Development of Auto-diagnostic Electrocardiograph for Dogs

Tomiya UCHINO, Rie KANO, Daisuke KATO, Naoyuki TAKEMURA, Hidekazu KOYAMA, Kunito KOBAYASHI, Toshinori SAKO, Shigekatsu MOTYOYOSHI, *Hisao FUKUDA, Takeshi KATUMATA and *Yasuo SAI TO

*Fukuda M-E Kogyo Co., Ltd. 18-2 Yoshima 2-Chome, Bunkyo-ku, Tokyo 113, Japan
Department of Medicine, Nippon Veterinary and Zootechnical College, 1-7-1 Kyonancho, Musashino-shi Tokyo 180, Japan

Abstract. Development of an autodiagnostic electrocardiograph for canine use has apparently not been published to date, and there is no such product on the market. In the present study, modification of the conventional canine autoanalyzing electrocardiograph was tried with the purpose of performing computer assisted ECG diagnosis for dogs. Model 503 FB-D (Fukuda M-E Kogyo Co., Ltd.) of autoanalyzing electrocardiograph was used for the modification study. The system consisted of a Model 8086 computer as the CPU with 80 and 128 Kb memories, ECG amplifier, R wave detector, A/D converter, ECG recorder, LED display, thermal printer and floppy disk drive. ECG and measurement data are recorded continuously for 10 to 20 sec as the database for analysis of heart rate, PR interval, QRS duration, QT interval, all the P, Q, R, S and T waves, ST segment and VAT time from each lead. These values were then used to calculate the QTc and QRS electric axes and VAT time. The above data were then used for diagnosis of abnormal ECG patterns and to analyze arrhythmia of dogs. The accuracy of this improved system was assessed by using 200 cases with abnormal ECG findings. The results suggested that the modified model 503 FB-D autodiagnostic ECG with the computer program, might be practically applicable to canine medicine.

There has been no automatic ECG analyzer intended for dogs such analyzer was developed by the author and his group\(^1\)\(^-\)\(^5\). It is reported in this paper, Such analyzer was also reported by Tilly\(^4\) and his group. In 1983, the author and his group tried to apply some automatic ECG analyzers developed for human beings directly to dogs, but could not obtain good results from any of them. They concluded that none of these analyzers for human use were applicable to dogs\(^3\).

Accordingly, the author and his group and the Fukuda M. E. Kogyo Co., Ltd, started to develop an automatic ECG analyzer for dogs in 1984. In this year, a 3-channel model 503 FB-D (Fukuda M. E. Kogyo Co., Ltd.) was developed as an automatic ECG analyzer to be used for basic experiments on dogs. Its analytical accuracy was

--- 40 ---
reported was published before a meeting of the Japanese Society of Veterinary medicine (1984)¹ and the 10th World Congress of WSAVA in Tokyo².

Also reported were the actual measurement values of 1,500 beagles and the normal values for beagles obtained by using the 503 FB-D³.

In 1986, this device was put on the market as an automatic ECG analyzer for laboratory dogs by the Fukuda M. E. Kogyo Co., Ltd. Next, the author and his group tried clinical application of the automatic ECG analyzer incorporating an automatic diagnostic function. By incorporating the analytical function of the 503 FB-D into a 1-channel ECG analyzer and loading an automatic diagnostic program on it, the author and his group developed an automatic analyzer, model 501 AX-D.

The canine ECG analyzer was developed as one of the steps for the veterinarian acting in the field of small animal medicine who does not use the ECG machine to know the worth of the machine.

The canine ECG analyzer is therefore designed for the veterinarian who has little knowledge on the ECG to be provided with a guide not only for the diagnosis of elementary cardiac disease, but also for its treatment.

With the canine ECG analyzer, various measurements may not be welcome to the veterinarian who is familiar with the ECG. ECG can be automatically and immediately performed. In addition, the detailed diagnosis can be made by analyzed coefficient variation of the R-R interval.

The outline of this device was reported at the 10th World Congress of the WSAVA³.

In the following, the functions and diagnostic accuracy of the automatic ECG analyzer are reported.

