<td>1 y, 5 m</td>
<td>0.08 (0.12)</td>
<td>Normal or IC · LBBB (?) (occ. RBBB + RAD)</td>
<td>approx. Pneumonia 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>78</td>
<td>F</td>
<td>CAVB, AR, dementia</td>
<td>-</td>
<td>2 y</td>
<td>0.10</td>
<td>Normal</td>
<td>30</td>
<td>45</td>
<td>Sudden</td>
</tr>
<tr>
<td>3</td>
<td>77</td>
<td>F</td>
<td>CHF, CAVB, AR</td>
<td>+</td>
<td>2 y, 10 m</td>
<td>0.10</td>
<td>Normal or IC · LBBB (?)</td>
<td>20</td>
<td>35</td>
<td>Sudden</td>
</tr>
<tr>
<td>4</td>
<td>82</td>
<td>F</td>
<td>CHF, CAVB + SSS (?), CVD</td>
<td>+</td>
<td>2 y, 5 m</td>
<td>0.10</td>
<td>Normal</td>
<td>30</td>
<td>50</td>
<td>CVD</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
<td>M</td>
<td>CHF, CAVB + SSS, dementia, CVD</td>
<td>+</td>
<td>3 y, 11 m</td>
<td>0.08</td>
<td>Normal</td>
<td>30</td>
<td>35</td>
<td>CVD</td>
</tr>
<tr>
<td>Group 2 (HV block)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>46</td>
<td>F</td>
<td>CHF, CAVB, sarcoidosis</td>
<td>+</td>
<td>3 y, 11 m</td>
<td>0.12</td>
<td>RBBB + LAD</td>
<td>30</td>
<td>140</td>
<td>CHF</td>
</tr>
<tr>
<td>7</td>
<td>79</td>
<td>M</td>
<td>CHF, CAVB</td>
<td>+</td>
<td>50 d</td>
<td>0.12</td>
<td>LBBB</td>
<td>35</td>
<td>100</td>
<td>Pacing failure</td>
</tr>
<tr>
<td>8</td>
<td>81</td>
<td>M</td>
<td>CHF, CAVB, CVD, sepsis</td>
<td>-</td>
<td>6 y, 4 m</td>
<td>0.15</td>
<td>RBBB + LAD</td>
<td>20</td>
<td>120</td>
<td>Sepsis</td>
</tr>
<tr>
<td>9</td>
<td>82</td>
<td>M</td>
<td>CAVB</td>
<td>-</td>
<td>1 y, 3 m</td>
<td>0.16</td>
<td>RBBB + LAD</td>
<td>20</td>
<td>100</td>
<td>Sudden</td>
</tr>
</tbody>
</table>

Abbreviations: CHF = congestive heart failure; CAVB = complete atrioventricular block; AR = aortic regurgitation; ? = possible; SSS = sick sinus syndrome; CVD = cerebrovascular disease; y = years; m = months; d = days; IC · LBBB = incomplete left bundle branch block; occ. = occasional; RBBB = right bundle branch block; RAD = right-axis deviation; LAD = left-axis deviation; LBBB = left bundle branch block; HBE = His bundle electrogram.
of 20–30 msec and 35–50 msec, respectively. All patients in group 2 had HV block by HBE with PA intervals and AH intervals of 20–35 msec and 100–140 msec, respectively. No patient in group 1 had a split His on HBE. The interval between catheterization and death averaged 18.3 months (range 20 days to 3 years, 6 months).

In group 1, two patients died suddenly and three died of noncardiac causes. In group 2, one patient died of congestive heart failure, one of pacing failure, one of septicemia, and one of cardiac arrest. Permanent pacemakers were implanted in eight of the nine cases for the treatment of CAVB-associated complications.

Pathohistologic Findings (table 2)

The average heart weight was 350 g in group 1 and 433 g in group 2. The coronary stenotic index was moderately elevated in all cases; there was no significant difference between the two groups. Cases 3 and 5 showed small old myocardial infarcts.

