General Considerations

Computerized electrocardiography had its inception in the late 1950s with the work of Pipberger (17, 23) and Caceres (5), followed in the early 1960s by Smith (21) and Pordy (19). This initial thrust was extended in other centers, including Arvedson in Sweden. The basic principle involved is the conversion of the analog electrocardiographic (ECG) or vectorcardiograph (VCG), or both signals to digits, using an analog to digital converter. The records in digital format are then processed by the modern digital computers, with proper programming and at incredible speeds to produce analyses of the tracings comparable to that obtained by the human observer.

In the late 1960s, as a spin-off of the above efforts, three channel electrocardiography was introduced into clinical electrocardiographic practice. Thus, the standard 12-lead electrocardiogram, recorded in four-lead sets containing simultaneously leads I, II, and III; AVR, AVL, and AVF; V1, V2, and V3; and V4, V5, and V6, was recorded on analog tape, and this reduced computer processing time by two thirds. Furthermore, by simultaneously recording three leads, the exact onset and offset of the various waves involved could be determined exactly both for the human and for the computer. For example, lead II, which for many years had served as the interval measurement lead, was quickly found to contain many portions of ECG waves perpendicular to it. Only then could the resultant error in measurements of P, QRS, T, and the intervals P-R and QT be appreciated fully. It therefore became obvious that newer and more accurate measurements of various parameters could be obtained easily and errors that had persisted for many years could finally be corrected.

The second major advantage of three-channel electrocardiography was that both the 12-lead electrocardiogram and the component vectorcardiographic leads could be recorded with facility on the same patient, and the diagnostic value of each method could be established readily in huge numbers of cases. The old-fashioned methods for vectorcardiographic recordings by photographing the oscillographic Lissajousou loops were now readily replaced by recording component VCG leads simultaneously, followed by rapid computer analysis.

The basic issues then became focused into two main problems: (a) computer ECG analysis both for the standard ECG tracings and for ECG monitoring as compared with human observer interpretation and (b) classic 12 lead electrocardiography as compared with VCG.
Computer Compared with Human Analysis

Most humans are naturally apprehensive about the possibility that computer processing may eventually eliminate them from their specific occupations. In defense of their position, in the case of computer electrocardiography, the human observer is armed with the fantastic ability to recognize patterns. Since routine electrocardiographic interpretation depends on empirical observations of patterns, the diagnostic accuracy of most ECG interpreters ranges in the high 90th percentile. It is interesting to note, however, the famous study of Simonson et al. (20) in which the collective accuracy of 10 of the world's foremost ECG and VCG experts was approximately 54 percent for ECG interpretation but less for VCG analysis (47 percent). Furthermore, documented studies have shown an inter- and intraobserver variability of about 20 to 30 percent. Moreover, only a portion of the analyses may be supported by surgical, angiographic, and/or autopsy evidence, since rhythm defects and conduction pathway abnormalities cannot be verified by the aforementioned methods. However, the human, unlike the computer, is subject to fatigue and distractions that may diminish his performance. To compensate for this, he may review the ECG data several times and/or may consult with others before formulating his final analytic judgement in a particular case. On the other hand, the computer is neither subject to fatigue nor to error if it is programmed properly, but the digital data must be presented in a special format to compensate for the computer's inability to recognize patterns. The incredible speed with which mathematical computations are performed covers this latter fault quite adequately for clinical purposes. The final advantage of computer technology in electrocardiography is that vast amounts of accumulated data can be stored on either disk, drum, or digital tape and retained for later statistical or other detailed study. The application of these data will be discussed later in the section on ECG as opposed to VCG.

The use of the computer for ECG monitoring, although involving tremendous programming efforts, has just recently achieved success for clinical application. Here, the fatiguability of the human is well-recognized and combined with the large number of false technical alarms, has even caused unplugging of many monitoring units. In fact, recent studies by Oliver et al. (16) and by Nolle et al. (15) demonstrated the superiority of computer as compared with human monitoring over the long term. Interestingly, many of the computer ECG monitoring systems include interaction between the human observer and the machine. For example, the human, on computer query, identifies the dominant beat and the program then proceeds.

Current methodology does not place the computer in competition with the human but has evolved in such a manner that the bulk of the tedious work involved is performed by the computer and the physician retains his control by overseeing the results.

Electrocardiography vs. Vectorcardiography

Since the introduction of the Mann monocardio gram, the clinical application of vectorcardiography has attained a status superior to that of the electrocardiogram in our cardiographic diagnostic armamentarium. The change from the original un-