ACC/AHA CLINICAL COMPETENCE STATEMENT

ACC/AHA Clinical Competence Statement on Electrocardiography and Ambulatory Electrocardiography

A Report of the ACC/AHA/ACP–ASIM Task Force on Clinical Competence (ACC/AHA Committee to Develop a Clinical Competence Statement on Electrocardiography and Ambulatory Electrocardiography)

Endorsed by the International Society for Holter and Noninvasive Electrocardiology

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TABLE OF CONTENTS

I. PREAMBLE

The granting of clinical staff privileges to physicians is a primary mechanism used by institutions to uphold the quality of care. The Joint Commission on Accreditation of Health Care Organizations requires that the granting of continuing medical staff privileges be based on assessments of applicants against professional criteria specified in the medical staff bylaws. Physicians themselves are thus charged with identifying the criteria that constitute professional competence and with evaluating their peers accordingly. Yet, the process of evaluating physicians' knowledge and competence is often constrained by the evaluator's own knowledge and ability to elicit the appropriate information, problems compounded by the growing number of highly specialized procedures for which privileges are requested.

The American College of Cardiology/American Heart Association/American College of Physicians–American Society of Internal Medicine (ACC/AHA/ACP–ASIM) Task Force on Clinical Competence was formed in 1998 to develop recommendations for attaining and maintaining the cognitive and technical skills necessary for the competent performance of a specific cardiovascular service, procedure, or technology. These documents are evidence-based, and when evidence is not available, expert opinion is utilized to formulate recommendations. Indications and contraindications for specific services or procedures are not included in the scope of these documents. Recommendations are intended to assist those who must judge the competence of cardiovascular health care providers entering practice for the first time and/or those who are in practice and undergo periodic review of their practice expertise. The assessment of competence is complex and multidimensional; therefore, isolated recommendations contained herein may not necessarily be sufficient or appropriate for judging overall competence.

The ACC/AHA/ACP–ASIM Task Force makes every effort to avoid any actual or potential conflicts of interest that might arise as a result of an outside relationship or personal interest of a member of the ACC/AHA Writing Committee. Specifically, all members of the Writing Committee are asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest. These changes are reviewed by the Writing Committee and updated as changes occur.

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II. INTRODUCTION

A. Organization of Committee and Evidence Review

This document is a revision of the 1995 ACP/ACC/AHA Clinical Competence Statement in Electrocardiography. The Writing Committee consisted of acknowledged experts in electrocardiography representing the ACC (five mem-

bers), and the AHA (two members). Both the academic and private practice sectors were represented. The document was reviewed by three official reviewers nominated by the ACC, three official reviewers nominated by the AHA, the ACC Clinical Electrophysiology Committee, the Electrocardiography and Arrhythmias Committee of the Council on Clinical Cardiology, and 16 content reviewers nominated by the Writing Committee. On August 31, 2001, the document was approved for publication by the ACC Board of Trustees and the AHA Science Advisory and Coordinating Committee. This document will be considered current unless the Task Force revises or withdraws it from distribution. In addition, the governing board of the International Society for Holter and Noninvasive Electrocardiology has formally endorsed this document.

B. Purpose of This Clinical Competence Statement

This competence statement is one in a series developed by the ACC and the AHA to assist in the assessment of physicians' competence on a procedure-specific basis. The minimum education, training, experiences, and cognitive and technical skills necessary for the competent reading and interpretation of electrocardiograms (ECGs) and ambulatory electrocardiograms (AECGs) are specified. It is important to note that these are minimum training and experience recommendations for competence in these disciplines (or procedures) in a broad sense. Expertise in the performance of these procedures in patients with infrequently encountered diagnoses, or of less commonly performed variations of standard procedure, may well require additional experience or training. It is therefore expected that even highly competent practitioners will occasionally benefit from consultations with colleagues who have specialized interest, experience, or skills. It is recognized that other physicians not meeting these criteria may provide preliminary interpretations of ECGs in selected circumstances such as emergencies or settings in which a formally trained physician is not available. In such circumstances, a formally trained physician should be accessible to provide backup support. This document applies to specialists trained in internal medicine and/or adult cardiology who are interpreting ECGs of adults. The interpretation of pediatric ECGs requires special competence and is not covered by the guidelines developed here.

