COMPUTERIZED SYSTEM FOR EVALUATION OF CORONARY ARTERY DISEASE BY NONINVASIVE TECHNIQUES

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ABSTRACT

The accepted method of determining the presence and extent of coronary artery disease is by coronary angiography. A method of obtaining this information noninvasively is being developed. The kinetocardiogram, ballistocardiogram, vectorcardiogram, heart sounds, and carotid pulse pressure tracings have been recorded on analog tape from 903 patients. These patients have also been studied by the angiographic invasive techniques within 24 hours of the noninvasive study. A data processing system has been developed using one of the remote satellites to the Multiple Laboratory Computer Center of the University of Alabama. A technician interacting with this system selects usable portions of the analog records and controls the A to D conversion of the data. Calibration and time normalization is performed so that several heartbeats can be averaged together for each data source. The technician again has the opportunity to view the results and accept or reject them. Accepted data is spooled to magtape and merged with clinical records.

Comparisons of mean curves of patients with similar coronary artery abnormalities indicate that there are significant differences. Preliminary statistical models using multiple regression techniques separate the seriously ill patients from those with less abnormality with 77% accuracy.

INTRODUCTION

The extent of vessel involvement, and thus severity of coronary artery disease, is currently determined by coronary arteriography. The method consists of inserting catheters into the heart and injecting a radiopaque dye into each artery, determining the extent of obstruction. This has proven quite successful but not without a certain amount of risk to the patient. An equally good noninvasive technique would be more desirable. A laboratory has been established in the Veterans Administration Hospital in Birmingham to gather the ballistocardiographic, kinetocardiographic, vectorcardiographic, heart sounds, and carotid artery pulse pressure wave cardiac data and determine if these noninvasive data could provide the clinician with sufficient information to quantitate the coronary artery lesion, thus reducing the need for coronary arteriography.

On-Line System:

The laboratory as described by Swatzell, et al.,[1] is equipped for recording vectorcardiograms, kinetocardiograms, ballistocardiograms, carotid pulses, and heart sounds and is a subunit to the multilaboratory on-line computer system designed by Macy.[2] Figure 1 shows the flow of the data from the patient to the

