Electrocardiographic Observation on Spontaneously Occurring Arrhythmias in Chickens

Shin MUKAI, Noboru MACHIDA, Masaaki NISHIMURA, Takashi NAKAMURA, Akio AMADA, and Keiji KIRYU

Department of Veterinary Pathology, Tokyo University of Agriculture and Technology, 3-5-8 Saiwaicho, Fuchu-shi, Tokyo 183, and Blood Horse Training Center JRA Foundation, Laurel Building No.2 7F, 1-10 Toranomon 1-chome, Minato-ku, Tokyo 105, Japan

(Received 12 March 1996/Accepted 6 June 1996)

A study on electrocardiograms of chickens was first reported by Buchanan [5] in 1909. In 1949, Sturkie [22] established a method for recording electrocardiograms of chickens, using standard bipolar limb leads. Analysis of normal electrocardiograms was performed by Kisch [12] in 1951, and by Rakalska [20] in 1964. There have been, however, few reports regarding spontaneous occurrence of arrhythmias in chickens. Sturkie [22] recorded alternating sinus rhythm and amplitude in 1949, Szabniewicz and McCrady [28] recorded respiratory sinus arrhythmia in 1967, and Mitchell and Brugh [18] reported ventricular premature contraction (VPC) in 1982. On the other hand, there have been a relatively large number of reports on experimentally induced arrhythmias in chickens. The reports published to date include those of the occurrence of arrhythmias induced by potassium deficiency [23, 24], thiamin deficiency [25], deficiencies of vitamin E and the B complex vitamins [27], administration of autonomic agents [9], Newcastle disease virus infection [17, 18], and avian influenza virus infection [18]. Types of arrhythmias induced experimentally under these conditions include sinus arrhythmia (SA) [9, 23, 25], sinus arrest [25], sinoatrial block [23, 24], sinus bradycardia [9, 24, 25, 27], sinus tachycardia [9, 18], VPC [9, 18, 23, 27], atrioventricular (A-V) block (AVB) [9, 17, 23, 27], A-V dissociation [24, 25], and atrial fibrillation (AF) [9].

Although numerous studies on arrhythmias in chickens have been reported, as mentioned above, almost all of them are concerned with experiments. By means of an electrocardiographic survey, we aim, in the present study, to clarify the spontaneous occurrence of arrhythmias and to discuss the relationship between chicken breed and arrhythmogenic tendency.

MATERIALS AND METHODS

As shown in Table 1, a total of 461 chickens (7 breeds) were used in this study. The total group was composed of 3 pure breeds and 4 crossbreeds. The former were Rhode Island Red (RIR, n=125), Japanese Game (JG, n=101), and White Leghorn (WL, n=52). The latter were the first filial generation (F1) obtained by mating RIR with JG (RIR × JG, n=44), the backcross obtained by mating the F1 of RIR × JG with the parental JG (RIR × JG) × JG, n=10), the F1 obtained by mating RIR with WL (RIR × WL, n=75), and the F1 obtained by mating RIR with the commercial hybrid chicken, Dekalb Amber Link (DAL)(RIR × DAL, n=65). Nine types of arrhythmias were observed in 107 chickens (23.2%, 107/461): 66 had sinus arrhythmia, 19 had atrial premature contraction, 9 had ventricular preexcitation syndrome, 7 had ventricular premature contraction, 2 had second-degree atrioventricular block, 1 had atrial fibrillation, 1 had aberrant ventricular conduction, 1 had intraventricular conduction disturbance, and 1 had ventricular electrical alternans. Except for sinus arrhythmia, the incidence of other arrhythmias in RIR was significantly high, compared with that in pure breeds other than RIR (p<0.001) and that in crossbreeds of RIR (p<0.01). Arrhythmias other than ventricular premature contraction and sinus arrhythmia will be the first to be described as spontaneously occurring arrhythmias in chicken. Although the reason for both the highest incidence of sinus arrhythmia in WL and the predominance of other arrhythmias in RIR were obscure, the present results suggest the possibility of using chickens, especially RIR which shows a high incidence of arrhythmias, as a relevant animal for studying arrhythmias.