C. Background

Introduced in 1902 by Einthoven, electrocardiography is the graphical display of electrical potential differences of an electric field originating in the heart as recorded at the body surface (1). As a record of electrical activity of the heart, it is a unique technology that provides information not readily obtained by other methods. In fact, recording of the resting 12-lead ECG continues to be the most commonly used laboratory procedure for the diagnosis of heart disease. The procedure is safe, simple, and reproducible; the record lends itself to serial studies; and the relative cost is minimal. The

development of portable devices to record ECGs led to the development of AECG recordings and expanded the use of this technique to the diagnosis of transient arrhythmias, providing crucial information at the time that symptoms occur. An AECG can be obtained via continuous recorders (Holter monitors) or with intermittent recorders (also known as event monitors or loop recorders) and is used for patients with infrequent symptoms, in whom a clinical correlation is needed.

The indications, contraindications, and recommendations for the minimum education, training, experience, and skills necessary to interpret AECGs and surface electrocardiography are derived primarily from the ACC/AHA Guidelines for Ambulatory Electrocardiography (2), ACC Guidelines for Training in Adult Cardiovascular Medicine: Core Cardiology Training Symposium (COCATS) (3), the prior ACP/ACC/AHA Task Force Statement on Clinical Competence in Electrocardiography (4), the prior ACP/ACC/AHA Task Force Statement on Clinical Competence in Ambulatory Electrocardiography (5), and the opinion of the ACC/AHA Writing Committee to Revise the 1995 Competence Statement on Electrocardiography.

III. TWELVE-LEAD ECGS

A. Overview and Indications for the Procedure

There are numerous potential clinical uses of the 12-lead ECG. The ECG may reflect changes associated with primary or secondary myocardial processes (e.g., those associated with coronary artery disease, hypertension, cardiomyopathy, or infiltrative disorders), metabolic and electrolyte abnormalities, and therapeutic or toxic effects of drugs or devices. Electrocardiography serves as the gold standard for the noninvasive diagnosis of arrhythmias and conduction disturbances, and it occasionally is the only marker for the presence of heart disease (6).

As is the case with any other laboratory procedure, appropriate and accurate use of the ECG requires that its sensitivity and specificity be understood and considered in the interpretation of the recording. This is somewhat more complex for ECGs than for many other laboratory tests because ECGs are composed of a number of waveforms, each with its own sensitivity and specificity and each influenced differently by a variety of pathologic and pathophysiologic factors.

In the diagnosis of arrhythmias and conduction disturbances, sensitivity and specificity of ECGs are far higher than in the diagnosis of structural and/or metabolic abnormalities. In the latter, the diagnosis is made by inference—based on extensive studies correlating the ECG tracings with a variety of clinical, pathological, and experimental states—and as such has limitations. There are far more structural and pathophysiologic abnormalities than recognizable ECG patterns, which results in considerable overlap and thus reduces the specificity of ECGs for many forms of heart disease. For example, although ST-segment and T-wave changes are the most common and most sensitive ECG abnormalities, these changes are the least specific (7). The technological development of powerful personal computers enabled the development of extremely sophisticated signal processing algorithms, introducing another dimension in the usefulness of ECG recordings. Analysis of RR intervals; QRS and T-wave morphology, including late potentials; QT dispersion; and T-wave alternans are currently being evaluated as prognostic markers in patients with structural heart disease (8). In addition, transtelephonic monitoring of implanted devices has become a standard technique of evaluating and following patients. Because training in these new modalities has not been standardized, neither the 12-lead ECG portion nor the AECG portion of this document will deal with these new technologies.

B. Minimum Knowledge Necessary for Competence in Interpreting 12-Lead ECGs

Electrocardiograms are interpreted by physicians in many specialties, including cardiology, internal medicine, family practice, and emergency medicine. Interpretative skills vary among specialists (9). The Institute for Clinical Evaluation (ICE) is a foundation of the American Board of Internal Medicine (ABIM) that offers certifying examinations in clinical skills. A physician in any specialty whose interpretations of ECGs contribute to clinical decision-making should have a sufficient knowledge base to make accurate diagnoses.