Materials and Methods

1. Manufacturing of automatic ECG analyzer

Fig. 1-A shows the automatic ECG analyzer, model 503 FB-D, developed for the first time. Fig. 1-B shows the external view of the automatic ECG analyzer, model 501 AX-D. Fig. 2 shows a structural block diagram of the 501 AX-D manufactured by the author and his group.

Built around a V 30 microprocessor, the system consists of a 128 kilobyte ROM, a 256 kilobyte RAM, ECG signal amplifiers, an R-wave detector, an analog-to-digital converter, and a liquid crystal display. The analysis is printed out on the thermal printer.

Fig. 3 is an outline illustration of the diagnosis mechanism. A QRS-wave is sampled from the input ECG to distinguish some typical waves. Then, from these waves, a P-wave, a QRS-group, and a T-wave are distinguished. Their amplitudes and conduction times are measured. If fluctuations at the base line level, myogram

---

Fig. 1-A 503 FB-D type

Fig. 1-B 501 AX-D type
current, noise of utility voltage, etc. are detected, they are corrected or removed by the noise suppressor. The microprocessor compares the measurements with the criteria that we have prepared and programmed. After comparison, the device makes diagnoses and prints out suggested remedies.

Six-limb leads were adapted as a lead method for this device to simplify electrode placement as far as possible. A clip electrode designed by the author and his group was used.

2. Analysis Items and Diagnosis Items

Our device can analyze data, such as heart rate, PR, QRS, QT-time, amplitudes of waves from six-limb leads, ST-segment, QTc, QRS, axi, and VAT-time. The ECG shown at the bottom is one the signal waves from the six leads. The signal was printed on the device's thermal recorder.

When arrhythmia appears, 30-second ECG can be performed by switching the mode. For all ECGs recorded, the R-R interval is measured and analyzed. The measured values of R-R interval fluctuation coefficient, R-R histogram, heart rate trend graph and R-R interval are printed out.

Table 1 is the list of diagnoses that the device suggests. The criterion for the diagnoses are those we have used at our laboratory.

The device gives 45 diagnoses that include RVH, LVH, RAD, LAD, BVH, ST-segment depression, abnormal T, low voltage, RA overload, LA overload, QT prolongation, first degree A-V block, second degree A-V block, third degree A-V block, WPW syndrome, short PR interval, complete RBBB, complete LBBB, SVPC, VPC, SVPC short run, atrial flutter, atrial fibrillation, SV rhythm, V rhythm, sinus arrhythmia, sinus arrest, tachycardia, bradycardia, ventricular tachycardia, and wandering pacemaker.

In addition, a guide to treatment for the 18 items to be automatically diagnosed is lastly printed out.

3. Functions of 501 AX-D

The specification of the device is shown in Table 2 and its functions are shown in Table 3. The device weighing 5 kg is handy to carry and its power supply is selectable between DC and AC. The automatic diagnostic function can be switched into the manual mode. The device can also be used as various types of monitor by operating the built-in display and QRS sound switches.

The 501 AX-D is not provided, however, with
Table 1 Diagnosis with the Cardisuny 501 AX-D

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Left Axis Deviation</th>
<th>Left Ventricular Hypertrophy</th>
<th>Right Axis Deviation</th>
<th>Both Ventricular Hypertrophy</th>
<th>Third Degree A-V Block</th>
<th>Second Degree A-V Block (Wenckebach)</th>
<th>Short PR Interval</th>
<th>Intraventricular Block</th>
<th>Ron T</th>
<th>Ventricular Tachycardia</th>
<th>Ventricular Rhythm</th>
<th>Tachycardia</th>
<th>Sinus Arrhythmia</th>
<th>Sinus Arrest</th>
<th>Right Atrial Overload</th>
<th>Dextrocardia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Ventricular Hypertrophy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indeterminate Axis Deviation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST Segment Depression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Degree A-V Block</td>
<td></td>
<td>Abnormal T</td>
<td></td>
<td>2:1 A-V Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Degree A-V Block</td>
<td></td>
<td>WPW Syndrome (Wolff-Parkinson-White)</td>
<td></td>
<td>Supraventricular Premature Beat Short Run</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete Left Bundle Branch Block</td>
<td></td>
<td>Complete Right Bundle Branch Block</td>
<td></td>
<td>Supraventricular Premature Beat Short Run</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventricular Premature Beat</td>
<td></td>
<td>Ventricular Premature Beat Short Run</td>
<td></td>
<td>Supraventricular Tachycardia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supraventricular Rhythm</td>
<td></td>
<td>Wandering Pacemaker</td>
<td></td>
<td>Sinus Arrhythmia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bradycardia</td>
<td></td>
<td>ST Elevation</td>
<td></td>
<td>QT Prolongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Voltage</td>
<td></td>
<td></td>
<td></td>
<td>QT Prolongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Atrial Overload</td>
<td></td>
<td></td>
<td></td>
<td>QT Prolongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 501 AX-D SPECIFICATION