In group 1, the site of the main lesion was not located in the approaches to or in the AV node, but was found in the penetrating portion of the bundle of His in one case and in the branching portion of the bundle of His in three cases. In the other case, a major lesion in the AV conduction system could not be demonstrated histologically. However, marked fibrosis was found in the approaches to the SAN and in the surrounding atrial muscle (table 2).

In contrast, the main lesion in all group 2 patients resulting in HV block was present in both bundle branches.

Case Presentations

Case 1

Patient 1, a 77-year-old female, entered the hospital with complaints of edema and dyspnea. Her ECG (fig. 1A) showed CAVB with a ventricular rate of 33 beats/min and a QRS duration of 0.08 second, which was the dominant pattern during her clinical course; but other patterns of escape beats, such as right bundle branch block (RBBB) with right-axis deviation (RAD) pattern and incomplete left bundle branch block (IC-LBBB) with left-axis deviation (LAD) pattern, were occasionally noted. In this case the HBE tracings (fig. 1B) were obtained at a paper speed of only 25 mm/sec; however, the presence of AH block, with an HV interval of approximately 40 msec, was unequivocally demonstrated. The simultaneous surface ECG apparently showed 2:1 AV block, but analysis of the longer ECG strip demonstrated CAVB without 2:1 AV block. She died of pneumonia 1 year and 5 months after the onset of CAVB.

The heart weighed 330 g, and showed moderate coronary atherosclerosis and mitral ring calcification. The changes of the conduction system were as follows: The SAN and its approaches were normal, as were the approaches to the AV node; however, the end of the AV node (fig. 2A) was compressed by a large, calcified

<table>
<thead>
<tr>
<th>Heart weight (g)</th>
<th>Lesions of the conduction system*</th>
<th>Main sites of lesions inducing CAVB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case</td>
<td>Cor.</td>
<td>SAN</td>
</tr>
<tr>
<td>Group 1 (AH block)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>330</td>
<td>10/15</td>
</tr>
<tr>
<td>2</td>
<td>380</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>440</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>310</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>290</td>
<td>9</td>
</tr>
</tbody>
</table>

| Group 2 (HV block) |
| 6 | 480 | 9 | 40 | N | + | 2 | 2 | 3 | 5 | 5 | 4 | 5 | BBB |
| 7 | 390 | 9 | 30 | N | 1 | 3 | 3 | 5 | 5 | 4 | 2 | 3 | BBB |
| 8 | 440 | 9 | 30 | N | 2 | 2 | 3 | 5 | 5 | 4 | 2 | BBB |
| 9 | 420 | 10 | 40 | +~++ | fat | 1 | 3 | 4 | 5 | 5 | 5 | 4 | HISb + BBB |

*In SAN, number of viable conducting cells expressed as a percentage of normal; in SANapp, INT and AVNapp; N = normal, + = slight, ++ = moderate, +++ = severe. In the AV conduction system: 5 = complete interruption of conduction cells, 4 = 75% destruction, 3 = 50% lesion, 2 = 25% lesion, 1 or 0 = slight or no lesion.

Abbreviations: Cor. SI = coronary stenotic index; SAN = sinoatrial node; SANapp = approaches to the SAN; INT = internodal tract; AVNapp = approaches to the AVN; AVN = atrioventricular node; HISp = penetrating portion of the His bundle; HISb = branching portion of the His bundle; LBp = posterior fascicles of the left bundle branch; LBa = anterior fascicles of the left bundle branch; RB1, RBII, RBIII = first, second or third portion of the right bundle branch; fib = fibrosis; fat = fatty infiltration; BBB = bilateral bundle branches.
nodule extending from the summit of the ventricular septum to the central fibrous body. The penetrating portion of the His bundle was remarkably compressed by this large calcified mass within the septum (fig. 2B), resulting in marked degeneration of conducting cells. The branching portion of the His bundle was largely spared, with only slight fibrosis. The posterior fascicle of the left bundle branch showed severe fibrosis, but the anterior fascicle was only slightly involved. Examination of the right bundle branch revealed slight fibrosis in the first and second portions, but the third portion of the right bundle branch was markedly interrupted by subendocardial fibrosis and endocardial fibroelastosis of the right ventricle.

