

**AHA/ACC/HRS SCIENTIFIC STATEMENTS**

# Recommendations for the Standardization and Interpretation of the Electrocardiogram

## Part I: The Electrocardiogram and Its Technology

A Scientific Statement From the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society

*Endorsed by the International Society for Computerized Electrocardiology*

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**Abstract**—This statement examines the relation of the resting ECG to its technology. Its purpose is to foster understanding of how the modern ECG is derived and displayed and to establish standards that will improve the accuracy and usefulness of the ECG in practice. Derivation of representative waveforms and measurements based on global intervals are described. Special emphasis is placed on digital signal acquisition and computer-based signal processing, which provide automated measurements that lead to computer-generated diagnostic statements. Lead placement, recording methods, and waveform presentation are reviewed. Throughout the statement, recommendations for ECG standards are placed in context of the clinical implications of evolving ECG technology. (*J Am Coll Cardiol* 2007;49:1109–27)

**Key Words:** AHA Scientific Statements ■ electrocardiography ■ computers ■ diagnosis ■ electrophysiology ■ intervals ■ potentials ■ tests

In the century since the introduction of the string galvanometer by Willem Einthoven (1), the electrocardiogram (ECG) has become the most commonly conducted cardiovascular diagnostic procedure and a fundamental tool of clinical practice (2,3). It is indispensable for the diagnosis and prompt initiation of therapy in patients with acute coronary syndromes and is the most accurate means of diagnosing intra-

ventricular conduction disturbances and arrhythmias. Its interpretation may lead to the recognition of electrolyte abnormalities, particularly of serum potassium and calcium, and permit the detection of some forms of genetically mediated electrical or structural cardiac abnormalities. The ECG is routinely used to monitor patients treated with antiarrhythmic and other drugs, in the preoperative assess-

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ment of patients undergoing noncardiac surgery, and in screening individuals in high-risk occupations and, in some cases, for participation in sports. As a research tool, it is used in long-term population-based surveillance studies and in experimental trials of drugs with recognized or potential cardiac effects.

Indications for use of the ECG were summarized in a joint American Heart Association (AHA)/American College of Cardiology report in 1992 (4). Because of its broad applicability, the accurate recording and precise interpretation of the ECG are critical. The establishment of and adherence to professionally developed and endorsed evidence-based standards for all phases of the ECG procedure is an important step in ensuring the high level of precision required and expected by clinicians and their patients (5). However, there has not been a comprehensive updating of ECG standards and criteria since 1978 (6–14). Since 1978, there have been many advances in the technology of electrocardiography; in the understanding of the anatomic, pathological, electrophysiological, and genetic information underlying ECG findings; and in the clinical correlations of ECG abnormalities. One of the most important changes in electrocardiography is the widespread use of computerized systems for storage and analysis. Many if not most ECGs in the United States now are recorded by digital, automated machines equipped with software that measures ECG intervals and amplitudes, provides a virtually instantaneous interpretation, and often compares the tracing to those recorded earlier by the same system. However, different automated systems may have different technical specifications that result in significant differences in the measurement of amplitudes, intervals, and diagnostic statements (15,16).

For these reasons, the AHA initiated an updating of guideline statements for standardization and interpretation of the ECG. The project has been endorsed by the American College of Cardiology, the Heart Rhythm Society, and the International Society for Computerized Electrocardiology. The purposes of this project are as follows: (1) to review the status of techniques currently used to record and interpret the ECG and to identify opportunities for modification; (2) to simplify and unify the various descriptive, diagnostic, and modifying terminologies currently used in order to create a common and more easily applied lexicon; and (3) to identify the weaknesses of the descriptive, interpretative, and comparative algorithms and recommend changes that incorporate the newly recognized factors referred to above.

The chairman (L.S.G.) was selected by the Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology of the AHA. He formed an advisory group to assist in setting goals and to recommend other writing group members. The committee met on 5 occasions to discuss goals, identify specific areas that required updating, and review progress. A smaller working/writing group with a group leader was chosen for each topic. This is the first of 6 articles written in response to the AHA mandate. It is followed by a glossary of descriptive, diagnostic, and comparative statements that attempts to minimize repetitive and noninformative statements. Additional articles, to be published subsequently, will discuss the ECG interpretation of intraventricular

conduction disturbances, abnormalities of ventricular repolarization, hypertrophy, and ischemia/infarction.

## The ECG and Its Technology

The purposes of this statement are (1) to examine the relation of the resting ECG to its technology, (2) to increase understanding of how the modern ECG is derived and recorded, and (3) to promote standards that will improve the accuracy and usefulness of the ECG in practice. Special emphasis will be placed on the digital recording methods and computer-based signal processing that are used in current electrocardiographs to provide automated measurements that lead to computer-generated diagnostic statements. The writing group recognizes that technical details of the processing and recording of ECGs may be unfamiliar to clinicians. Accordingly, a major purpose of this document is to provide clinicians with insight into the generally missing link between technology and its consequences for clinical ECG interpretation. The evolution and application of ECG technology have profound clinical implications, as exemplified by the demonstration that measurements made by different automated ECG systems from reference ECG data can vary enough to alter diagnostic interpretation (15,17). Sensitivity and specificity of computer-based diagnostic statements are improving, but at the same time, it remains evident that physician overreading and confirmation of computer-based ECGs is required (15,16,18).

## Previous Standards and Reviews

A number of recommendations for the standardization of ECG recording and guidelines for ECG interpretation in the computer era have appeared during the past several decades. The most recent comprehensive AHA recommendations for the standardization of leads and general technical requirements of ECG instruments were published in 1975 (5). In 1978, task forces of the American College of Cardiology produced a collection of reports on optimal electrocardiography (7), which addressed standardization of terminology and interpretation (13), the development of databases (6), the quality of ECG records (12), computers in diagnostic cardiology (9), the use of ECGs in practice (10), cost-effectiveness of the ECG (11), and a discussion of future directions (14). In Europe, international common standards for quantitative electrocardiography (CSE) evolved from the work of Willem and colleagues (19–22). The CSE studies were designed to reduce the wide variation in wave measurements obtained by ECG computer programs and to assess and improve the diagnostic classification of ECG interpretation programs (22). Given the expanding use of computer-based ECG systems and evolving technology, recommendations for bandwidth and digital signal processing standards during automated electrocardiography were formulated in 1990 by a committee of the AHA (23). In 1991, recommendations of the 1975 and 1990 AHA documents were incorporated into a summary document on diagnostic ECG devices that was developed by the Association for the Advancement of Medical Instrumentation (AAMI) and approved by the American National Standards Institute (ANSI) (24). This document was reaf-

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