COMPUTERIZED ECG PROCESSING IN EXERCISE TEST

By Shoji Yasui

Recently, the incidence of the coronary heart disease has been remarkably increasing in Japan. The Master double two-step test has been evaluated as an acceptable method for screening of the coronary heart disease, essential in the multiphasic health testing of adult population.

In order to perform the exercise test to a large number of subjects with ease and to get accurate diagnosis of the ECGs objectively, computer-assisted diagnosis is desired, especially, in the field of cardiovascular mass-screen.[1-5]

An unique computer system for automated ECG diagnosis has been developed with the man-machine interfaces originally designed. In this paper, the reliability of computer interpretation was analysed on the ECGs of ten thousand subjects.

METHOD

As one part of the multiphasic health testing, both resting and post-exercise electrocardiograms are automatically interpreted on-line and in real time effectively, using the following computer system. (Fig. 1)

This system were designed by the center for Health Care of Aichi, and medical group of Nagoya University as the medical side, and by Nippon Denshi Co. and Fukuda Denshi Co. as the engineering side. In the planning of this system, these points were especially taken into consideration.

1. Personal identification is to be performed exactly.
2. ECG is to be fed into computer in short time and exactly.
3. Handling of the system is to be so simplified not to be nervous about the computer.
4. Both resting and post-exercise ECGs of 100 persons are to be diagnosed automatically in the morning.
5. The phonocardiograms recorded on a magnetic tape are to be interpreted automatically in the afternoon.

From these requirements, specially designed man-machine interface was developed. The computer system accomplished in this way are shown in Fig. 1. The system is comprised of three electrocardiographs with three input channels, the central processing unit, the external A-D converter with four input channels, three magnetic drums, a teletype, a high-speed tape puncher and a tape reader.

1-1 COMPUTER

A high speed, small scale digital computer is utilized. Main core memory is composed of 8,000 words, binary 16 bits. The cycle time is 5 microsecond.

This system is furnished with a sharing function. This function is possible to feed ECGs from three electrocardiographs sequentially to the computer without a waste of time. Utilizing the respective signals from three electrocardiographs, the priority for processing is determined automatically by this function.

1-2 EXTERNAL A-D CONVERTER

This machine is capable of digitalizing the 0 to 10 volt analogy input of four channels at the same time, of which conversion speed is 5 microsecond, with accuracy of binary 10 bits (0.1%).

The full-scale input range of the A-D conversion unit is adjusted to the range between the maximal upward and downward deflections of the pen on the chart of the recorder, 4.0 cm each channel. Since the input range of ECG waves are monitored as usual, by the deflections on the pen recorder, processing of resting ECG, for example, is necessary to push only a button of Ready 1 on the control unit panel. So, the operation of the electrocardiograph in this computer system is relatively simple as compared to the ordinary recording of ECGs.

1-3 CONTROL BOX

This unit is facilitated to check the condition of electrode attachment to the body, to regulate the level and amplitude of the signals fed into the A-D converter, to control automatically the generation of the signals such as calibration of 1 mV and ECG, and to control the driving of the ECG paper and instomatic function of electrocardiograph. As other function, this control box is capable to give a complemental instruction by the lamp on the control panel whether the exercise test in contraindicative or not for the subject, utilizing computer interpretation of resting ECG. (Fig. 2).

1-4 PERSONAL IDENTIFICATION

The identification stub plate of plastic specially designed is inserted to the slit on the panel of the control box. This plate has the binary coded notches on the lower edge, and is used for personal identification, also, in another sections of multiphasic health testing.

1-5 EXECUTION OF COMPUTER ASSISTED INTERPRETATION

By the set of either the "Ready 1" button for the resting ECG or the "Ready 2" button for the post-exercise ECG, Frank lead X, Y, and Z scalar ECGs from three electrocardiographs are fed into the computer sequentially by the digital multiplexer under the control of the sharing function, (Fig. 3).

