The Electrocardiogram in Ambulatory Medical Practice

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The electrocardiogram is one of medicine's most frequently ordered procedures. A review of the current use of electrocardiograms in ambulatory clinical practice and the possible information that might be supplied by an electrocardiogram was undertaken. The electrocardiogram's advantages and disadvantages when used in evaluating specific cardiac disorders are discussed including the use of the electrocardiogram as a baseline. Both their values and their limitations in diagnosis and management are examined to support the authors' conclusion that electrocardiograms should be used as an adjunct to clinical diagnosis, not as a screening procedure.

Ever since the electrical impulses of the human heart were recorded for the first time in 1887 by Augustus Waller,[1] a general practitioner, the use, number, and complexity of electrocardiograms (ECGs) have steadily increased. As have the hemogram, urinalysis, and chest radiograph, the standard 12-lead resting electrocardiogram has become a "routine" screening test, particularly in initial office visits, yearly physical examinations, hospital admissions, and insurance examinations. But is such frequent use of electrocardiograms medically indicated?

Information from some of the new cardiologic investigative techniques[2-4] and from epidemiological studies on the incidence and prevalence of various heart diseases now enables a physician to make a more rational clinical decision about when to take an electrocardiogram. The authors believe that too often an electrocardiogram becomes part of a "routine" evaluation without the physician having a definite objective in mind.

Current Use of Electrocardiograms

To ascertain how frequently electrocardiograms are used in clinical decision making, it is necessary to estimate how often physicians use ECGs. In the Province of Quebec, the documentation of the medicare system before 1976 differentiated electrocardiograms taken in institutions such as hospitals and those taken by physicians in offices or clinics. These latter figures provide a unique source for analysis of the use of electrocardiograms in the situation in which the physician is the predominant determinant in decision making.

In 1972 in Quebec, 7,723 physicians performed over 34 million "procedures" (all visits, tests, and examinations).[5] Electrocardiograms represented

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0.4 percent of all such procedures; their frequency of use and that of other common diagnostic and therapeutic procedures is summarized in Table 1. (Table 1 does not include information pertaining to patients referred to hospitals or other public clinics for routine tests.) Electrocardiogram use cost $1.2 million, or 4.5 percent of the total cost of the diagnostic and therapeutic procedures done in offices. It appears that in Quebec, family physicians take an ECG only occasionally, and that they order a urinalysis 15 times as frequently. All medical specialists grouped together are responsible for almost 80 percent of the electrocardiograms taken; they ordered a urinalysis only 2.4 times as often as an ECG.

Use of Information Derived from an Electrocardiogram

Information from an electrocardiogram may be of value in two respects, diagnostic and operational. From the *diagnostic* point of view the electrocardiogram can give useful information in four main areas: (1) rhythm abnormalities, (2) conduction abnormalities, (3) ventricular hypertrophy, and (4) ischemic heart disease.

The electrocardiogram may also show alterations reflecting the metabolic and pharmacologic milieu of the individual, and nonspecific changes are also seen in many other diseases; these findings of low diagnostic value, however, will not be discussed further.

From the *operational* point of view the electrocardiogram may be used to provide information with respect to a condition in one or more of the following time frames: (1) changes that have occurred in the past (eg, evidence of a previous myocardial infarction); (2) a current, acute event, the diagnosis of which requires support (eg, to confirm that the onset of an irregular rapid pulse is in fact due to atrial fibrillation); and (3) for future comparisons (eg, the "baseline" electrocardiogram that would be available at the time of an acute event to determine whether an alteration has in fact occurred).

Differences of opinion concerning the value of routine electrocardiography often can be related to the failure to distinguish between these three types of information. Insurance companies, for example, generally want information of the first type to help them determine the statistical probability of the individual being at an increased risk of premature death.[6] The practicing physician is concerned primarily with information of the second and the third types, which will influence a present or future management decision.