Case 2

Patient 2, a 78-year-old female, was admitted to the hospital for evaluation of bradycardia and aortic
regurgitation. Because of blindness (from previous glaucoma) and senile dementia, she was confined to bed. Her ECG (fig. 3A) showed CAVB with a narrow QRS of 0.10 second and the HBE (fig. 3B) showed AH block with a PA interval of 30 msec and an HV interval of 45 msec. She died suddenly 1 1/2 years after the implantation of a pacemaker.

The heart weighed 380 g at autopsy, with moderate coronary atherosclerosis, mitral ring calcification and sclerotic changes of the aortic valve. Histologic examination of the conduction system revealed that SAN conducting cells were moderately decreased in number and the atrial internodal tract was within normal limits. The approaches to the AV node had

---

**Figure 3.** (A) ECGs of case 2, showing normal sinus rhythm on the left and complete atrioventricular block with narrow QRS complexes 0.10 second long on the right. (B) His bundle electrogram (HBE) of case 2, showing complete atrioventricular block due to AH block with an HV interval of 45 msec.
FIGURE 4. Photomicrographs of the conduction system in case 2, showing an intact penetrating portion of the His bundle (B) in panel A, complete interruption of the conduction cells by fibrosis in the branching portion of the His bundle (B), marked by arrows in panel B, and intact conduction cells in the more peripheral branching His in panel C. LB = left bundle branch. Elastic van Gieson stain; magnification × 10.

moderate fatty infiltration. The AV node and the penetrating portion of the His bundle (fig. 4A) were intact, but the proximal two-thirds of the branching portion of the His bundle (fig. 4B) showed complete interruption of the conducting cells by marked fibrosis. Conduction cells in the distal third of the branching His (fig. 4C) were intact, with slight bilateral fibrosis of the bundle branches.

Case 3

Patient 3, a 77-year-old female, entered the hospital with complaints of recurrent attacks of syncope. Her ECG (fig. 5A) showed CAVB with a narrow QRS of 0.10 second and the HBE (fig. 5B) showed AH block with a PA interval of 20 msec and an HV interval of 35 msec. She died suddenly 4 years after the onset of CAVB and 2 years after the implantation of a pacemaker.

Autopsy revealed a heart weight of 440 g with slight coronary atherosclerosis associated with a small old anterior myocardial infarction. The tip of a pacemaker catheter was located in the posterior cardiac
vein of the left ventricle through the coronary sinus.

In the conduction system, the SA node showed a moderately decreased number of conduction cells and the approaches to the SA node and the internodal tract showed moderate fibrosis. The approaches to the AV node showed minimal fatty infiltration. The AV node and the penetrating portion of the His bundle revealed moderate fibrosis. In the branching portion of the His bundle and the posterior fascicle of the left bundle branch (fig. 6A), marked destruction of the conduction cells was found, but the more distal branching His was intact (fig. 6B). There was moderate fibrotic change in the anterior fascicle of the left bundle branch and slight fibrosis of the right bundle branch.

Case 4

Patient 4, an 82-year-old female, entered the hospital with complaints of dizziness and edema. Her ECG (fig. 7A) showed CAVB with a QRS complex width of 0.10 second. The morphology of the QRS complexes during CAVB showed a slight change in leads V_{1-3} compared with those during sinus rhythm, with 1:1 AV conduction. The HBE (fig. 7B) showed the presence of AH block with a PA interval of 20 msec and an HV interval of 50 msec. She died of a massive cerebral infarction 2 years and 5 months after the onset of CAVB. After the cerebral infarction her ECG showed transient normal rhythm similar to that shown in figure 7A.