unanaesthetized and unrestrained in a dark cage until they became quiet, and the electrocardiographic examinations were started. Such electrocardiographic examinations were performed in the day time: from 10:00 to 15:00. Electrocardiograms using standard bipolar limb leads (leads I, II and III) were recorded using one of two electrocardiographs, MINGOGRAPF 420 SYSTEM (Siemens-Elema AB, Sweden) or FD-31P (FUJUDA DENSHI Co., Ltd., Japan), both calibrated to 2 cm/mV at a paper speed of 25, 50, or 100 mm/sec. Electrocardiograms of each chicken were recorded continuously for 5 min or longer, and at least twice during the entire two-week of examination period. Since the waveforms recorded from lead II were the clearest and most stable among those recorded from the 3 leads, the duration of the wave was measured using lead II in most cases, but lead I on occasions. The QRS complex waveform was described using the standard nomenclature; namely, small waveforms were designated by small letters q, r, and s, and large waveforms by capital letters Q, R, and S. The heart rate of each chicken was calculated based on the electrocardiograms obtained. For each type of arrhythmia, incidences by type and chicken breed were compared statistically by chi-squared analysis.

**RESULTS**

The average heart rate (HR) per minute in the 354 chickens which showed normal sinus rhythm was 265.4 ± 47.1/min (mean ± SD). Statistically, the following relation was obtained between the duration of the P-R interval and the HR,

$$P - R \text{(in seconds)} \times 100 = -0.0062 \times HR \pm 8.3 \quad (R^2=0.423)$$

The standard error was ± 0.63 and the normal limits were regarded as being ± 2 times the standard error, the value of which was used to elucidate the abnormality of the P-R interval with arrhythmia. When the HR increased to more than 300/min, the P wave was superimposed on the T wave. As shown in Table 2, nine types of arrhythmias were exhibited by 107 of the 461 chickens (23.2%). These were SA (66 cases), atrial premature contraction (APC, 19 cases), AF (1 case), VPC (7 cases), ventricular preexcitation syndrome (VPE, 9 cases), aberrant ventricular conduction (AVC, 1 case), intraventricular conduction disturbances (ICD, 1 case), ventricular electrical alternans (VEA, 1 case), and AVB (2 cases).

### Table 1. The number of chickens studied by electrocardiography

<table>
<thead>
<tr>
<th>Breed</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purebreeds</td>
<td>No. (Age: M)</td>
<td>No. (Age: M)</td>
<td>Total</td>
</tr>
<tr>
<td>RIR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34 (14)</td>
<td>91 (10-13)</td>
<td>125</td>
</tr>
<tr>
<td>JG&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22 (15)</td>
<td>79 (15)</td>
<td>101</td>
</tr>
<tr>
<td>WL&lt;sup&gt;c&lt;/sup&gt;</td>
<td>52 (10)</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>Crossbreeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIR × JG</td>
<td>2 (5)</td>
<td>42 (5)</td>
<td>44</td>
</tr>
<tr>
<td>(RIR × JG) × JG</td>
<td>10 (24)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>RIR × WL</td>
<td>73 (15)</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>RIR × DAL&lt;sup&gt;d&lt;/sup&gt;</td>
<td>56 (10)</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>403</td>
<td>461</td>
</tr>
</tbody>
</table>

<sup>a</sup> Rhode Island Red, <sup>b</sup> Japanese Game, <sup>c</sup> White Leghorn, <sup>d</sup> Dekalb Amber Link (available as commercial fowl from DEKALB Poultry Research, Inc., USA.).