Electrocardiograms in Specific Cardiac Disorders

Rhythm Abnormalities

Supraventricular Arrhythmias

These are common in the younger age group: among over 100,000 applicants to the US Air Force, of whom the majority were under 40 years of age, atrial rhythms and atrial and nodal premature beats were seen in approximately one percent.[7] In youth, variable degrees of vagal and sympathetic tone can produce remarkable variations and irregularities of heart rate. The sinus bradycardia of physical conditioning is well known. Atrial and nodal escape beats are physiological in this situation and should never be treated. The prevalence of these abnormalities tends to decrease with age, which supports the concept that they are benign and the prognosis good.[8]

Specific atrial arrhythmias, such as paroxysmal atrial tachycardia, are well-recognized clinical entities that can be suspected from the history, and supported by the physical findings. The ECG has a confirmatory role in diagnosis.

In older patients (over 50 years) sinus bradycardia, especially if associated with cerebral symptoms and other atrial rhythms (tachybrady syndrome), may have a more serious implication—a sick-sinus syndrome.[9] Patients with these arrhythmias and symptoms of unexplained lightheadedness or syncope must be investigated, as the condition can be treated with a permanent pacemaker.

There appears to be little value in using routine electrocardiography to detect atrial arrhythmias in asymptomatic patients with a normal cardiac examination.

Ventricular Arrhythmias

The significance of ventricular arrhythmias is quite different. The majority of sudden coronary deaths occur outside hospitals and are due to electrical instability of the ventricles. Ventricular premature beats (VPBs) are a common precursor of this catastrophe.[10] This cause of "sudden death" is potentially treatable if cardiopulmonary

Table 1. Procedures Performed by Physicians, 1972, Quebec

Procedures Performed	Numbers of Procedures: All Physicians (n=7,723)	Other Specialists (n=4,331)	Family Physicians (n=3,392)
Office visit	8,018,629	1,283,560	6,735,069
Complete examination (office)	2,941,649	1,705,189	1,236,460
Urinalysis*	720,611	270,706	449,905
Individual psychotherapy**	191,897	165,116	36,410
Radiography			
Lungs	166,523	155,075	—
Upper gastrointestinal	81,964	81,025	—
Gallbladder	73,570	72,110	—
Electrocardiogram	142,318	112,193	30,125

*Without microscopy.
**Duration—30 to 50 minutes.

resuscitation with electrical defibrillation is immediately available.[11]

It has also been suggested that patients at high risk for this condition can be identified. Profiles of these patients include the following characteristics: 80 percent are male and between the ages of 45 and 65 years; 75 percent have a history of previous ischemic heart disease (angiograms show an average of 1.5 coronary vessels with greater than 75 percent narrowing; and, glycosuria, hypertension, and cigarette smoking are common.

At first sight it might appear to be relatively easy to identify such patients and to provide them with an appropriate prophylactic antiarrhythmic drug. Continuous monitoring, however, shows that ventricular ectopic beats are common, and that short bursts of ventricular tachycardia may be seen even in otherwise healthy individuals. Ventricular premature beats (VPBs) tend to be randomly scattered throughout a 24-hour tracing and may be frequent one day and absent the next.[12] It is purely a matter of chance whether the VPBs happen to be registered on a routine electrocardiogram, which only records between 12 and 60 seconds of cardiac activity. If an ECG of 60 seconds duration is recorded, only 0.07 percent of a day's cardiac activity is sampled; the routine electrocardiogram thus yields a very low detection rate for VPBs. If, by chance, one or more VPBs is recorded, there is a serious risk of overemphasizing the prevalence of the arrhythmia in such an individual. The only resolution of this dilemma is to identify those individuals who appear to be at high risk of developing sudden cardiac death and to investigate them with one of the forms of continuous ambulatory cardiac monitoring such as the Holter monitor.[2,3] Only in this way can adequate information be obtained to establish whether prophylactic therapy is indicated and whether it is effective.

It is evident that such an investigation can only be offered to a small percentage of those individuals with VPBs. A compromise can be made if the characteristics of "benign" VPBs can be distinguished from "malignant" VPBs. Patients in whom ventricular premature beats are associated with an acute ischemic episode are always considered to have a serious disorder and must be treated with an antiarrhythmic agent. Those having VPBs that are multifocal, occurring in pairs or triplets, or originating on the descending limb of the previous T-wave will usually require treatment.[13] Patients with overt cardiac disease and receiving diuretic or digitalis therapy require special attention. In the absence of any of these findings, it is advisable to ignore the occasional benign VPB rather than raise an anxiety for which there is no satisfactory resolution.