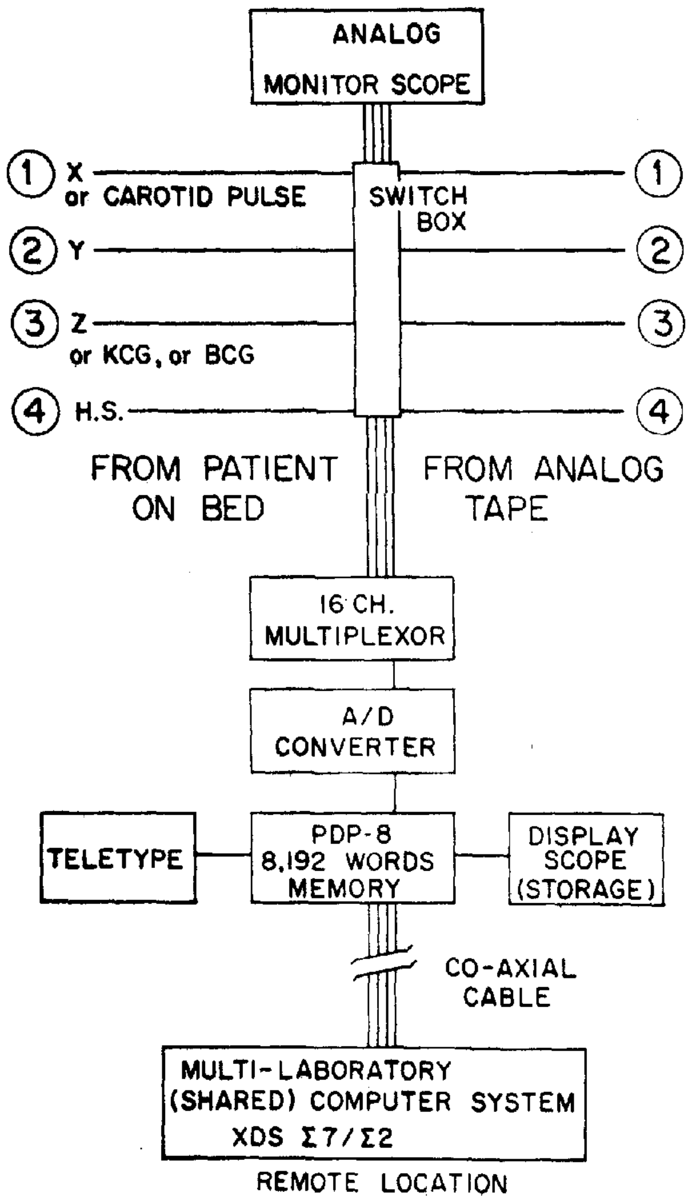

Figure 1

multilaboratory computer system. The signals are fed into a satellite PDP-8 Laboratory Computer (8K memory) which consists of a 16-channel multiplexer, A/D converter, a storage oscilloscope and a teletype. As the signals are digitized four simultaneous traces are displayed on the storage oscilloscope. However, only three signals are stored; either the vectorcardiogram (X, Y, and Z leads), or the lead Y, kinetocardiogram and the carotid pulse, or the lead Y, carotid pulse and ballistocardiogram, or the lead Y, carotid pulse and heart sounds. Three to four complexes are processed at a time, but the procedure can be repeated sequentially to obtain as many complexes as required. There is a person built into the computer loop to insure consistent quality in the digitized data. After digitization the operator of the PDP-8 computer has several options. (1) If the signals are too noisy or if the baseline varies too much they can be rejected and the procedure repeated. (2) If the signals are of sufficient length and adequate quality the operator may accept them and they are processed at the multilaboratory computer.

The Data:

The following data are computed at the Sigma-7 computer and stored on magtape: (1) From the vectorcardiogram the heart rate is computed. (2) From the carotid pulse, Y lead, and heart sounds the systolic time intervals, shown in Table 1, are obtained. (3) From the kinetocardiogram a time normalized and

TABLE I

THE SYSTOLIC TIME INTERVAL DATA

Q-Q - Duration of the heart cycle
Q-CU - Duration of beginning of beat to carotid upstroke
Q-S_2 - Duration of the beginning of beat to second heart sound
CU-CIN - Duration left ventricular ejection
PEP - Preejection period
PEP/LVT - Ratio of preejection period to left ventricular ejection
Ejection Fraction

averaged complex is computed, as described by Eddleman.[3] There will be eight of these recorded for each patient at eight positions on the patient's chest. Figure 2 shows the mean curves computed at one of these positions, K_{44}. Three-hundred seventy-five patients with coronary artery disease were separated into one of four groups according to the number of vessels obstructed. Mean curves were computed for each of the eight positions of each disease group. The separation indicates the changes in the kinetocardiogram as the disease progresses.