- **General specification**
  - Recording: Thermal array dot printer
    - (8 dots/mm, 56 mm width)
  - Chart paper: 63 mm×30 cm (Roll type)
    - 63 mm×50 cm (Z-fold type)
  - Chart speed: 25, 50 mm/s.
  - Recording lead: Limbs’ 6 ECG leads
- **Power requirements, Size**
  - Power supply: AC 110-120 V/200-240 V, 50/60 Hz DC 12 V rechargeable battery (PE 2-12 R 12 V 2 AH×1), continuous operation time more than 2.5 hours.
  - Power consumption: 13 w
  - Dimensions: 300(W)×242(D)×87(H) mm.
    - (12"×9.5"×3.4")
  - Weight: 5 kg (11 lbs)
- **Technical characteristics**
  - Input: Floating circuit, Pacemaker pulse suppression circuit
  - Input impedance: Greater than 50 Mohms
  - Linearity: Better than 5% in a range of ±28 mm
  - Time constant: Over 3.2 sec
  - CMR: Better than 70 dB
  - Frequency response: -3 dB at 0, 0.5-100 Hz
  - Filter: AC HUM(HF) -20 dB at 50/60 Hz
    - EMG (MF) -3 dB at 35-45 Hz
    - Baseline drift (DRIFT) -3 dB at 0.5 Hz
  - Sensitivity: 1/2, 1, 2, AUTO A/B
  - DC input: 10 mm/0.5 V
  - CRO output: 0.5 V/1 mV
  - Calibration: 1 mV square wave
  - LCD: 64×240 dot
- **Safety standard**
  - Classification: Class 1, Type CF
  - Leakage current: Less than 30 μA
  - Patient leakage current: Less than 5 μA
  - Withstand voltage: AC 3000 V, 1 minute
- **Environmental conditions (free from dew)**
  - Temperature: 10-40°C
  - Humidity: 30-85%
- **Accessories**
  - 1 Power cord
  - 1 ECG lead cord
  - 1 Grounding wire
  - 5 Clip type electrode
  - 5 Needle type electrodes
  - 1 Electrode case
  - 1 Small screw driver
  - 1 Accessory case
  - 2 Power fuses
  - 1 Chart paper (Z-fold type 63 mm×50 m)
  - 1 Dust cover
  - 1 Carrying bag
  - 1 Operating instructions
  - 1 ECG analysis code book
- **Optional accessories**
  - Carrying cart (AT-185)
  - ECG lead cord hanger (DP-100)
Table 3. Function menu in 501 AX-D

<table>
<thead>
<tr>
<th>Item</th>
<th>Menu Key (1)</th>
<th>Menu Key (2)</th>
<th>Menu Key (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Filter</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) Sex message</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Critical Point</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Beat Sound</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Paper Margin</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Measurement</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Auto Centering</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) Power Frequency</td>
<td>50Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(9) Unit (Amplitude)</td>
<td>mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(10) Unit (Interval)</td>
<td>msec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(11) Marker selection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(12) Interpretation</td>
<td>Dominant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(13) Copy wave</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14) R-R Analysis</td>
<td>ON</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(15) R-R Analysis Select</td>
<td>All data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(16) R-R Analysis List</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Study on Automatic Diagnostic Accuracy

To study the diagnostic accuracy, a comparison was made between the judgment results obtained by the device from some cases of cardiac abnormalities out of the patient dogs brought to the affiliated hospital, and the analysis results on human patients.

The measurement accuracy of each channel is already reported\(^1\)\(^2\)\(^3\). Therefore, regarding causes, a comparison was made on only the diagnostic accuracy rate.

A study was made on the diagnostic accuracy rate in about 326 cases of abnormal ECG and 231 cases of arrhythmia.