Conduction Abnormalities

The prevalence of various degrees of atrioventricular block is relatively constant (about one percent) up to the age of 55 years, when the rate gradually increases (Table 2). These abnormalities in the younger age group are usually either con-

Table 2. Prevalence of Classified Electrocardiographic Findings According to Age[14]

Abnormality	Rate* by Age (years) 20-29	30-39	40-49	50-59	60-69	70-79
Pathological Q-waves	—	—	1.7	5.1	9.0	9.9
Left axis deviation	1.1	3.5	5.6	8.5	18.0	25.7
ST-segment depression	0.9	1.0	3.2	3.3	6.2	10.9
Abnormal T-waves	5.1	5.9	12.9	17.5	30.9	35.6
AV block	0.7	1.3	1.5	1.2	4.5	7.9
Incomplete RBBB	1.6	1.3	2.8	2.7	3.9	3.0
Premature beats	1.1	1.6	2.6	1.5	6.7	7.9

* Rate per 100 men examined.

genital or associated with previous infarction. It is important to know that heart rate is adequate at rest and exercise.

Beyond the age of 50 years the development of increasing atrioventricular (AV) block is usually due to ischemia. A progressive lesion may lead to complete heart block and syncope (Stokes-Adams disease); in patients with such a lesion a permanent artificial pacemaker is necessary. It is reasonable to take ECGs on a yearly basis in patients with known ischemic heart disease. Once a degree of AV block has been identified the frequency of surveillance should be increased.

The prevalence of right bundle branch block was revealed by an epidemiological investigation of the natural community of Tecumseh, Michigan.[14] The study showed that 18 of the 5,129 adults examined showed electrocardiographically complete right bundle branch block (RBBB), and that incomplete RBBB occurred four times as frequently. Interestingly, neither arrhythmia was correlated with other variables measured, such as hypertension, hypercholesterolemia, hyperglycemia, or obesity. RBBB and incomplete RBBB have been shown to have no prognostic significance.[6]

The Tecumseh study revealed complete left bundle branch block (LBBB) in 18 adults, only two of whom were under the age of 50 years. There is good evidence that LBBB is never a congenital lesion and that it is a sign of heart disease (usually coronary artery disease), with a mortality rate twice the average.[6]

One conduction disturbance, the ventricular pre-excitation syndrome (Wolff-Parkinson-White syndrome), is of special interest. As a congenital lesion with an incidence of 3 in 1,000 at all ages, it is a useful indicator of the sampling bias in an ECG survey. Most life insurance companies increase the cost of a policy for these subjects. The evidence that the mortality is appreciably increased in those cases without arrhythmias is weak. This represents one of the drawbacks of taking an electrocardiogram without a good clinical indication. One form of the Wolff-Parkinson-White syndrome (type B) is occasionally confused with an inferior myocardial infarction, an embarrassing error.

Overall, it seems that conduction abnormalities of import to the patient occur either in the presence of ischemia or in association with physical symptoms that would bring the patient to a physician. Considering the overall prevalence of conduction abnormalities found in the studies cited, the incidence of new, clinically important abnormalities detected by routine screening would be low.

Ventricular Hypertrophy

Most textbooks on electrocardiography delight in expounding upon the advantages of the various diagnostic criteria[15,16] of left ventricular hypertrophy. The criteria include the height and width of the QRS complexes and alterations in the ST-segment and T-waves. As only actual autopsy measurements can confirm the degree of hypertrophy, few good studies have addressed themselves to the sensitivity and selectivity of the various criteria. There is a technical problem in that the height of QRS complexes changes with age, body build, and cardiac position.[17] Another source of confusion is that the development of acute left anterior hemi-

Table 3. Prevalence, Annual Incidence, and Mortality* for Coronary Heart Disease (CHD) and Myocardial Infarction (MI) According to Age