### Table 2. The incidence of nine types of arrhythmias compared among the chicken breeds

<table>
<thead>
<tr>
<th>Breed</th>
<th>SA&lt;sup&gt;e&lt;/sup&gt;</th>
<th>APC&lt;sup&gt;e&lt;/sup&gt;</th>
<th>VPE&lt;sup&gt;e&lt;/sup&gt;</th>
<th>VPC&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Arhythmias</th>
<th>Incidence of arrhythmias including SA(%)</th>
<th>Incidence of arrhythmias except SA(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure breeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>JG&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WL&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossbreeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIR × JG</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(RIR × JG) × JG</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIR × WL</td>
<td>7</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIR × DAL&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total of Crossbreeds</td>
<td>20</td>
<td>7</td>
<td>4</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (%)</td>
<td>66</td>
<td>19</td>
<td>9</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>a</sup> Rhode Island Red, <sup>b</sup> Japanese Game, <sup>c</sup> White Leghorn, <sup>d</sup> Dekalb Amber Link (available as commercial fowl from DEKALB Poultry Research, Inc., USA.), <sup>e</sup> sinus arrhythmia, <sup>f</sup> atrial premature contraction, <sup>g</sup> ventricular preexcitation syndrome, <sup>h</sup> ventricular premature contraction, <sup>i</sup> second-degree atrioventricular block, <sup>j</sup> atrial fibrillation, <sup>k</sup> aberrant ventricular conduction, <sup>l</sup> intraventricular conduction disturbance, <sup>m</sup> ventricular electrical alternans.

<sup>2</sup> Analysis for the incidence of arrhythmias except for WL because of only SA in WL: (1) RIR vs. JG and WL with 1 degree of freedom (df) (p<0.001), (2) RIR vs. crossbreeds of RIR (1 df) (p<0.01). Including SA, there was, however, no statistical difference among the breed in the incidence of arrhythmia.
Electrocardiographic features of arrhythmias

SA: This arrhythmia was characterized by a greater than 10 percent difference between the shortest and longest P-P interval. Each SA in all 66 chickens was phasic, similarly to respiratory SA.

APC: In the 19 chickens which were diagnosed with APC (Fig. 1 A, B), premature occurrence of the ectopic P waves (P') with deformation or omission of QRS-T was observed (Fig. 1B). Among these 19 chickens, the number of cases of APC followed by a noncompensatory pause was 11, including 7 cases of nonconducted APCs and 4 conducted APCs. Nonconducted APCs occurred during the period corresponding to approximately the first half of the P-P cycle (Fig. 1B). HRs of the 19 APC-affected chickens were 196–413/min (283.0 ± 55.3/min). Marked deformation of the P' wave was observed in 6 chickens (Fig. 1C); the 6 included a biphasic P' wave (3 cases) and decrease in amplitude or shortened duration of the P' wave (3 cases). In the other 13 chickens, the degree of deformation of the P' wave was relatively small, and the P' wave showed a configuration similar to the P wave in a tracing of the normal sinus rhythm. The P' wave was uniform in each case. The P-P interval at the time of the normal sinus rhythm was 148–284 msec (215.9 ± 39.6 msec). In contrast, the P-P' interval at the occurrence of APC decreased markedly to 94–167 msec (131.2 ± 24.4 msec). In particular, in the 7 chickens which showed nonconducted APCs followed by a noncompensatory pause, the P-P' interval decreased by 53.9 ± 3.9% compared with the normal P-P interval. The frequency of occurrence of APCs per min was 1–41 beats (9.1 ± 8.9 beats). In 12 of the 19 chickens, APCs were observed in a follow-up test performed approximately 1 month later; however, no APC was observed in the other chickens of this group.

AF: In 1 RIR, absence of P wave, presence of f waves and irregular rate in R-R intervals were observed, and it was thus diagnosed with AF (Fig. 2). In this chicken, AF was observed in all 4 electrocardiograms recorded. The amplitude and duration of the f wave varied: f wave ranged from 0.03–0.25 mV, and the frequency of fibrillation was 1,200–1,500 times/min. R-R interval varied irregularly within a range of 155–213 msec. Waveform of QRS complexes was of the RS type with lead II.