Autopsy revealed a heart weight of 310 g with slight coronary atherosclerosis. Histologic examination of the conduction system revealed severe damage to the SAN. The internodal tract and the approaches to the AV node were slightly to moderately fibrotic. The AV node showed moderate fibrosis. The penetrating His and the proximal portion of the branching His were intact (fig. 8A), but almost complete interruption of conduction cells in the middle part of the branching portion of the His bundle and the posterior fascicle of the left bundle branch (fig. 8B) was found. The more

Figure 5. (A) ECGs of case 3, showing complete atrioventricular block and narrow QRS complexes of 0.10 second. (B) His bundle electrogram of case 3, showing complete atrioventricular block due to AH block with an HV interval of 35 msec.
distal conducting cells of the branching portion of the His bundle (fig. 8C) were intact. The anterior fascicle of the left bundle branch also showed marked fibrotic changes, but in the right bundle branch the first (fig. 8D) and second portions were intact and the third portion showed moderate fibrosis.

Case 5

Patient 5, an 81-year-old male, entered the hospital with recurrent attacks of syncope. His ECG (fig. 9A) showed CAVB with a QRS complex of 0.08 second. The HBE (fig. 9B) showed the presence of AH block with a PA interval of 30 msec and an HV interval of 35 msec. Because of recurrent episodes of syncope, a pacemaker was implanted. During temporary pacing, a retrograde P wave was noted on the ECG (fig. 9C) and showed secondary suppression of the P wave. The latter findings and the prolonged corrected sinus node recovery time of up to 3580 msec obtained by the rapid atrial stimulation suggested that this patient might have sick sinus syndrome in addition to CAVB. After replacement of his first permanent pacemaker, his ECG showed persistent atrial fibrillation and at the time of the surgery for pacemaker replacement we documented that the patient's ECG still showed CAVB. Thus, the patient's CAVB persisted for 2 years after implantation of his initial pacemaker. He died of cerebral infarction 3 years and 11 months after the onset of CAVB.

Autopsy revealed a heart weight of 290 g and slight coronary atherosclerosis. Histologic examination of the conduction system revealed moderate fibrosis and dropout of conduction cells in the SAN (fig. 10A), moderate-to-marked fibrosis in the approaches to the SAN and severe fibrotic changes of the internodal tracts (fig. 10B) and surrounding right atrial muscle. The AV conduction system, including the approaches to the AV node, was remarkably intact except for marked fibrosis of the posterior fascicle of the left bundle branch (fig. 10C and D).

Case 8

Patient 8, an 81-year-old male, entered the hospital with right hemiparesis. His ECG in 1967 showed sinus rhythm, RBBB and marked LAD (fig. 11A). In 1971, he had CAVB (fig. 11A) without any associated syncopal episodes. The QRS complex was wide (0.15 second) and its configuration varied, including a pattern of LBBB, RBBB associated with LAD, and RBBB associated with RAD (fig. 11A). HBE (fig. 11B) revealed CAVB due to an HV block with a PA interval of 20 msec and an AH interval of 120 msec. To

Figure 6. Photomicrographs of the conduction system of case 3. Panel A shows marked fibrosis of the branching portion of the His bundle (B), marked by broad arrow, and complete interruption of the posterior fascicle of the left bundle branch (LPF), marked by arrows. Panel B shows the surviving more distal branching His (B) and left anterior fascicle of the left bundle branch (LAF). Elastic van Gieson stain; magnification × 10.
treat progressive bradycardia, a pacemaker was implanted in 1973. The patient became septic and died 3 years and 6 months after surgery.

Autopsy showed a heart weight of 440 g with moderate coronary atherosclerosis. The SAN and its approaches were normal. The approaches to the AV node, the AV node itself, and the penetrating His were also normal. The branching His revealed moderate fibrotic changes, but both left bundle branch and right bundle branches were severely fibrotic (fig. 12). The other three cases (patients 6, 7 and 9) of CAVB with wide QRS and HV block also showed similar changes in both left and right bundle branches.