Age (years)	Prevalence[27]		Incidence[28]		Mortality[28]
	CHD	MI	CHD	MI	CHD
30	0.4	0.3	—	—	0.01
40	1.1	0.7	0.3	0.2	0.09
50	3.5	1.9	0.9	0.5	0.36
60	9.7	4.3	2.2	1.6	0.93
70	11.6	6.3	1.3	1.3	2.00

* Per 100 males in United States.

block can produce all the changes of left ventricular hypertrophy in a single beat.[18] Notwithstanding all these difficulties, analysis of the results of the Framingham study showed that left ventricular hypertrophy was associated with a threefold increased incidence of myocardial infarction.[19]

There are several causes of left ventricular hypertrophy. The most common is essential hypertension, but hypertension should, of course, be identified clinically before ECG changes occur. The electrocardiogram then becomes a tool for evaluating the long-term effects of increased blood pressure in the known hypertensive patient.

Electrocardiographic changes diagnosed as left ventricular hypertrophy are significant in association with valvular heart disease, such as aortic stenosis and mitral insufficiency. The development of hypertrophy, especially with the ST-segment changes that are given the misleading term "strain pattern," is one of the factors that indicates a progressive lesion and might raise the question of earlier rather than later surgical intervention. Because cardiac examination of patients with such abnormalities also reveals abnormalities, it would be totally inefficient to use routine electrocardiography as a case finding procedure in this situation.

Thus, an astute physician uses the electrocardiogram as a useful tool to evaluate the presence and progression of left ventricular hypertrophy, having already clinically identified patients in whom it should be suspected.

Ischemic Heart Disease

The majority of the proponents of routine electrocardiography claim that this test is useful in detecting and managing coronary or atherosclerotic heart disease.[20-22] The prevalence of electrocardiographic changes that could indicate ischemia has been reviewed in a number of studies. Most of these reflect investigation of selected populations, such as those of applicants to the US Air Force,[7] clinic patients,[23] or patients who have been transferred from physicians' offices.[24] The Tecumseh survey[14] is one of the few studies in which an unselected representative sample has been carefully analyzed. The various abnormalities detected are summarized in Table 2, which shows that the number of electrocardiograms with pathological Q-waves increased with age, and that almost ten percent of those studied in their seventh or eighth decade had this abnormality. This change is almost always correlated with occlusive coronary disease and identifies that portion of the population with advanced coronary atherosclerosis.

Other electrocardiographic changes are suggestive of significant coronary disease, but there is a poor correlation with acute coronary events and with age-specific mortality rates. Only with pathological Q-waves can one predict a twofold increase in mortality. Left axis deviation approaches a prevalence of 20 percent in the seventh decade, and the proportion of patients with decreased T-wave voltage or T-wave inversion is over 30 percent in this age group (Table 2). The frequency of these abnormalities is several times greater than the estimated prevalence of coronary heart disease. T-wave changes are notoriously "nonspecific" and are influenced by many variables such as serum potassium concentrations, hyperventilation, and other metabolic and pharmacological influences. If T-wave changes alone

on an electrocardiogram are thought to indicate coronary heart disease, there will be many false-positive findings, but there are few reliable data in this area. A serious clinical dilemma results when routine electrocardiography in a healthy male reveals T-wave changes. Such a change can affect the insurability of the individual's life and, if he should be a pilot, may affect his ability to earn a living. If further investigation of these individuals were recommended, massive resources would have to be developed, for 17.5 percent of the male population at 50 years and 30.9 percent of the male population at 60 years have T-wave changes.