Experimental Results

1. Performance of Automatic ECG Analyzer

The experimental results of the performance of this device are given below. Fig. 4-1 is a record and diagnosis of some case. First, the ECG in the upper part is a real ECG of lead II. The ECG on the next column is an ECG of 6 limb lead, recorded on the computer during lead II recording. The ECG of 6 leads being the second is reproduced from the left of the ECG in the upper column.

The dot line recorded in each waveform indicates the start point of P-wave, the start point and end point of QRS and the end point of T-wave, indicating the time serving as the measurement point for each channel.

By comparing this dot line with the measurement value, it can be clarified if each wave has been correctly recognized.

When the base line sways or an EMG is mixed, the measurement point may be shifted and the measurement value may be disturbed. That is, the values of PR, QRS and QT time may become abnormal. This judgment can be known by the dot line.

Fig. 4-2 shows an analysis result and judg-
Fig. 4 ECG & Analysis Result
The device first prints out the date and time of measurement, then the heart rate, PR, QRS, QT-time, axis, and QTc.

The ID No., sex, age, weight, breed, and diagnosis are filled in by the veterinarian. Then, device prints out its analyses of the ECG and a diagnosis. If there is more than one diagnosis, all are printed out.

Fig. 4-3 shows a guide to treatment and remedy for the diagnosis result. Comments are not programmed, however, about all diagnosis items. If the analysis result is wrong, a wrong comment will naturally be printed out.

The numeric values given in the lower right part are measured amplitude values, VAT values and QRS times, P-wave, QRS complex ST segment and T-wave of 6 limb leads.

This measured amplitude value is measured on the ECG after passing the filter if the filter switch has been turned on. Therefore, QRS may be fairly attenuated, leading an judgment error. Accordingly, care must be exercised when the filter is used.

Fig. 5 shows a compressed ECG, R-R fluctuation analysis, R-R histogram and heart rate trend.

If arrhythmia is diagnosed, the device operator changes the recording mode from “A” to “B” to set the recording period to 30 seconds. Then, observing the LCD, stores an ECG of 30 seconds in the computer. After several seconds, the machine presents a compressed ECG, (Fig. 5-1).

A triangle-mark at a QRS-group indicates that the QRS is recognized and analyzed. On this ECG, the device measures an R-R interval for the entire 30 seconds.

Fig. 5-2 shows R-R interval histogram and heart rate trendgram.

Regarding the R-R fluctuation rate, a study has not been made on dog’s arrhythmia, but may be used as an index to judge the disease condition of arrhythmia.

For the R-R histogram, all the R-R intervals recorded for 30 seconds are recorded with the
vertical axis of the degrees of R-R interval and the horizontal axis of the time of R-R interval.

The heart rate trend graph indicates the heart rate on the vertical axis and the number of R-waves on the horizontal axis.

In **Table 4**, all the measurement values executed for 30 seconds are printed out in the order of measurement.

The maximum number of R-Rs to be printed out, however, is 170 and the part exceeding this limit is discarded.

That is, the limit of the measurable heart rate of this device is 340 for 1 minute. However, on dog's ECGs, most tachycardia will not exceed this limit.

Our device has other functions. One is a copy function. You can get a hard copy of the ECG and diagnoses simply by pressing the copy switch. The copy function always works unless you have turned off the power switch or you take another ECG. You can check heart rate aurally by listening to the R-wave single sound.

### 2. Results of Automatic Diagnosis

I will present some examples of diagnosis, and discuss the strength and weakness of our device.

**Fig. 6-1** shows an example where a judgement was given as VPC.

In **Fig. 6-1**, the heart rate is 171 BPM. The device diagnosed this case as VPC and tachycardia.

**Fig. 6-2** shows fluctuation of the base line but no VPC. However, the diagnosis was VPC. This is a most typical erroneous diagnosis. It is caused by movement of the animal body during measurement.

By observing the ECG being taken with some knowledge of reading ECGs, you can easily detect this phenomenon. To prevent this, fix the animal body securely.

**Fig. 7** shows a correct diagnosis and erroneous diagnosis on SVPC.

SVPC is an arrhythmia that is hard to recognize by machine.