Figures 13 and 14 summarize the histologic findings in the conduction system in all nine patients.

Discussion

In patients with advanced or CAVB, those with wide QRS complexes may correspond to cases with HV block (block distal to the His bundle deflection) on HBE, and those with narrow QRS complexes may be attributed to AH block (block proximal to the His bundle deflection) or to intra-Hisian block (block within the His bundle). However, there have been only sporadic reports on the comparison of the find-
ings of HBE with the histology of the conduction system. From those limited correlation studies, it has been generally assumed that CAVB with a narrow QRS or AH block shown by HBE might be induced by the lesion in the approaches to the AV node, in the AV node itself or in the upper part of the bundle of His, and that CAVB with wide QRS complexes and HV block shown on HBE might result from bilateral lesions of the bundle branches. In general, there seems to be a good correlation between the sites of block as defined by HBE and the histopathologic analysis of the conduction system in cases with HV block. However, in cases of chronic CAVB with a narrow QRS, showing either AH block or intra-Hisian block on HBE, such correlation remains to be confirmed.

This study demonstrated that CAVB in cases with narrow QRS complexes and AH block resulted not only from lesions in the upper part of the His bundle, but also from lesions in the branching portion of the His bundle. In case 1, there was severe damage to the end of the AV node and the entire penetrating portion of the His bundle resulting from compression by a calcified nodule, which may have caused CAVB. However, her ECG (fig. 1A) showed a pattern of escape beats consisting of small R waves in leads V1,4 compatible with a pattern of possible incomplete LBBB. These findings suggest that in case 1, the idioventricular pacemaker may arise from either the lower branching His or the proximal right bundle branch. Case 1 had evidence of severe damage to the posterior fascicles of the left bundle branch and the third portion of the right bundle branch. These findings might explain her ECG changes, which occasionally demonstrated RBBB and RAD pattern during CAVB.

In case 2, there was a slight modification in the QRS when changing from AV conduction to AV block and the histologic examinations showed marked interruption of the branching His by fibrosis from the proximal to the middle portion, but in the distal portion (almost compatible with the "pseudobifurcation" described by Rosenbaum), the surviving conduction cells were found. In case 3, the idioventricular QRS was again compatible with a pattern of IC-LBBB, as in case 1. This case also showed complete destruction of the proximal two-thirds of the branching His with distal sparing. The posterior fascicle of the left bundle branch was also markedly interrupted, but ECG tracings demonstrated a normal frontal plane electrical axis both during intact AV conduction as well as in CAVB. Case 4 showed impressive histologic changes in the left bundle branch in addition to those of the branching His; however, this patient never demonstrated abnormal axis deviation or LBBB or patterns of escape rhythm in CAVB. In these three cases (cases 2–4) we tried repeatedly to manipulate the tip of the electrode catheter to different areas under the tricuspid valve, but a split His potential could not be recorded. Therefore, we considered that CAVB was due to AH block, with a possible lesion located in the AV node and/or in the upper part of the His bundle. The histologic findings, however, were compatible with intra-Hisian block. Intra-Hisian bundle blocks were first documented by electrophysiologic studies in 1969 by Narula et al. Gupta et al. assumed that various patterns may be seen on the HBE depending upon the level of block within the His bundle. If block is in the proximal part of the His bundle adjacent to the AV node, the HBE resembles AV nodal block and split His bundle potentials are not present. However, if block is located in the middle part of the His bundle, a typical split His potential is recorded, with H and H' denoting the activity of the proximal and distal segments of the His bundle. These authors also stated that if the distal part of the His bundle is involved, no H' is recorded and block occurs distal to the H potential in the presence of narrow QRS complexes. Schuilenburg and Durrer reported four clinical cases of conduction disturbance within the His bundle and stressed that the distal part of the His bundle might be the site of the AV conduction disturbance in some cases with intra-Hisian block.