VPC: In the 7 chickens diagnosed with VPC (Fig. 3), premature QRS complexes were characterized by bizarre and wide QRS complexes that were unrelated to the P waves. VPC was unifocal with fixed coupling interval and followed by a compensatory pause (Fig. 3). HRs of the 7 VPC-affected chickens were 224–468/min (302.1 ± 84.3/min). Durations of abnormal QRS complexes (30–80 msec) were apparently increased compared with durations of QRS complexes in a tracing of the normal sinus rhythm (approximately 20 msec). Configurations of QRS complexes were as follows: 6 chickens exhibited QS type, and the other Rs type with lead II. The T wave that was involved in the anomalous QRS complexes was amplifed positively in the case of QS type with limb lead II, and the T wave was amplified negatively in the case of Rs type. The frequency of occurrence of VPCs was 1–2 beats/min (1.1 ± 0.3/min). No VPC was observed in any of the 7 chickens.
chickens in a follow-up test performed approximately 1 month later.

**VPE:** In the 9 chickens diagnosed with VPE (Fig. 4), shortened P-R interval following normal P waves and QRS complexes with anomalous waveform and prolonged duration were observed (Fig. 4A). There was, however, no delta wave. HRs of the 9 VPE-affected chickens were 272–390/min (317.5 ± 34.6/min). Referring to Fig. 4A, the P-R interval was abnormal. The P-R intervals in the case of occurrence of VPE were 18–58 msec (34.0 ± 15.0 msec), which were apparently shorter compared with those of the normal sinus rhythm. Although in 3 chickens the waveform of QRS complexes upon the occurrence of VPE was almost the same as that at the time of normal sinus rhythm or slightly anomalous, the waveform of QRS complexes showed marked anomalies in 6 chickens. These waveforms included RS type (5 cases) and Rs type (1 case) (Fig. 4B). The duration of QRS complexes at the occurrence of VPE was almost the same as or slightly longer than that at the time of normal sinus rhythm in the 3 chickens mentioned above (approximately 20 msec). However, in the other 6, apparent prolongation was observed (30–80 msec). The frequency of occurrence of VPE was 1–5/min (2.0 ± 1.5/min). In 3 of the 9 chickens, VPE was observed in the follow-up test performed approximately 1 month later; however, VPE was not observed in the other 6 chickens in a follow-up study. Ventricular tachycardia was not recorded in any of the 9 chickens at the occurrence of VPE.

**AVC:** One chicken (RIR) was diagnosed with AVC (Fig. 5), in which extremely bizarre QRS complexes were observed as 4–20 successive beats. The rhythm was sinus with 260/min. The frequency of occurrence of AVC was 200 beats/min on average. The configuration of the QRS complexes was altered as two (Rs and Qt type with lead II) or more, and the duration of each of those was prolonged (40–80 msec). There was always a P wave preceding the bizarre QRS complexes. AVC was observed in a follow-up test performed approximately 1 month later.

**ICD:** One Fl of RIR × DAL was regarded as ICD, from the tracing of which we were unable to define whether there was right or left bundle branch block. The occurrence of anomalous QRS-T complexes of 2–5 successive beats was observed (Fig. 6). The rhythm was sinus with 310/min. The waveform of QRS complexes upon the occurrence of ICD was Rs type followed by a negatively amplified T wave, and the QRS duration increased to more than 30 msec.

![Figure 2](image.png)

**Fig. 2.** Electrocardiographic tracings of 13 months-old RIR chicken (upper: standard limb lead I, middle: standard limb lead II, lower: standard limb lead III, all the tracings were recorded simultaneously), demonstrating atrial fibrillation with absence of P wave, presence of f wave, and irregular ventricular rate.

![Figure 3](image.png)

**Fig. 3.** Electrocardiographic tracings of 10 months-old RIR chickens (100 mm/sec, 2 cm/mV, standard limb lead II), demonstrating unifocal ventricular premature contraction followed by compensatory pause.
Fig. 4. Electrocardiographic tracings of 10 months-old RIR chickens (100 mm/sec, 2 cm/mV, standard limb lead II), demonstrating ventricular preexcitation syndrome. A: ventricular preexcitation syndrome with shortened P-R interval and QRS complexes with anomalous waveform (arrow) and prolonged duration, B: 2 types showing the anomalies of configuration of QRS complex. B-1: RS type, B-2: Rs type.

