Computerized Electrocardiogram Interpretations: Are They Useful for the Family Physician?

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Computerized electrocardiogram (ECG) interpretation programs have become increasingly popular in this country, especially in hospital settings. In general, they reliably calculate heart rate, intervals, and mean QRS axis. When the computer interprets an ECG as normal, it is usually correct. The second opinion provided by computerized readings further benefits the primary care physician by suggesting findings not initially considered, and by forcing careful scrutiny of the original interpretation. Speed of interpretation may be greatly increased, particularly for the more experienced electrocardiographer who has a high volume of tracings to interpret. Each computer statement, however, must be carefully overread by the physician, for failure to do so may result in overlooking significant electrocardiographic findings. It is important that the family physician appreciate the strengths and weaknesses of computerized ECG interpretations so that he or she derives the greatest benefit from this diagnostic tool.

Computerized electrocardiogram (ECG) interpretation programs have become increasingly popular during recent years. As of 1983, an estimated 15 percent of the approximately 100 million ECGs recorded annually in this country were processed by computer.[1] It is likely that this number has substantially increased since then.

At present, computerized ECG analysis systems are used predominantly in the hospital setting. Continued advances in technology and further reductions in cost should soon lead to these systems becoming a commonplace feature of the primary care physician's diagnostic armamentarium.[2] Currently, the cost of a portable computerized analysis system that is contained within the ECG cart averages between $10,000 to $12,000. Considering that the average cost of a three-channel ECG recorder is $5,000 to $7,000, the potential benefits derived from computerized ECG interpretations probably make the additional $5,000 expenditure worthwhile.

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Even if the family physician is not routinely using computerized ECG analysis systems in the office, he or she is still likely to encounter these systems in the hospital. It is therefore important to become familiar with this diagnostic modality and to appreciate how it may best be used.

ABSENCE OF A RELIABLE STANDARD OF INTERPRETATION

To assess the value of computerized ECG interpretation programs, one must first appreciate how their accuracy is determined. Although studies have compared ECG analyses rendered by computerized programs with those put forth by independently blinded cardiologists,[3-10] it is difficult to derive meaningful conclusions from these data because of differences in ECG interpretation among experts, inadequate attention to methods in the studies that have been done, and unrealistic expectations of computer performance.

Another problem is that electrocardiographic terminology differs dramatically among expert interpreters. Such differences appear to persist even among physicians who practice in the same community.[11,12] Despite the efforts of a task force at the 1977 Bethesda Conference on Optimal Electrocardiography, stand-

ardization of terminology has simply not been achieved.[11] Numerous terms continue to be used to describe comparable electrocardiographic findings, particularly for alterations in ST segment and T wave morphology. As a result, ST-T wave abnormalities for a given tracing may be interpreted as normal, nonspecific, or suggestive of ischemia, strain, subendocardial injury, electrolyte disturbance, or digitalis effect.[8,12,13]

Multiple diagnostic criteria for similar conditions are also in use. The multiple criteria, together with a nonstandardized terminology, account for the 30 to 40 percent interobserver variability among expert electrocardiographers that is reported in the literature.[14] Consider the case of left ventricular hypertrophy. No fewer than 33 sets of criteria have been described for the ECG diagnosis of this condition.[15] None demonstrates a sensitivity greater than 60 percent, and the criteria used for the interpretation of any given electrocardiogram seem to depend most on the individual preferences of the interpreter.[6,12]

Intraobserver variability among experts is also considerable. When the same electrocardiographer unknowingly interprets an identical ECG on separate occasions, a 10 to 20 percent variability in interpretation may be expected.[14]

One important reason for the existence of such differences among experts is the lack of a universally accepted "gold standard" for ECG interpretation. Many electrocardiographic findings simply cannot be verified by nonelectrocardiographic means. It is virtually impossible, for example, to prove the existence of a bundle branch block. Although ST segment and T wave changes may be characterized according to their morphology, it is often difficult to establish conclusively the cause of these changes. How can one prove that ischemia is present? Is there any way to demonstrate "strain"? How does one determine how much of the ST segment depression on a particular tracing is because of hypokalemia, and how much is the result of a medication effect?

Similar unanswerable questions are raised in the diagnosis of cardiac arrhythmias, calculation of PR, QRS, and QT intervals, and determination of mean QRS axis. Because these are all purely electrocardiographic terms for which there are no anatomic or pathophysiologic substrates, there is no way to confirm these findings by nonelectrocardiographic means. Even for conditions that produce definite anatomic and pathophysiologic alterations, such as chamber enlargement and myocardial infarction, objective correlation by other means is often disappointing. Noninvasive testing with chest roentgenography and echocardiography is often imprecise, while more objective testing with cardiac catheterization is too invasive to justify. Autopsy studies themselves may be inconclusive. Because muscle tone is lost following death, wall thickness on postmortem examination may differ significantly from what it was during life.[16] Objective correlation of chamber hypertrophy by determination of heart weight at autopsy may also be inaccurate, because such correlation depends to a certain extent on dissection technique, a factor for which it is impossible to control.[16] At best, anatomic criteria for chamber enlargement, such as wall thickness and heart weight, are empirically determined. Precise definition of cutoff points that consistently separate normal from pathologic for subjects of different age, sex, and race has never been established.