Bharati et al. reported a clinicopathologic study in two cases with split His potentials. In that study they demonstrated calcific impingement on and degenerative changes within the bundle of His (in the middle portion of the His bundle), with apparently normal His bundle tissue proximal and distal to the lesion. The location of the main lesion was markedly different from that in our cases. All three cases in this study had complete or marked interruption of conducting cells in the branching portion of the His bundle, while the upper and middle parts of the His bundle were intact. Therefore, the main site of block in our cases was demonstrated in the distal part of the His bundle. Apparently, such lesions might occur in cases with CAVB showing block distal to the H potential (HV block) in the presence of either narrow or wide QRS complexes. In our cases, CAVB had a narrow QRS and AH block in spite of the complete interruption in the distal His.

In our three cases showing the main site of the lesion in the branching portion of the His bundle, conduction cells survived in the more peripheral portion of the His bundle, and there was only slight change of the adjacent bundle branches. In these three cases the His potential might originate in one of two ways. First, the His potential could originate from the viable cells at the more peripheral portion of the branching His bundle; and second, the His potential might be induced by summation of the remaining fibers in the more peripheral part of the His bundle, the intact right bundle branch and, rarely, an intact fascicle of the left bundle branch. The

![Figure 8](http://circ.ahajournals.org/)

**Figure 8.** Photomicrographs of the conduction system in case 4. (A) The surviving proximal portion of the branching His (marked B) with marked fibrosis of the left posterior fascicle of the left bundle branch (LBF, arrows). (B) Marked fibrosis of the branching His (broad arrows) and LBF (arrows). (C) The surviving more distal portion of the branching His and moderate fibrosis of the anterior fascicle of the left bundle branch (LAF). (D) The first portion of the right bundle branch (RB) is intact. Elastic van Gieson stain; magnification × 10.
Figure 9. (A) ECGs of case 5, showing complete atrioventricular block with narrow QRS complexes of 0.08 second. (B) His bundle electrogram of case 5, showing complete atrioventricular block due to AH block with an HV interval of 35 msec. (C) ECGs before and during temporary pacing in the same patient, showing the existence of retrograde P wave (p') and (lower panel) the secondary suppression of the P wave just after the cessation of ventricular pacing. ES = esophageal lead.

Figure 10. Photomicrographs of the conduction system in case 5. (A) Marked fibrosis in the sinoatrial node (SAN). (B) Severe fibrotic changes of internodal tract (INT) and right atrial muscle (RA). (C) Intact atrioventricular node (N). (D) The intact branching portion of the His bundle (B) and fibrosis of the posterior fascicle of the left bundle branch (LPF) (arrows). CFB = central fibrous body. Elastic van Gieson stain; magnification × 10.
first possibility may be applied in cases 2 and 3. The second seems likely in case 4 because the remaining peripheral His bundle was too short to be a likely site for initiation of an isolated potential. These three cases are also similar to those reported by Narula and Narula.24

The exact reason for the failure to record a proximal H potential despite absence of significant patho-

logic lesions in the AV node or upper portion of the His bundle is not clear. Narula and Narula21, 24 pointed out that in some patients with intra-Hisian block, a split His potential could not be found. In our three cases this may be attributed in part to the inability of the bipolar electrode to override the lesion because the site of block was not located in the middle portion but in the distal His bundle. Alternatively, the H potential may be obscured by the atrial complex if the AV nodal transmission time is short at the spontaneous rate.25 To further evaluate the latter possibility, atrial pacing might be performed. These findings in our three patients may suggest some limitations of HBE and teach us that in patients with CAVB showing apparent block proximal to the His bundle deflection (AH block), we should rule out the cases with these types of intra-Hisian block, as also pointed out by Schuilenburg and Durrer.25