Some degree of ST-segment depression found on the resting electrocardiogram is seen in three to six percent of males between 40 and 60 years of age. Because of the poor correlation of this change with coronary heart disease, most authorities will only relate ST-segment changes on exercise to prognosis. In one study, almost 22,000 stress tests were performed in 2,003 asymptomatic men over a 13-year period.[25] In 264 individuals (13.2 percent), coronary heart disease developed during this period. In 75 of these men (28 percent of those with coronary heart disease), the first manifestation was a positive exercise test. Over the next five years there was an 85 percent probability that these men with an abnormal electrocardiographic response to exercise would suffer angina pectoris or a myocardial infarction. Even this highly sophisticated prospective study failed to detect 72 percent of patients in whom some manifestation of ischemic heart disease developed. The sensitivity of continuously monitored ECG stress tests varies from 57 to 80 percent (mean sensitivity, about 72 percent); the specificity or accuracy of continuously monitored ECG stress tests varies from 82 to 100 percent (mean accuracy, 90 percent).[6] The sensitivity of ST-segment changes on the resting electrocardiogram is, however, not known, but it must be exceedingly low.

Another study indicated that the 12-lead electrocardiogram in individuals at rest and free of pain is normal in approximately 50 percent of the patients with typical angina pectoris and arteriographically demonstrated coronary atherosclerosis. Absence of an electrocardiographic abnormality does not exclude the diagnosis.[26]

Because of this low sensitivity and the poor specificity of particular changes when seen, one must seriously question the value of routine electrocardiograms in the detection of ischemic heart disease.

Electrocardiograms as Baseline Information

It is often stated that the main reason for taking a routine electrocardiogram is to obtain a record so that, when an acute coronary event occurs, electrocardiographic changes can be more readily interpreted and so that, presumably, treatment may be more enlightened. It has been strongly recommended that any male patient over the age of 40 years should carry a small reproduction of his most recent electrocardiogram in his wallet for this purpose, but to the authors' knowledge this proposal has never been put to a critical test.

Underlying this approach are a number of assumptions. It is assumed that the baseline electrocardiogram would be readily available at the required moment and place. Because of multiple record systems in various locations, such as physicians' offices, hospitals, and clinics, the record either would have to be carried by the patient or be available in a centralized computer bank having widely dispersed terminals. Using the incidence figures from Table 3,[27,28] one can calculate that if 1,000 males at age 40 years were to have an electrocardiogram annually for the ten years from ages 40 through 49 years, 10,000 electrocardiograms would need to be taken to demonstrate 35 myocardial infarctions.

It is further assumed that the presence or absence of changes on the electrocardiogram, when compared to a previous one, contribute to the decision regarding management. Physicians with little experience often rely excessively on the electrocardiogram in the management of a patient with acute chest pain. Both false-positives and false-negatives are sufficiently frequent that the diagnosis and management is more reliable when the emphasis is placed on a careful history and physical examination. Patients who are obviously ill or distressed will have to be watched carefully regardless of what the initial electrocardiogram shows. With the general availability of tests based on serum enzyme concentrations (eg, creatinine phosphokinase), which have a high sensitivity for even small amounts of myocardial necrosis, the diagnostic value of the electrocardiogram in an acute illness is less essential and a comparison ECG relatively unimportant.

Drawbacks of the Screening Electrocardiogram

Electrocardiography is noninvasive and should be free of morbidity. It is, however, not uncommon for the findings of an electrocardiogram taken on an asymptomatic individual to create more problems than are solved. Several examples of potential clinical dilemmas have been suggested. A physician must realize that, on the average, one or more abnormality can be expected in approximately ten percent of individuals at 40 years, fifteen percent at 50 years, and twenty percent at 60 years.[29] The majority of the changes are nonspecific and do not correlate with morbidity or mortality. A physician ordering an electrocardiogram for an asymptomatic patient must be prepared to deal with whatever results might be received. The public today is well informed on the significance of suspected heart disease and the ever-present danger of sudden death in middle-aged men. Currently there is no satisfactory management of an asymptomatic patient whose electrocardiogram shows changes consistent with ischemia, unless some treatable condition such as hypertension or anemia can be identified. The possibility of precipitating a cardiac neurosis, which can be as debilitating as organic heart disease, must always be borne in mind.

Conclusion

Electrocardiography as a tool to provide useful diagnostic and management information has both strengths and weaknesses. A review of electrocardiography from the standpoints of its value and limitations supports the hypothesis that an electrocardiogram should be regarded as an adjunct to clinical diagnosis rather than as a screening procedure.

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