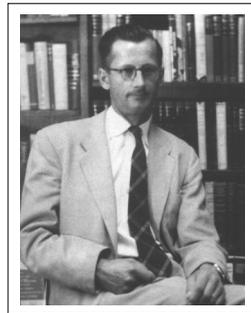


## The birth of computerized electrocardiography: Hubert V. Pipberger (1920–1993)



Medical electronics started a period of growth in the late 1950s, some 15 years after the end of the Second World War. There was also a slowly increasing expectation that digital computers will gradually revolutionize ECG analysis. The Veteran's Administration (VA) Hospital in Washington, DC, established a Special Research Program for Medical Electronic Data Processing in 1957, and Dr. Hubert V. Pipberger, a recent immigrant to the U.S., was appointed as the director of that VA research program. In 1959 NIH established its Medical Systems Development Laboratory and launched an extensive effort directed by Dr. Cesar Caceres to develop a computer program for ECG analysis.

Pipberger was convinced that the use of the Frank three-lead system rather than the conventional 12-lead ECG was the method of choice and that advanced statistical analysis was superior to the traditional analysis of the 12-lead ECG. Caceres, in contrast, based the approach of his team on the analysis of the 12-lead ECG along the traditional lines, one lead at the time, using conventional clinical ECG criteria. There was a tangible feeling of fierce competitive spirit in these pioneering efforts those days in Washington. Everything done in computer-ECG was exciting news.

By the end of 1959, Pipberger's collaborating team from various VA hospitals had collected nearly 1,000 ECG recordings of three-lead vectorcardiographic XYZ signals. The missing link was a converter that could sample three simultaneous ECG channels to digital information suitable for digital computer analysis. The National Bureau of Standards was contracted by the VA to build the device. The Bureau also made available a digital computer for the pilot study of Pipberger's team.

Pipberger's group first described digital conversion of ECGs at the American Heart Association's 1959 Scientific Sessions and in *Circulation* in

1960 [1]. In 1961, they reported the results from a pilot project designed to demonstrate the feasibility of screening of normal and abnormal ECGs [2]. That ECG classification program was based on Wilson's ventricular gradient vector concept that did not require complex ECG wave detection and measurement. A more comprehensive automatic ECG wave detection and measurement program was described by Stallman and Pipberger in 1961 [3]. That same year both competing groups described their approach to ECG analysis in the 1961 International Medical Electronics Conference held in New York City.

The initial setup of Caceres at NIH for ECG wave detection and measurement was slow and cumbersome. The analog-to-digital conversion was first performed using single-channel ECGs recorded on magnetic tape and converted to punched cards for input to a digital computer [4]. Substantial gradual progress was made during the subsequent ten-year effort, which culminated in the release of the ECAN-D version of the program. That program was translated to several computer languages and adapted to a variety of computers, and a system for certification for compatibility of various versions of the program used by new users was established by the Health Care Technology Division of the institute. Subsequently, various versions of the ECAN program by commercial enterprises mushroomed.

Pipberger collaborated with Jerome Cornfield, a noted statistician, in designing a multi-group classification program based on the so-called Bayesian logic that used prior probabilities to optimize classification accuracy. After demonstration of the feasibility of the approach for differential diagnosis between normal and left ventricular hypertrophy [5], the clinically documented ECG record library steadily expanded. Over 2,300 records were selected as the so-called development set containing seven diagnostic categories (in addition of atrial overloads and

bundle branch blocks with and without myocardial infarction). Pipberger labeled the final product as “the second generation ECG program” [6]. A total of 66 measurements were used by the statistical analysis logic, and the prior probabilities were selected primarily according to the estimated prevalence of each of the seven clinical conditions among the patient population in each clinical setup.

Inspired by the efforts of these early pioneers, several other groups of investigators in the US and other countries developed ECG programs at that time based on the use of the 12-lead ECG or vectorcardiographic leads, or a combination of both the three-lead and 12-lead ECGs.

In final analysis, both the ECAN program as well as the VA program turned out to be the losers in the overall picture. Pipberger’s approach was doomed because cardiologists found it difficult to accept the Bayesian approach to diagnostic ECG classification. They also found Frank’s Z lead unfamiliar because of its inverted polarity in comparison with V1 and V2. And the ECAN approach to 12-lead analysis was doomed to failure because ECG wave detection logic based on the use of each single ECG lead individually has insurmountable problems. By 1978 the use of the VA and ECAN programs amounted to a small portion of the overall volume of computer-processed ECGs.

What then, were the importance and the impact of the personal contributions of Pipberger in the evolution of computerized ECG? Perhaps most significantly, Pipberger promoted the objectivity in the evaluation of the diagnostic performance of ECG classifiers and in comparing various classification programs. He recognized early, that in addition of testing of the ECG wave measurement accuracy and

detection of arrhythmias, ECG classification accuracy has to be evaluated primarily using adequately large test libraries, with test cases selected on the basis of ECG-independent evidence.

Secondly, Pipberger had a substantial early and long-term impact on national and international efforts on computer-ECG standardization and on improving professional standards in ECG interpretation.

Finally, Pipberger created serious new interest in computer-ECG research using tools of advanced biomedical engineering and computing technology for improved ECG signal processing and ECG classification.

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