Case 5 showed no significant histologic changes in the AV conducting system to explain the site of the CAVB. However, there were marked fibrotic changes in the approaches to the SAN, internodal tracts and the surrounding atrial muscle. We could not rule out the possibility of functional block in the AV node or His bundle. These pathohistologic findings may explain not only sinus node dysfunction, as previously reported,5 but also chronic CAVB. Zipes et al.26 proved summation in antegrade AV nodal conduction, while Konishi and Matsuyama27 emphasized the im-

Figure 11. (A) ECGs of case 8, showing a normal sinus rhythm and complete right bundle branch block with left-axis deviation (8/3/67), complete atrioventricular block with wide QRS complexes with a pattern of left bundle branch block (1/28/71), right bundle branch block with left-axis deviation (9/16/71), and right bundle branch block with right-axis deviation (5/15/72). (B) His bundle electrogram (HBE) of case 8, showing complete atrioventricular block due to HV block with an AH interval of 120 msec.
FIGURE 12. Photomicrographs of the conduction system in case 8, showing severe fibrotic changes in the posterior fascicle of the left bundle branch (LPF) in panel A, in the anterior fascicle of the left bundle branch (LAF) in panel B and in the right bundle branch (RB) in panel C (arrows). The branching portion of the His bundle (B) is intact. Elastic van Gieson stain; magnification × 10.

The importance of atrial excitation required for the atrial input to pass through the AV node and the His bundle. On the other hand, Mitsui et al.\textsuperscript{28} reported that some patients showed persistent AV block after the repair of atrial septal defect, although direct damage to the AV node could not be caused by surgery. The AV block in such cases was thought to be due to intracardiac manipulation, closure of an atrial septal defect or atrial incision producing injury to intraatrial pathways, which may influence AV transmission.\textsuperscript{28} In addition, the existence of unidirectional block during temporary pacing (fig. 9C) may support the above-mentioned interpretation as to the mechanism of the AV block in case 5.

In patients with CAVB showing narrow QRS complexes of escape beats, it is also necessary to rule out the lesions in the approaches to the AV node.\textsuperscript{29} In this study the changes on the approaches to the AV node were minimal, but only case 5 showed apparent changes in the atrial preferential pathways causing CAVB. In addition, no patient had a severe lesion in the AV node itself. In cases with chronic CAVB with narrow QRS complexes, the main site of anatomical
lesion located solely in AV nodal tissue may be exceptional.30

With regard to our four cases of CAVB with wide QRS complexes and HV block, the main sites of lesions in the conduction system were found in the bilateral bundle branches, which corresponds to so-called trifascicular block postulated by Rosenbaum et al.30 These findings are similar to those reported by Rosen et al.11 Details of cases 6, 7 and 9 were reported previously.13,17

In conclusion, a correlation study between HBE and histologic findings of the AV conduction system showed that some cases of CAVB with AH block (block proximal to the His bundle deflection) but not showing split His on HBE can have an anatomic lesion in the branching portion of the His bundle (distal His). On the other hand, cases of CAVB with HV block (block distal to the His bundle deflection) on the His bundle electrogram correspond to lesions of the bilateral bundle branches.

Acknowledgment

The authors thank Drs. Donald B. Hackel and Raymond E. Ideker, Department of Pathology, Duke University Medical Center, for their kind suggestions and criticisms of the manuscript. We appreciate the technical assistance of Ayako Toku and we are indebted to Linda Brogan and Marjorie Penny for typing the manuscript.

References

Electrophysiologic and histologic correlations in chronic complete atrioventricular block.
S Ōhkawa, M Sugiura, Y Itoh, K Kitano, K Hiraoka, K Ueda and M Murakami

doi: 10.1161/01.CIR.64.2.215
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1981 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on
the World Wide Web at:
http://circ.ahajournals.org/content/64/2/215

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally
published in Circulation 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 is online at:
http://circ.ahajournals.org/subscriptions/