**Fig. 7-1** is an example of SVPC correctly diagnosed.

In **Fig. 7-2**, the SVPC is missing. The device diagnosed the case as sinus arrhythmia. The type of arrhythmia is determined based on the relationship between current and former R-R
Fig. 6-1 Judgment VPC

Fig. 6-2 Misjudge VPC
Fig. 7-1 Judgment SVPC

Fig. 7-2 Misjudge SVPC
intervals. And this method can cause sometimes incorrect diagnoses. We are working to improve the method of diagnosis.

Fig. 8 is a diagnosis of ventricular tachycardia. In this example, the case has been diagnosed correctly as VPC and ventricular tachycardia, but this is sometimes diagnosed incorrectly as simple sinus tachycardia. Discrimination of VPC is performed by comparison after obtaining a mutual correlation coefficient in the vicinity of QRS about its form.

When the same waveform continues, the case may be diagnosed as sinus tachycardia in spite of VT. This point can be known by watching the waveform and judgment with a little knowledge of ECGs.

In the case of dogs, the heart rate varies greatly with weight and its normal range is very wide. Therefore, the device diagnoses a case exceeding 160 BPM as tachycardia putting a standard around a weight of 10 kg. Regarding bradycardia in which the same will occur, the device diagnoses a case under 70 BPM as brady-cardia.

Fig. 9 is an ECG that was diagnosed as atrial fibrillation. The diagnosis of this type of arrhythmia is based on a heart rate of 160 BPM or more and absolute arrhythmia, thus on a fluctuation of the R-R interval. In this case the fluctuation is 16.4%. Occasionally, atrial fibrillation could be incorrectly diagnosed as sinus arrhythmia. We have to reconsider the method of detecting the f-wave.

Fig. 10-1 shows the first degree A-V block, with a P-R time of 0.158 seconds. The first degree A-V block is diagnosed when the R-R time is 0.130 seconds or longer.

Fig. 10-2 shows an example where the case was diagnosed as second A-V block. At this arrhythmia, if it is attended with the Wenckebach, the P-R time is not printed out.

This is due to a fluctuation of the P-R time at every pulsation. Fig. 11 shows an example of RVH, LVH and BVH.

RVH is determined based on the lead waves, axis, and amplitude of the QRS group. Our
Fig. 9 Atrial fibrillation

Fig. 10-1 1st degree A-V block
Fig. 10-2 2nd degree A-V block

Fig. 11-1 RVH
Fig. 11-2 LVH

Fig. 11-3 BVH
device is especially strong at diagnosing these abnormalities.

**Fig. 11-1** is a case of RVH that was correctly diagnosed.

**Fig. 11-2** is a case of mitral insufficiency that had developed LVH. The device diagnosed it as LVH.

**Fig. 11-3** is a case of BVH. Based on Q-wave amplitude, QRS-time, and axis, the device made a correct diagnosis.

**Fig. 12** shows a diagnosis of an R-wave abnormality, indicating an example of RAO and LAO. RAO is diagnosed at an amplitude of 0.4 mV or more and LAO at a P-wave duration of 0.04 sec. or more.

At the top the slide is an example of right atrium overload. The bottom is the left atrium overload. Both cases were properly diagnosed.

### 3. Diagnostic Accuracy of the Device

A study was made on the diagnostic accuracy rate of the device with 326 cases of abnormal ECG and 231 cases of arrhythmia.

The diagnostic accuracy rate for abnormal ECGs is shown in **Table 5**.

<table>
<thead>
<tr>
<th>Abnormal ECG Cases</th>
<th>Automatic analysis</th>
<th>Diagnosis rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVH</td>
<td>65</td>
<td>92.3</td>
</tr>
<tr>
<td>LVH</td>
<td>26</td>
<td>96.1</td>
</tr>
<tr>
<td>BVH</td>
<td>7</td>
<td>85.7</td>
</tr>
<tr>
<td>Low Voltage</td>
<td>38</td>
<td>71.0</td>
</tr>
<tr>
<td>ST Elevation</td>
<td>8</td>
<td>100.0</td>
</tr>
<tr>
<td>ST Depression</td>
<td>32</td>
<td>100.0</td>
</tr>
<tr>
<td>Abnormal T</td>
<td>105</td>
<td>83.8</td>
</tr>
<tr>
<td>RAO</td>
<td>4</td>
<td>50.0</td>
</tr>
<tr>
<td>LAO</td>
<td>23</td>
<td>78.2</td>
</tr>
<tr>
<td>QT Prolongation</td>
<td>18</td>
<td>100.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>326</td>
<td>85.7</td>
</tr>
</tbody>
</table>

As a result, the diagnostic accuracy rate for RVH, LVH, ST elevation, ST depression and QT prolongation was 92.3 to 100%.