In details, when the computer recognizes the set of "ready 1" or "ready 2" of the ECG processing, the computer turns on the relay switch of the ECG control box to feed automatically the ECG from the electrocardiograph of waiting condition into the computer. The computer turns off the instomatic switch, drives the ECG chart paper, generates the personal identification signal served as the calibration signal and feeds the ECG signal for ten seconds. These signals are also recorded simultaneously on the heat writing paper. When the input of the electrocardiographic waves for ten seconds is over, the instomatic function is again turned on and driving of the ECG chart paper is stopped. This ECG input signal of the initial two second length is utilized for wave form classification, and that of the whole ten second length is utilized for arrhythmia interpretation. (Fig. 4).

The result of the computer assisted interpretation is punched on the paper tape and, also, is typed out by teletype, which is confirmed at a glance by physician.

It takes 35 seconds to interpret the resting ECG and 25 seconds to interpret the ECG approximately 1 minute after exercise, including the input time.

When the switch of the control box is turned from "on-line" to "off-line", the electrocardiograph is available independently of the computer system as ordinary.

RESULT

During the past one year, ten thousand cases were analyzed in the computerized ECG station of the center for Health Care of Aichi.

In the wave from interpretation among the ten thousand apparently healthy cases, 76 of myocardial infarction and 272 of ST-T abnormalities were found,

*1st Division of Internal Medicine, Nagoya University School of Medicine, 65 Tsurumai-cho, Showa-ku, Nagoya, Japan.