Fig. 5. Electrocardiographic tracings of 10 months-old RIR chickens (100 mm/sec, 2 cm/mV, upper: standard limb lead I, lower: standard limb lead II, both I and II tracings were recorded simultaneously), demonstrating aberrant ventricular conduction showing a variety of the bizarre QRS complexes with a preceding P wave. A: atrium, A-V: atrioventricular, V: ventricle.

compared with that in the tracing of normal sinus rhythm (approximately 20 msec). ICD was observed in the follow-up test performed approximately 1 month later.

VEA: In 1 RIR, the configuration of QRS-T complexes alone alternated with regular rhythmicity: the underlying rhythm was actually sinus, and the chicken was diagnosed with VEA (Fig. 7). HR at the time of both normal sinus rhythm and VEA was almost the same at approximately 330/min. This chicken exhibited intermittent 2:1 VEA. The waveform of QRS complexes upon the occurrence of VEA was Qr type, followed by a positively amplified T wave, VEA was observed in a follow-up test performed approximately 1 month later.
AVB: In the 2 RIRs which were diagnosed with AVB, P waves were clearly recorded with lead I (Fig. 8). Occasionally, the P-R intervals became progressively prolonged until a P wave was not followed by the QRS complex. In one of these two chickens, P-R intervals at the time of normal sinus rhythm were approximately 65 msec and those at the time of AVB increased to a maximum of 170 msec. AVB with 2:1 A-V conduction and AVB with 3:2 A-V conduction coexisted. The number of dropped beats was approximately 120/min. In the other chicken, P-R intervals at the time of normal sinus rhythm were approximately 70 msec, and these increased to a maximum of 111 msec at the time of AVB. Here, both AVB with 2:1 A-V conduction and that with 3:2 A-V conduction were frequently observed, and the frequency of dropped beats was approximately 170/min. In these 2 chickens, AVB was observed in a follow-up test performed approximately 1 month later. In addition, both exhibited AVB after intramuscular administration of 1 mg atropine sulfate.

Incidence of arrhythmias

Table 2 shows the incidence of nine types of arrhythmias among the chicken breeds. The incidence of only SA in WL was found to be significantly higher than that of the other arrhythmias in each breed. Except for SA, the incidence of the other types of arrhythmias in RIR was significantly higher than that in both JG and WL (p<0.001) and that in crossbreeds of RIR (p<0.01).

DISCUSSION

In the electrocardiograms of 461 chickens of 7 breeds, arrhythmias were observed in 107 chickens (23.2%). Arrhythmias in this study were of 9 types: SA, APC, AF, VPC, VPE, AVC, ICD, VEA, and AVB. Except for SA, the incidence of APC was the highest. Since all SA, which was predominant in WL, was phasic, it seemed to be associated with normal respiratory cycles [29] and was considered to be physiologic in, for example, a companion bird [15] and a dog [4]. Eventually, the spontaneous arrhythmias in chickens revealed 14.3% in SA and 8.8% of arrhythmias other than SA. Consequently the incidence of arrhythmias other than SA was the highest in RIR, though the relationship between the incidence of arrhythmia and age could not clarify due to lack of chickens of appropriate age groups. It seems probable that the present report is the first on the spontaneous occurrence of APC, AF, VPE, AVC, ICD, VEA, and AVB in chickens. Neither spontaneous nor experimentally induced VPE, AVC, ICD and VEA have been reported previously. As stated in the introduction, there have been very few reports regarding spontaneous occurrence of arrhythmias in the chicken [26], contrary to reports on experimentally induced arrhythmias [9, 17, 18, 23–25, 27].

APC and AF: In humans, AF seems likely to follow properly timed APC [3, 10, 21]. Meanwhile, frequent occurrence of APC around the same time that AF occurs is reported for cows [7, 16] and horses [1]. Therefore, although the present case was only one chicken which exhibited a type of sustained or chronic AF, transient or paroxysmal AF seems likely to emerge more frequently in chickens, especially in RIR in which the incidence of APC is most prominent. In addition, since nonconducted APC occurred during the period corresponding to the first half of the P-P cycle in 7 of the 19 chickens with APC in this study, the arrhythmia of APC, in particular nonconducted APC, may possibly affect the occurrence of AF in chickens in a manner similar to that in mammals [21].