Next, the diagnostic accuracy rate for low voltage, abnormal T and LAO was the second highest, 71.0 to 83.8%, but that for RAO was 50%, being the lowest. This is due to the fact that the device in the early stage, the P amplitude of the diagnostic standard for RAO was set at 0.5 mV or more for lead II and RAO
Table 6 Diagnosis rate of Arrhythmia

<table>
<thead>
<tr>
<th>Arrhythmia</th>
<th>Gases</th>
<th>Automatic analysis</th>
<th>Diagnosis rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tachycardia</td>
<td>32</td>
<td>30</td>
<td>2</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Wandering Pacemaker</td>
<td>16</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>Sinus Arrhythmia</td>
<td>38</td>
<td>28</td>
<td>10</td>
</tr>
<tr>
<td>Sinus Arrest</td>
<td>12</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>AF</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>A-V Block</td>
<td>40</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>SVPB</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>VPB</td>
<td>65</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>VT</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>231</td>
<td>191</td>
<td>40</td>
</tr>
</tbody>
</table>

was not identified at a lower amplitude. At present, this standard is set at 0.4 mV.

The average diagnosis rate for the abnormal cardiograph was 85.7 %. Various rates of diagnosis of arrhythmia are shown in Table 6. The diagnosis rates of sinus tachycardia, sinus bradycardia, AF, and SVPC were favorable, ranging from 93.8 to 100 %. The diagnosis rates for wandering pacemaker, sinus arrest and VPC were 81.3–84.6 %. The diagnosis rates for sinus arrhythmia, A-V block and ventricular tachycardia were low, or 66.7–75 %. The reason for ventricular tachycardia having the lowest diagnosis rate is due to the fact that it is diagnosed as sinus tachycardia when only the wave for ventricular tachycardia is found.

DISCUSSION

Studies to establish an automatic electrocardiogram analysis system for use in human medicine were started about 20 years ago. It was only a few years ago that devices and application programs for such a diagnostic system were first put on the market. Since then, the number of cases diagnosed by using automatic electrocardiographs has rapidly grown to 2–3 million per year at present, which accounts for about 10% of the total number of electrocardiographic diagnosis cases, including manual operation, in the area of human medicine.

On the other hand, the number of automatic electrocardiographic systems in operation is still very small in the area of veterinary medicine. Actually, the first model of such a system, which was designed for clinical treatment of small animals, appeared on the market in January, 1962. Although the number in operation is small, the use of such a system becoming more and more common. The system's success in the area of small animal treatment depends completely on its accuracy.

It is said that automatic analyzers for human use properly diagnose 95% of the patients in the case of mass examination and 80–85% in the case of general clinical treatment. The rate shows no large differences among models from different manufacturers. It is also said that the system has shown an excellent performance in wave analysis, even better than young doctors. The system is not reported, however, to be successful in arrhythmia analysis, which is why the system is still untrusted.

The reason for this failure is reported to be as follows: The system is not so good in recognizing spikes with small wave wave heights, such as P-wave, f-wave and delta-wave. Also, the period for entering electrocardiogram data is as short as 10–20 seconds. Therefore, it is difficult for the system to determine fundamental waves. The same can be said for our 501 AX-D model. Here too, this is becoming a major problem. We diagnosed 85.7% of our subjects properly as abnormal electrocardiogram from the obtained wave shape data. This group included hypertrophy, axis shift, abnormal ST, abnormal T-wave, bundle-branch block, and low voltage. The results showed, however, an especially poor performance in diagnosing low voltage, RAO and LAO. This was not surprising for us, because we knew that more cases of low voltage had been reported when an automatic electrocardiogram analyzer was used. This is because QRS may attenuate during the process of filtering out impurity currents, such as electromyogram or A.C. Therfore, QRS amplitude tends to be smaller. This difficulty can be signi-
ficantly reduced by securing the animal firmly, switching off the filter, and comparing ECG. On the other hand, an inadequately small number of cases were reported for a trial load, because the diagnostic criteria of the device were set at an unnecessarily higher value. All the problems mentioned above have been solved by now. Therefore, a much better performance in diagnosing abnormal electrocardiograms is expected if calculation is made differently, based on our analysis.