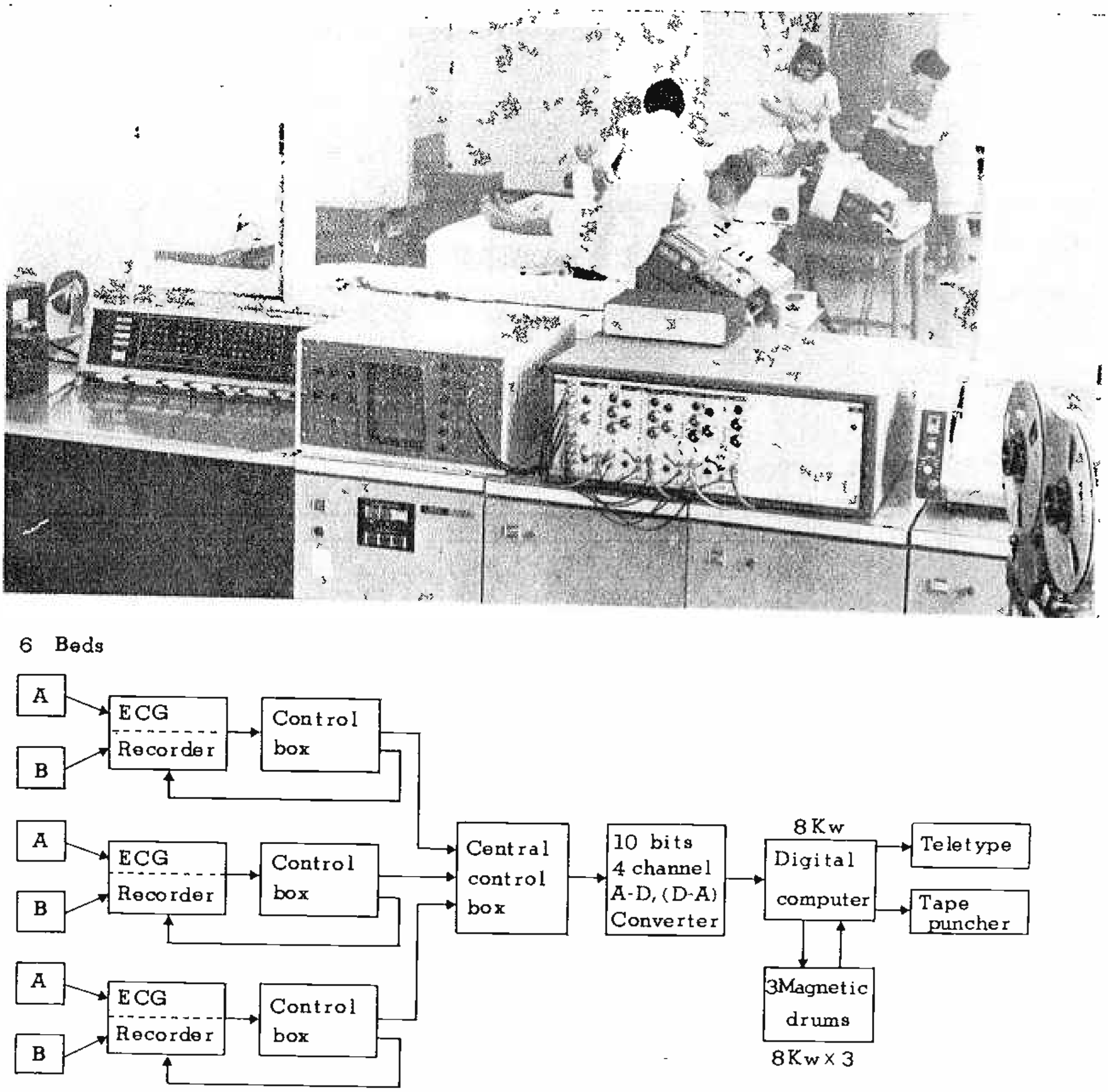

Fig. 1. In the upper half, a scene of ECG processing by the computer system is shown. In the lower half, a block-diagram of the computer system is presented.

TABLE I

ANALYSIS OF PHYSICIAN-COMPUTER AGREEMENT IN 10,000 RESTING ECG's

	Total Studied	Rate of Agreement
Wave-form Classification		
Normal	8361	99.3%
Ventricular Hypertrophy	1505	98.2
ST-T Abnormalities	272	93.3
Myocardial Infarction	76	92.1
Vent. Conduction Defects	186	94.0
WPW Syndrome	18	44.4
P Abnormalities	103	81.5
Arrhythmia Classification		
Sinus Rhythm	9764	99.5
Ventricular Extrasystole	95	88.4
Supra-vent. Extrasystole	67	70.1
Atrial Fibrillation	29	58.6
A-V Block	37	45.7
Others	8	62.5

and the agreements of interpretation between physician and computer were 92.1%, and 93.3% respectively. (Table 1)

Interpretation of post-exercise ECGs was made in 9537 cases, who were automatically indicated for exercise test. The cases who were confirmed to be negative response to the exercise test by physician were 8828 of the total 9537. Among the cases who were interpreted as negative exercise test by physician, negative, border-line, and positive responses by computer assisted interpretation were 99.3%, 0.1%, and 0.6% respectively. The cases who were interpreted to be positive response to the Master double exercise test by physician, amounted to 239 cases. In computer interpretation of these positive response cases, positive, border-line, and negative responses were 95.1%, 0.8%, and 4.1% respectively. (Table II). The disagreement between physician and computer interpretation was analysed in both the wave pattern and the arrhythmia classification. Measurement error of the ST-T segments in resting ECGs was only 10% of 252 cases with disagreement, while measurement error of QRS complexes was 15% of the total disagreement, which was caused by the S wave with broad nadir.

The disagreement cases of the post-exercise ECG interpretation were 155 cases of the total 9537, (1.6%).

