Intra-His Bundle Block Following Ligation of Anterior Septal Artery in Dog

KAZUHIKO MURATA, TSUNEMI TAJIMA, YOSHIHICHI HOJO, SHIN-ICHI TAKASE and KIMIO ITO
The Second Department of Internal Medicine, Gunma University School of Medicine, Maebashi

MURATA, K., TAJIMA, T., HOJO, Y., TAKASE, S. and ITO, K. Intra-His Bundle Block Following Ligation of Anterior Septal Artery in Dog. Tohoku J. exp. Med., 1977, 121 (4), 337-346 — Intra-His bundle block was produced by ligation of the anterior septal artery in dogs. The duration of the His bundle potential was gradually increased following the ligation, and an obvious splitting of the His bundle deflection was observed thereafter. Finally, spontaneous second and/or third degree intra-His bundle block appeared. Before the development of spontaneous block, a pacing induced intra-His bundle block was observed when the duration of the His bundle deflection was prolonged approximately to twice the control value. Careful measurements of the intervals between two split His bundle deflections (H₁-H₂) in spontaneous as well as in pacing induced block revealed atypical Wenckebach periodicity in all analyzed periods except in one. Repeating and/or transient decreases of H₁-H₂ intervals were frequently observed as atypical findings. ——— atrial pacing; intra-His bundle block; ligation of anterior septal artery; Wenckebach periodicity

Since the introduction of catheter technique for the recording of His bundle activity in clinical cases by Scherlag and coworkers (1969), much useful information has been accumulated for the accurate diagnosis of atrioventricular block. Although initially it was believed that the site of the block was usually above or below the His bundle, the recent investigations revealed a considerable frequency of intra-His bundle block (Narula and Samet 1970; Gupta et al. 1973; Ito et al. 1974; Kaseno et al. 1975; Schulenburg and Durrer 1975; Tajima et al. 1975). The present investigation was performed in order to observe the process of development of intra-His bundle block in dogs following the ligation of the anterior septal artery. We assume that this experimental model may provide useful pathophysiological knowledge for a better understanding of clinical intra-His bundle block.

MATERIALS AND METHODS

Fifteen mongrel dogs weighing 10-15 kg were anesthetized with intravenous administration of sodium pentobarbital 30 mg/kg. The animals were intubated and placed on a mechanical respirator. The left side of the thorax was opened at the fourth intercostal space. The heart was exposed by pericardiotomy and the left atrial appendage was retracted. The area of the bifurcation of the left coronary artery was dissected.

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carefully and the anterior septal artery was exposed. A silk ligature was placed around the vessel in order to ligate the artery after the control His bundle electrograms were recorded. The right side of the thorax was opened thereafter at the fourth intercostal space, and a bipolar plunge wire electrode was placed on the right atrial appendage for pacing. The atrial pacing was performed with an external pacemaker (Devices, Type E 2991).

In order to record the His bundle activity, one electrode catheter was inserted into the right femoral vein to the right ventricle and another into the right carotid artery to the aortic root. In addition, a bipolar teflon coated stainless electrode was inserted into the His bundle region via the right atrium in most cases. Validation of the recording was made by pacing from various sites and by vagal stimulation. The His bundle electrogram was monitored with an oscilloscope and the recordings were registered on an oscillographic recorder (Sanei-Sokki, Visigraph FR–301) at paper speeds of 500–200 mm/sec. Some of the records were stored on a magnetic tape recorder (TEAC R–200) in order to replay for detailed analysis of wanted sections.

The electrical stimulation of the right vagosympathetic nerve, square wave pulse of 1–10 volts intensity at a frequency of 5–100 Hz, was performed by using a needle electrode inserted directly into the nerve.

The control records were obtained during sinus rhythm, vagal stimulation, His bundle pacing and atrial pacing up to the rate which produced the second degree atrioventricular block. Then the anterior septal artery was ligated, and the electrograms were monitored up to 5 hr. Vagal stimulation, His bundle pacing and atrial pacing were repeated for intervals after the ligation of the artery.

The criteria described by Denes and coworkers (1975) were used to define typical and atypical Wenckebach periodicity. Wenckebach periods were defined as episodes of second degree block characterized by increasing the P-R, A-H or the intervals between two split His bundle deflections (H₁-H₂ intervals) from the first conducted beat of the period to that of any subsequent beat within the period, terminating in a dropped beat. Typical Wenckebach periodicity was diagnosed when the intermittent dropping out of a single ventricular beat associated with the following characteristics: (1) progressive lengthening of P-R, A-H or H₁-H₂ intervals, (2) progressive shortening of P-R, A-H or H₁-H₂ increment, and (3) a pause which was less than any two P-P intervals of consecutively conducted beats. Atypical periods were defined as those episodes which fulfilled the general definition of Wenckebach periods, but failed to meet all criteria for typical Wenckebach periodicity.

RESULTS

In the control records, the H-V intervals averaged 31.6±3.7 msec, and the duration of the His bundle deflection averaged 16.6±5.9 msec. A Wenckebach type second degree A-H block was observed during atrial pacing at a rate of 180–330/min.