In diagnosing arrhythmia, our 501 AX-D answered correctly to 85.5% of all cases, which was a higher percentage than we had expected. It is also a higher figure than that in human treatment. Among them, however, our system showed a poor performance in diagnosing sinus arrhythmia, sinus pause, A-V block, and VT. The reason for this is considered to be as follows:

Differences among sinus arrhythmia, sinus pause, and A-V block, especially between the first two, are sometime so subtle that the device cannot tell which is the case. Also, our application program for diagnosing sinus arrhythmia and sinus pause may not be a right one. Our criteria for sinus arrhythmia were the existence of an RR interval lasting 0.12 seconds or more. For sinus pause, the sudden disappearance of P, QRS and T accompanied with an RR interval twice as long as those preceding and following it was our criterion.

In the case of A-V block, misdiagnosis occurred most often in diagnosing second-class A-V block, which was often misdiagnosed as sinus arrhythmia because only a P-wave was found and there was no sign of QRS group. This phenomenon was observed only when the base line contained such artifacts as electromyogram, because these impurity components made it difficult to exactly trace the P-wave components.

Of all the nine VT cases examined, six were diagnosed properly and three improperly. The major problem here was that the pulse shapes resembled those of paroxysmal tachycardia in all the three misdiagnosed cases. Thus, the cases were misdiagnosed as sinus tachycardia. This mistake is again attributed to the device's poor capability of detecting P-waves. A more study is required, however, before we draw any conclusion, since the number of cases studied was too small.

As for diagnosing tachycardia and bradycardia, we need further discussion because examining a dog which weighs 1 kg and one which weighs 70 kg according to the identical criteria is not valid.

This discussion is part of what we have learned from the results of our study on our automatic electrogram analyzer. Although we have discussed here most of the major points, there is still room for further discussion. We will leave it for a later date.

In the field of human medicine, some people still claim that automatic analyzers are unnecessary. Some even say that they are harmful because doctors will not want to learn how to interpret electrocardiograms. On the other hand, some other people say that they have learned how to read electrocardiograms through automatic electrocardiography. All in all, specialists who make use of the system advocate it based on its contribution to reducing the time needed for examining electrocardiograms. They also endorse the well-organized output data.

This trend is also expected to be common in the field of veterinary cures in the future. However, other factors, such as properly securing animals and insertion of electrodes, should be kept in mind to prevent misdiagnosis. These factors have nothing to do with the performance of the electrocardiograph itself. Rather, proper handling of animals is important here.

The contents of this paper were reported at the symposium of the Small Animal Medicine and Surgery Section of the XXIII World Veterinary Congress, which was held in Montreal, Canada, in August, 1962.

— 56 —
REFERENCES


犬の自動診断心電計の開発

内野富弥・鹿野りえ・加藤大介・竹村直行
小山秀一・小林関仁・左向敏紀・本好茂一
福田久夫*・勝間田武司・斎藤康夫*

日本獣医寄生獣大学 獣医内科研究室
*フクダニム・イー工業株式会社

著者らは先に 503 F B 型自動解析心電計を実験動物用として開発した。今回はそれに由来の機能をもつ犬子犬心電計を作製し犬の自動診断プログラムを組み込む自動診断心電計を開発した。そしてその診断精度について検討した。

開発した心電計は、501A X D型（フクダニム・イー工業製）自動診断心電計で、診断プログラムは著者らの作成した自動解析診断基準を使用した。

供試犬は何らかの心臓異常が疑われたもの 200例を使用し、自動心動計の診断結果と人によるそれを比較した。

200例の診断精度について検討した結果、心室肥大、軸偏位、心房負荷、両室肥大、S T・T異常、低電位、Q T延長などについては、満足する結果をえた。しかし不整脈では、洞性不整脈、A-Vブロック、心室性頻拍の診断率が低かったが、平均診断率は85.8%であった。