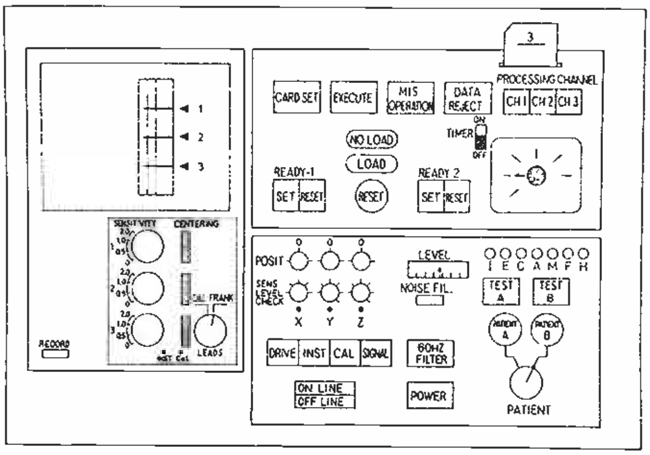

Fig. 2. A electrocardiograph at the left side and a control box (a man-machine interface) at the right side.
ECGs are easily fed into the computer with a personal identification signal by simplified handling of the control box and are interpreted promptly.

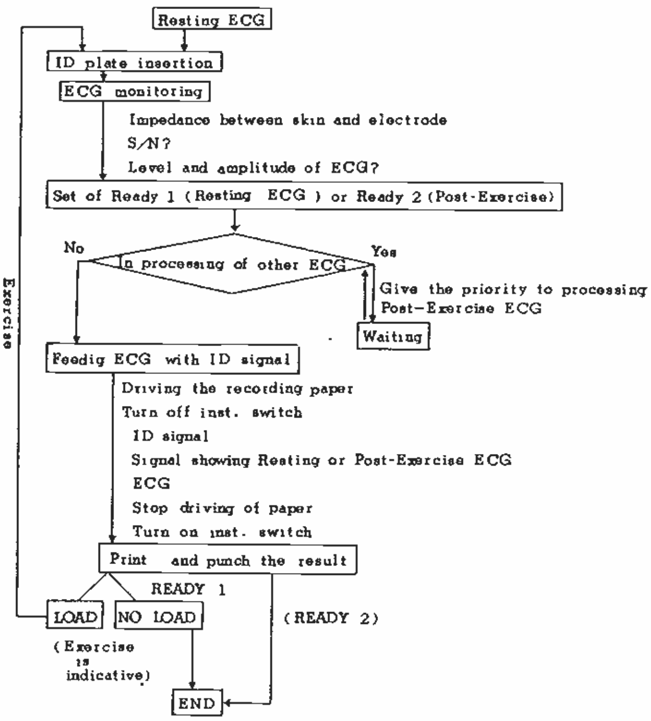

Fig. 3. Flow chart of computer processing of ECGs in exercise test.

TABLE II

VALIDITY OF COMPUTER INTERPRETATION IN 9,537 POST-EXERCISE ECG's

Physician's Interpretation	Total Studied	Computer Interpretation		
		Negative	Border-line	Positive
Negative	8822	99.3	0.1	0.6%
Border-line	476	15.5	83.3	1.2
Positive	239	4.1	0.8	95.1