Following the ligation of the anterior septal artery, the His bundle deflections were slurred and decreased in amplitude. The duration of the His bundle deflection was gradually increased, and an obvious splitting of the His potential into two distinct deflections was observed later. A spontaneous second degree intra-His bundle block appeared in 13 of 15 cases (87 percent) 22–130 min after the ligation. Of these 13, 9 were associated with intraventricular conduction disturbance as seen in Table 1; one was associated with alternating left and right bundle branch block, 7 with right bundle branch block, and 1 with left bundle branch block. A third degree intra-His bundle block appeared thereafter in 8 cases.

A pacing induced second and/or third degree intra-His bundle block was
Experimental Intra-His Bundle Block

<table>
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<th>Table 1</th>
<th>Site of block following ligation of anterior septal artery</th>
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<th>Dog No.</th>
<th>Bundle of His</th>
<th>RBB</th>
<th>LBB</th>
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RBB, right bundle branch; LBB, left bundle branch.

usually observed before the development of spontaneous block. Neither A-H nor H-V block appeared spontaneously in the present series. Right bundle branch block not associated with A-V block was seen in one case.

**Pacing induced intra-His bundle block**

A pacing induced intra-His bundle block was observed in 9 cases. The block was observed 9–126 min after the ligation of the anterior septal artery as seen in Table 2. At this stage, the duration of the His bundle deflection was 32.7±10.9

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<th>Table 2. His bundle electrogram in control period and in the stage of pacing induced intra-His bundle block</th>
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<tr>
<th>Dog No.</th>
<th>Duration of HBD (msec)</th>
<th>H-B (msec)</th>
<th>Time after ligation (min)</th>
<th>HBE without pacing</th>
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<td>H1-H2 (msec)</td>
<td>H2-V (msec)</td>
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IHBB, intra-His bundle block; HBD, His bundle deflection; HBE, His bundle electrogram.
Fig. 1. Split His bundle deflection following the ligation of the anterior septal artery (Dog No. 2). The upper panel is a control tracing. An obvious splitting of the His bundle deflection is seen in the lower panel. The tracing B was recorded 60 min after the ligation. HBE(R): His bundle electrogram recorded by using a catheter electrode inserted into the right ventricle. HBE(L): His bundle electrogram by using a catheter electrode in the aortic root.

msec, while the H₁-H₂ interval was 17.2±5.8 msec and the interval between the initial His bundle deflection (H₁) and the ventricular complex (H₁-V) was 43.4±8.5 msec.

Representative His bundle electrograms in a series of experiments (Dog No. 2) are illustrated in Figs. 1–4. Fig. 1A is the control record before the ligation of the anterior septal artery. The His bundle deflection was biphasic in the record obtained by the electrode catheter introduced into the aortic root (HBE-L), while triphasic in the record from the right side of the heart (HBE-R). The A-H interval was 61 msec and the H-V interval was 29 msec. The duration of the His bundle deflection was increased following the ligation of the anterior septal artery, and an obvious splitting of the deflection was seen 60 min after the ligation as shown in Fig. 1B.

Sixty-eight min after the ligation, a 2:1 intra-His bundle block was induced by
Fig. 2. Pacing induced 2:1 intra-His bundle block (Dog No. 2). A 2:1 intra-His bundle block was induced by rapid atrial pacing at a rate of 277/min, 68 min after the ligation of the anterior septal artery.

Fig. 3. Distal His pacing in split His bundle (Dog No. 2). The interval between pacing impulse and the ventricular complex was essentially the same as the duration between the distal His deflection and the ventricular complex in the control tracing (upper panel).
Fig. 4. Atypical Wenckebach periodicity in pacing induced 6:5 intra-His bundle block (Dog No. 2). Decrease in $H_1$-$H_2$ interval as compared with the preceding cycle was observed in the third and fifth cycles.

atrial pacing at a rate of 277/min as seen in Fig. 2. A His bundle stimulation performed at this stage showed that the interval between the stimulation spike and the ventricular complex was exactly the same as the interval between the distal His deflection and the ventricular complex before the stimulation as seen in Fig. 3. Fig. 4 was recorded 105 min after the ligation. The tracing shows a pacing induced 6:5 intra-His bundle block. The succeeding $H_1$-$H_2$ intervals in this tracing were 15, 30, 21, 30 and 25 msec, respectively, while the $H_1$-$V$ intervals remained unchanged during the period.

**Spontaneous intra-His bundle block**

A spontaneous second degree intra-His bundle block appeared in 13 of 15 cases. The block was observed 22–130 min after the ligation of the anterior septal artery.

Fig. 5. A spontaneous 6:5 intra-His bundle block observed 106 min after the ligation of the anterior septal artery (Dog No. 2). The Wenckebach periodicity is atypical in this tracing, since the last $H_1$-$V$ was slightly shorter than in the preceding cycle.
Fig. 6. Improvement of intra-His bundle block following intravenous injection of propranolol (Dog No. 2). The control tracing in the upper panel shows a 2:1 intra-His bundle block. When the atrial rate was decreased by propranolol injection, 1:1 A-V conduction was resumed as seen in the lower panel.