Although confirmation of pathophysiologic states such as prior myocardial infarction can be determined reliably at autopsy, correlation of this anatomic finding with antemortem electrocardiographic evidence of infarction still leaves much to be desired. In a study by Horan and Flowers,[17] only 61 percent of 416 patients with myocardial infarction or scar tissue and normal ventricular conduction had abnormally wide Q waves on ECG. Specificity of these abnormally wide Q waves for myocardial infarction was equally disappointing in that 11 percent of the 768 patients in their study had such Q waves in the absence of infarction. Even poorer specificity would be expected if the prevalence of myocardial infarction in the population studied was less.[13] Clearly the ECG is an imperfect diagnostic tool, and attainment of a gold standard for ECG interpretation will probably remain an elusive goal.

Several additional factors should be considered in assessing the accuracy of computerized ECG interpretation programs. Principal among these factors is the method of analysis used for evaluation of computer performance. A particular program may demonstrate a high level of agreement with physician interpretations regarding the presence of an abnormality, but show marked disagreement with respect to the nature of the abnormality. Accuracy of a program will therefore depend on how agreement is defined. In general, higher levels of agreement are achieved when physicians are simply asked to comment on whether they agree with a computer interpretation than when they are asked to render a blinded interpretation that a panel of experts will subsequently compare with the computer analysis.[3,6]

The prevalence of various electrocardiographic abnormalities in the population studied may also significantly influence the results of a given study.[13] In general, computer programs are extremely accurate in detecting normal sinus rhythm and interpreting normal ECGs, but they are much less so in the analysis of complex arrhythmias and unusual electrocardiographic patterns.[1,2,12] A computer program would be expected to perform best, therefore, when used in a setting where a large proportion of subjects are normal. It is unrealistic to expect comparable accuracy in a study population where abnormal tracings are the rule.

The final factor to keep in mind in assessing the accuracy of computerized programs depends on the characteristics of the particular program being eval-

uated. Some programs overinterpret more than others. They provide enhanced sensitivity at the price of decreased specificity. In contrast, programs employing stricter diagnostic criteria are less likely to overinterpret, but more likely to miss certain abnormalities.

CLINICAL IMPLICATIONS

Advantages of Computerized ECG Interpretation Programs

Because of the lack of a universally accepted gold standard for ECG interpretation, the differences in the incidence of electrocardiographic abnormalities among different study populations, and the dissimilarities in available programs, it is unlikely that computer performance will ever be assessed to everyone's satisfaction.[12] Yet the family physician must still decide how best to utilize the information contained within the computer report. Understanding the relative strengths and weaknesses of computerized ECG interpretation programs will be extremely helpful in this regard.

Although characteristics of each program vary, most ECG analysis systems provide a number of common advantages. Perhaps the greatest benefit computerized ECG analysis systems provided to the less experienced interpreter is a backup opinion.[12] Not only may this second opinion suggest findings not initially thought of by the novice, but it also forces more careful scrutiny of the physician's original interpretation, particularly if it differs in any way from the computer reading. As a result, abnormalities may be picked up that otherwise would have been missed. By supplying feedback to the interpreter, the computer report may also serve as an effective teaching tool. Additional advantages of computerized readings are that interpretations are always legible and physician confidence may be bolstered when the computer analysis agrees with the physician's interpretation.[2]

Computerized ECG interpretations provide somewhat different advantages to the more experienced electrocardiographer. It is unlikely that the computer can improve on accuracy for such a physician if time is taken and he or she is meticulous in interpretation. However, even expert electrocardiographers have been shown to benefit from the availability of a second opinion, particularly when they are hurried or have a large volume of tracings to interpret.[12]

Of even more importance to the experienced electrocardiographer is the potential timesaving feature of computerized ECG interpretations. The average time spent by a cardiologist in manual interpretation of an ECG has been estimated to be 97 seconds (60- to 180-second range).[18] This length of time may be reduced by 50 to 75 percent with proper use of the computer analysis.[19] The timesaving feature is most valuable for physicians who read a high volume of ECGs in their daily practice, especially when many of the tracings are normal and complex arrhythmias are uncommon.

Computerized readings may help unify terminology among a team of interpreters. While individual physicians frequently retain their own personal preferences for certain electrocardiographic terms, there appears to be a tendency for physicians to accept computer nomenclature rather than to delete computer terms and add their own.[12] Thus, over time, final interpretations from a group of electrocardiographers using the same computer analysis program may show better agreement than they did before the computer was used.