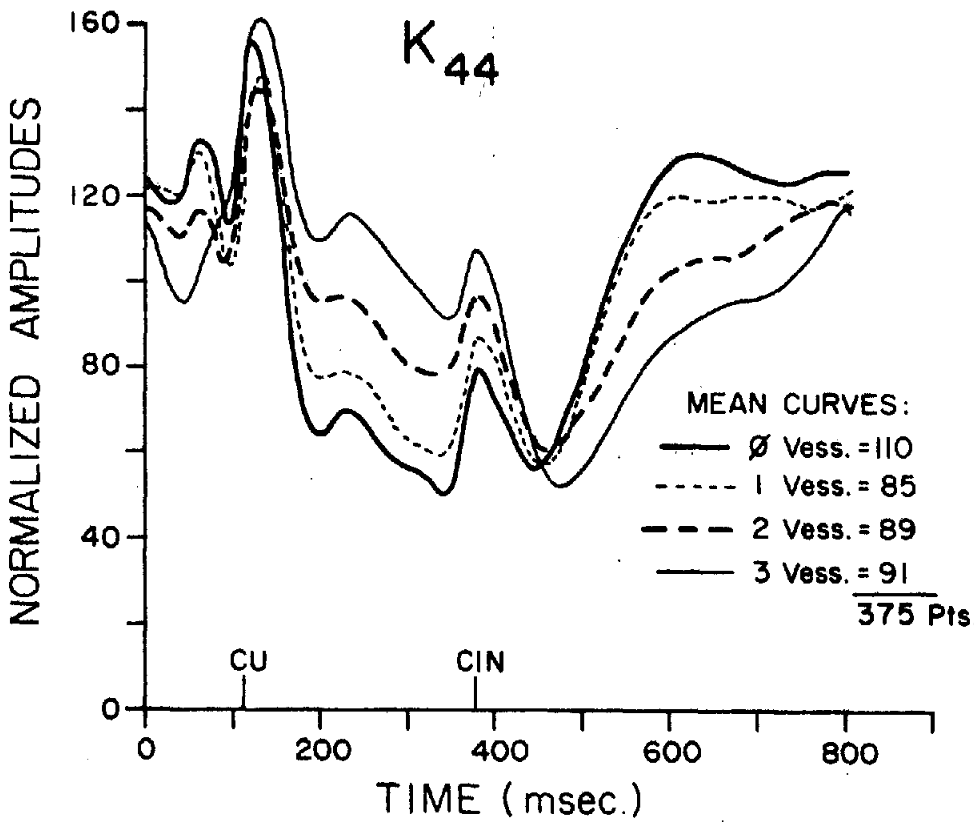

Figure 2

(4) From the ballistocardiogram a time normalized and averaged complex is computed for the patient's ballistocardiogram at held inspiration and held expiration, as described by Bancroft.[4] The locations of H, I, J, and K are determined and the amplitudes, slopes, and durations computed are listed below:

Amplitudes: H, J, HI, J1, IJ1, J2, J3, K
Durations: Q-H, Q-I, Q-J1, Q-K, H-I, I-J1, I-J2
Slopes: H-I, H'-I, I-J, I-J'

The data on magtape is merged with clinical data, i.e., age, sex, etc., and multivariate analysis is performed on the data.

Initial results are promising. An accuracy of 77% was obtained in the separation of seriously ill patients from those with less abnormality, but the clinician needs to know more information about vessel involvement. Further analysis on an even larger patient population is now underway to determine if the number of vessels involved and the approximate location of the obstruction can be accurately determined using this noninvasive data.

CONCLUSION

A need for a noninvasive method for determining existence and severity of coronary artery disease has been presented. A laboratory has been established to gather noninvasive cardiac data and reduce this data to a form which can be analyzed statistically.

The results of the analyses indicated that some quantitation of coronary artery disease could be made noninvasively. Further study is underway to establish a model which will give the location and extent of the obstruction within the vessel.

REFERENCES

1. R. H. Swatzell, Jr., W. H. Bancroft, Jr., J. Macy, Jr., and E. E. Eddleman, Jr., The On-Line Computer System for Determining the Systolic Time Intervals, Computers and Biomedical Research, Vol. 6, 1973, pp. 465-473.

2. J. Macy, Jr., A Multilaboratory Computer System with Distributed Logic. Proceedings of the Symposium on Computers in Medicine, Danish Biomedical Engineering Society, Riso, Denmark, Jan. 1971, pp. 49-63.

3. E. E. Eddleman, Jr., and W. H. Bancroft, Jr., Quantification of the Kinetocardiogram, Computers in Biomedical Research, Vol. 1, 1967, pp. 237-240.

4. W. H. Bancroft, Jr., M. Tucker, D. H. Jackson, and E. E. Eddleman, Jr., Automatic Computer Processing of Ultralow Frequency Ballistocardiograms, Bibliotheca Cardiologica, Vol. 32, 1973, pp. 26-36.