Fig. 7. Improvement of intra-His bundle block following vagal stimulation (Dog No. 4). A third degree intra-His bundle block was observed before the stimulation. When the atrial rate was decreased by vagal stimulation, 1:1 A-V conduction with split His bundle was resumed.
Fig. 5 shows a spontaneous 6:5 intra-His bundle block observed 108 min after the ligation. This is a later record in a series of experiment described before (Dog No. 2).

A third degree intra-His bundle block was observed in 8 cases 30–240 min after the ligation.

The atrioventricular conduction was improved by slowing the heart in spontaneous second or third degree intra-His bundle block. Figs. 6 and 7 are two illustrative tracings. The intra-His bundle block was improved from second degree to first degree when atrial rate was lowered by intravenous injection of propranolol in Fig. 6. On the other hand, third degree intra-His bundle block was converted to first degree block by induced bradycardia following the vagal stimulation in Fig. 7.

Wenckebach periodicity in pacing induced and spontaneous intra-His bundle block

The H₁-H₂ intervals were not constant both in spontaneous and in pacing induced second degree intra-His bundle block in the present series. Although Wenckebach periods were observed in all cases with A-V conduction ratio 3:2 or greater, a detailed analysis revealed that 105 of 106 periods with A-V conduction ratio 4:3 or greater were atypical. The atypical Wenckebach periodicity is seen in Figs. 4 and 5. Among atypical findings, repeating of H₁-H₂ interval and decrease in H₁-H₂ interval at least once in one period were frequently observed as seen in Fig. 8. Each of these was observed in 65 percent. The last increment was the largest in 5 percent, while the first increment was not the largest in 9 percent in the present series.
Discussion

Although the development of atrioventricular block following the ligation of the anterior septal artery in dogs has been well known (Lumb et al. 1959; Hashiba et al. 1965), it was recently recognized that the site of the block in these instances was usually within the His bundle (Scherlag et al. 1974; El-Sherif et al. 1974, 1975; Hiejima and Suzuki 1975). In agreement with the previous reports, an intra-His bundle block was frequently observed following the ligation of the artery in the present study. On the other hand, a spontaneous A-V block above or below the His bundle was not observed. The His bundle deflection was decreased in amplitude and increased in duration soon after the ligation, and an obvious splitting of the deflection was demonstrated thereafter. A second or third degree intra-His bundle block was induced by rapid atrial pacing when the duration of the His bundle deflection was approximately twofold as long as the control value. Following this stage of pacing induced block, spontaneous second and third degree intra-His bundle block appeared. This spontaneous block was usually tachycardia-dependent, and the A-V conduction was improved when the heart was slowed by vagal stimulation or by intravenous injection of propranolol.

The precise recognition and validation of the His bundle activity are essential for the accurate diagnosis of intra-His bundle block. Because of the decrease in amplitude, the splitting of the His bundle deflection is frequently overlooked, especially when only single catheter electrode recording is available. Therefore, the intra-His bundle block might be erroneously diagnosed as A-H or H-V block if multiple recordings were not performed. In the present study, two electrode catheters, one in the right ventricle and the other in the aortic root, were used. In addition, a plunge wire electrode was inserted into the His bundle region in most cases. On the other hand, a continuous monitoring of the His bundle electrograms made it possible to observe a gradual increase in the duration of the His bundle deflection until an obvious splitting appeared. The His bundle activity was further validated by vagal stimulation and pacing from catheter electrode in the present study.

El-Sherif and coworkers (1974, 1975) reported that a Mobitz type II intra-His bundle block was initially observed before the development of a Wenckebach type block when the anterior septal artery of dog was ligated. They considered that these two types might represent only different degrees of the same disorder rather than two distinct electrophysiological processes. Hiejima and Suzuki (1975) reported that both Mobitz type II and Wenckebach type intra-His bundle block developed following the ligation of the anterior septal artery. Disagreeing with the previous reports, a true Mobitz type II block was not observed in our study. Careful measurements revealed that the $H_1-H_2$ intervals were variable both in pacing induced and in spontaneous intra-His bundle blocks. A Wenckebach periodicity as defined by Denes and coworkers (1975) was demonstrated in every case. However, further analysis of the periodicity revealed that 105 of 106 periods were atypical. Infrequency of typical Wenckebach periodicity in intra-His bundle
block has been pointed out by El-Sherif and coworkers (1975). The frequent
atypical findings in the present series were those with repeating and/or transient
decrease of $H_1-H_2$ intervals. Each of these was observed in approximately 65
percent. Although Denes and coworkers (1975) reported that the first increment
was not the largest in more than half of the patients with atypical Wenckebach
type A-V block, this atypical finding was demonstrated in only 9 percent in the
present study. The difference may result from the different localization of the site
of block.

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