Drawbacks of Computerized ECG Interpretation Programs

Computerized ECG interpretation programs are not without their faults. Most programs are notoriously inaccurate for dysrhythmia interpretation except when sinus rhythm is present. Pacemaker rhythms and the Wolff-Parkinson-White syndrome commonly go undetected, and application of standard computerized programs for the interpretation of children's ECGs is futile.[2,20] Truly complex ECGs (ie, those from patients with multiple infarctions or unusual intraventricular conduction defects) frequently defy the computer's diagnostic ability.

Any computer is only as accurate as it is programmed to be. The same holds true for computerized ECG analysis systems. If all of the multiple facets of electrocardiography were reducible to numerical coding, computerized interpretations would be 100 percent accurate, although realistically this achievement would never be the case. The principal danger of computerized interpretations is the tendency for physicians to accept them without question and without carefully overreading each statement. For example, if a computer interprets a tracing as suggestive of acute infarction, and the physician accepts the reading as accurate, the patient is likely to be admitted to the hospital even if the clinical evidence and ECG are much more consistent with a normal repolarization variant. In contrast, the inexperienced user may overlook acute infarction if it is not also called by the computer.

Computerized ECG interpretation programs only analyze the electrocardiographic signal; they do not exercise judgment. As a result, they cannot carry out the essential integrative function of correlating electrocardiographic findings with clinical history. Most programs are also unable to compare current tracings with previous ones. Although more sophisticated units have been developed with comparison and editing capabilities (ie, allowing for revision of terminology and diagnostic criteria to conform to the individual preferences of the interpreter), their cost ($40,000 and more) is prohibitive for the practicing physician.

Strategy for Optimal Use of Computers as Aid to ECG Interpretation

The key to optimal use of computerized ECG interpretations is to adapt the strengths and weaknesses of a particular program to the needs of the interpreter. For the less experienced electrocardiographer, this means capitalizing on the improved accuracy and informative feedback that the second opinion may provide. A prerequisite for using computerized interpretations as a second opinion is to discipline oneself to analyze each ECG completely *before* referring to the computer report. To assure such discipline, the physician should first *write down* his or her impression before turning to the computer interpretation. Only in this way is it possible to avoid introducing bias or becoming overdependent on the computer reading. In addition, analyzing the ECG before looking at the computer report is essential to derive educational benefit from the feedback that the computer provides.

As mentioned earlier, many computer programs have been programmed to overinterpret electrocardiographic findings. More experienced electrocardiographers often view this feature as a drawback, as it slows interpretation by forcing them to wade through extraneous computer information. In contrast, less experienced interpreters frequently welcome such overcalling because it points out findings that they otherwise would have missed. In spite of the tendency of these programs toward overinterpretation, however, the computer occasionally misses abnormalities as major as acute myocardial infarction.[12] Failure to analyze ECGs routinely before referring to the computer report increases the likelihood that the inexperienced interpreter will also overlook such findings.

A somewhat different strategy for using computerized ECG interpretations may be employed by the more experienced electrocardiographer. In this instance the timesaving feature often assumes major importance. Because most computer programs are extremely accurate in calculation of heart rate, intervals, and mean QRS axis,[1,19,21] and rarely err in detecting normal sinus rhythm,[3,22] only minimal inspection is required to verify a computer interpretation in these areas. Duplication of computer calculations is not needed, and computer values for heart rate, intervals, and mean QRS axis may be accepted with a fairly high level of confidence. If, in addition to reading "normal sinus rhythm," the computer says "normal tracing," the electrocardiographer's task is further simplified and virtually complete after inscribing a check mark next to this computer statement.

On the other hand, should an ECG be interpreted as abnormal by the computer, more careful evaluation of the tracing is in order. Some experienced readers initially scan the ECG before examining the computer report. Others prefer to reverse this order, and examine the computer report before looking at the tracing. Either approach is acceptable for the more experienced electrocardiographer. Regardless of which approach is chosen, each computer statement must be carefully overread. If the computer statement is correct, a check mark may be placed next to the statement. If the statement is in error, it should be either modified or deleted and replaced with a corrected statement. After each computer statement has been reviewed, a final scan of the tracing should be made to ensure that no important findings have been overlooked by the computer.

In general, even when one or two modifications must be made in the computer report, the computer will save time, as some statements can be used in their entirety, and computer determination of heart rate, intervals, and mean QRS axis is usually acceptable with little or no revision. Speed of electrocardiographic interpretation tends to increase as the physician becomes more familiar with the characteristics of the particular computer program used.

CONCLUSIONS

In summary, computerized ECG interpretation programs appear to be here to stay. Already entrenched in the hospital setting, these systems will be increasingly adopted by office practices. Although unable to match the ECG interpretation ability of expert electrocardiographers for the interpretation of any one tracing, computerized readings provide a backup opinion and may substantially decrease the time required for interpretation. The second opinion they provide is particularly valuable for the less experienced electrocardiographer. Accuracy of interpretation is improved, a legible reading is produced, and informative feedback is given to the interpreter. Computerized ECG interpretations may be extremely helpful to the family physician who appreciates how to use these systems.

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