VPC, VPE, AVC, ICD, and VEA: Occasional VPC have been described in normal chickens which were maintained in isolators and showed no clinical signs of illness, and it is denied that VPC is due to disease- or agent-specific [18]. This condition seems to be consistent with our findings of VPC. On the other hand, the 9 cases of VPE observed in the present study were apparently different from those of APC or VPC, based on electrocardiographic characteristics such as normal P waves, shortening of P-R intervals and QRS complexes of abnormal waveform and prolonged duration. No delta wave was observed in the VPE of the present chickens, and their electrocardiographic characteristics were those of arrhythmia similar to Lown-Ganong-Levine syndrome rather than Wolf-Parkinson-White (WPW) syndrome in humans [29]. Interestingly, Lu et al. [13], who histologically examined the A-V conduction system in chicken heart, suspected that arrhythmia similar to WPW syndrome may occur in chickens, because of the possible relation to an accessory pathway in the A-V conduction system of the chicken. We agree with the suggestion of Lu et al. In the case of the arrhythmias such as VPE, AVC, ICD and VEA in the present chickens, the individual of which exhibits abnormal QRS complexes with preceding P waves, the A-V Parkinje ring and/or the middle bundle branch [11, 13, 19] may play a significant role in the genesis of those arrhythmias, though unknown in details.

With regard to human arrhythmias, it is well known that AVC is result of altered impulse propagation because of the refractoriness in parts of the usual conduction pathways, particularly, the delay in the right bundle branch [2, 6]. There is another interesting statement that when the ventricular rate is extremely rapid in AF with anomalous A-V conduction in WPW syndrome, AVC may lead to markedly bizarre QRS complexes [6]. The reason for taking an interest in this description is that we have found AF, VPE and ICD though each of them occurred separately. Furthermore, there have been 3 hypotheses on the mechanism of VEA [6]; (1) anatomic alteration of cardiac position, (2) alteration of cardiac output and (3) alternating prolongation of the refractory phase of some part of the heart. Although these hypotheses are not fully developed, the last one of alternating prolongation of the refractoriness seems to be correspond to the case of our chicken, and presumably VEA, from an arrhythmogenic viewpoint, may be associated with VPC, VPE, AVC and ICD in common with each other, at the avian A-V conduction [11, 13, 19]
with some disturbances [2, 6].

AVB: Experimental induction of AVB in chickens by potassium deficiency, administration of acetylcholine, and thiamin deficiency has been described [9, 17, 23, 27]. These conditions were ruled out as a possible case of arrhythmia in this study. AVB, type I or Wenckebach block, is an arrhythmia most frequently occurring in racehorses, caused by increased vagal tone due to training or other exercise in general [8]. The same AVB is also observed in racing pigeons [14], and is probably due to vagotonia in birds [15]. It is denied, however, that the present AVB observed in RIR chickens was not due to vagotonia, because the chickens still exhibited AVB after atropinization. Presumably, AVB in the present findings may be indicative of pathologic changes in the myocardium or cardiac conduction systems.

In the chickens used in this study, no specific clinical signs were observed, and the possibility that etiological factors, such as viral infection [17, 18], vitamin deficiency [25, 27] or potassium deficiency [23, 24], affected the spontaneous occurrence of arrhythmia is thus eliminated. In short, the predominant incidence of arrhythmias in RIR
is worthy of note, though no explanation for this phenomenon is found at present. We especially emphasize, however, that RIR is a relevant animal for studying arrhythmia. Further study, such as intracardiac electrophysiologic study and histopathological study, will be necessary in the future.

ACKNOWLEDGEMENTS. The authors are grateful to the staffs of both the National Livestock Breeding Center Okazaki Station and the Tokyo Metropolitan Livestock Experiment Station for the kind disposal of chickens.

REFERENCES

ARRHYTHMIAS IN CHICKENS