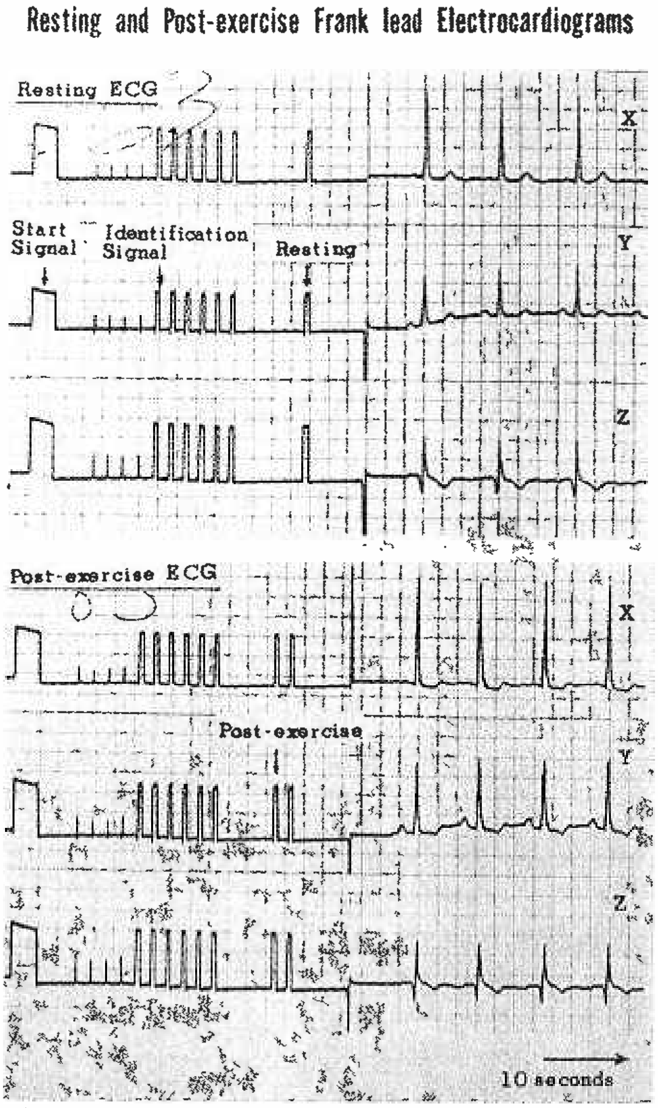

Fig. 4. An example of ECGs and identification signals fed into the computer.

Most of the mismeasurement is due to failure in recognition of the ST segment (50%), and of R-R interval (30%). It was mainly due to the base-line drift after the exercise.

DISCUSSION

1. COMPUTER APPLICATION TO THE MASS SCREENING OF THE CORONARY HEART DISEASES

Three electrocardiographs were utilized to feed ECGs both resting and post-exercise into the computer without a waste time. Development of the unique man-machine interface made possible to perform ECG screening of one hundred persons in the morning, on-line and in real time. Computerized ECG processing of the Master exercise test would be useful in the station of mass screening and also in the center of cardiology. Such an ECG processing might relieve physicians of some time-consuming work and decrease observer variability in interpretation.

2. COMMENT WHETHER EXERCISE TEST IS CONTRAINDICATIVE OR NOT?

On line and real time processing of resting ECG made possible to give such a comment to a technician and made safe to perform the Master double exercise test to the large number of the patients.

However, in off-line computer system, to receive such comment from computer is impossible.

In this point of view, our system is recommended to the mass screening of the coronary heart disease.

3. COMPUTATION TIME

It takes within a minute to process an ECG both resting and post-exercise, and this computation time was comparable to the time for setting the electrodes on the body of patient.

4. ACCURACY OF COMPUTER ASSISTED INTERPRETATION

The program interprets each ECG by exactly similar criteria, producing standardized readings for entired group screened.

Disagreement between physician and computer was within 5% of the total. ECG processing was performed one minute after exercise to avoid the base line drift, because mismeasurement of ST segment deviations were mainly due to the base line drift. Furthermore, the computer made the noise and base-line drift reduction by summation averaging of ST segments during 4 beats. To establish the criteria after the exercise test for the Frank X, Y, and Z scalar ECFS is urgently desired. A tentative criteria were utilized in this computer processing.

CONCLUSION

The early detection of the latent coronary heart disease in the apparently healthy subjects is becoming an important problem.

The rapid mass-screening program of the great populations requires the automated processing system for the ECG interpretation. In this point of view, this computer system are desirable to be introduced into the center of the mass screening of the coronary heart disease.

Operation of the computer system is simplified by the development of the man-machine interface originally designed and the computer interpretation is compatible with the physician interpretation except complex arrhythmia. In the practical use of the system, the usefulness, stableness and reasonable cost-performance of the computer system was emphasized.

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