An adequate knowledge base should include the ability to define, recognize, and understand the basic pathophysiology of certain electrocardiographic abnormalities. A categorical list of those abnormalities is displayed in Table 1. This is a minor modification of the diagnosis list used in the ECG Self-Assessment Program III (ECGSAP III) and the ABIM ICE ECG Exam (10,11). The ECGSAP I, II, and III were developed by the ACC to provide physicians with a means to compare their proficiency in ECG interpretation to that of others and to improve their own proficiency. These programs are also intended to help physicians prepare for the ECG exam. The ECGSAP III has recently become available. A competent ECG reader should also be able to recognize potential clinical diagnoses on the basis of ECGs. Clinical syndromes are listed under Clinical Disorders in Tables 1 and 2. Although these clinical syndromes do not always produce a diagnostic ECG pattern, ECG interpreters should recognize the characteristic patterns.

Electrocardiogram readers should understand the importance of comparing a current tracing to previous tracings in order to make correct diagnoses. All abnormal tracings should be compared with available previous tracings. The accuracy of some diagnoses may be considerably enhanced by reviewing previous tracings. Some examples are listed in Table 3.

Table 1. Electrocardiographic Diagnoses

NORMAL TRACING
1. Normal ECG

TECHNICAL PROBLEMS
2. Leads misplaced
3. Artifact

SINUS NODE RHYTHMS AND ARRHYTHMIAS
4. Sinus rhythm
5. Sinus tachycardia (>100 beats per minute)
6. Sinus bradycardia (<50 beats per minute)
7. Sinus arrhythmia
8. Sinus arrest or pause
9. Sino-atrial exit block

OTHER SUPRAVENTRICULAR RHYTHMS
10. Atrial premature complexes
11. Atrial premature complexes, nonconducted
12. Ectopic atrial rhythm
13. Ectopic atrial tachycardia, unifocal
14. Ectopic atrial tachycardia, multifocal
15. Atrial fibrillation
16. Atrial flutter
17. Junctional premature complexes
18. Junctional escape complexes or rhythm
19. Accelerated junctional rhythm
20. Junctional tachycardia, automatic
21. Supraventricular tachycardia, paroxysmal

VENTRICULAR ARRHYTHMIAS
22. Ventricular premature complexes
23. Ventricular escape complexes or rhythm
24. Accelerated idioventricular rhythm
25. Ventricular tachycardia
26. Ventricular tachycardia, polymorphous (including torsade de pointes)
27. Ventricular fibrillation

ATRIAL VENTRICULAR CONDUCTION
28. First-degree AV block
29. Mobitz Type 1 second-degree AV block (Wenckebach)
30. Mobitz Type 2 second-degree AV block
31. AV block or conduction ratio, 2:1
32. AV block, varying conduction ratio
33. AV block, advanced (high-grade)
34. AV block, complete (third-degree)
35. AV dissociation

INTRAVENTRICULAR CONDUCTION
36. Left bundle branch block (fixed or intermittent)
37. Right bundle branch block (fixed or intermittent, complete or incomplete)
38. Intraventricular conduction delay, nonspecific
39. Aberrant conduction of supraventricular beats
40. Left anterior fascicular block
41. Left posterior fascicular block
42. Ventricular pre-excitation (Wolff-Parkinson-White pattern)

QRS AXIS AND VOLTAGE
43. Right axis deviation (+90 to +180 degrees)
44. Left axis deviation (−30 to −90 degrees)
45. Indeterminate axis
46. Electrical alternans
47. Low voltage (less than 0.5 mV total QRS amplitude in each extremity lead and less than 1.0 mV in each Precordial lead)

Table 1. Continued.

CHAMBER HYPERTROPHY OR ENLARGEMENT
48. Left atrial enlargement, abnormality, or conduction defect
49. Right atrial abnormality
50. Left ventricular hypertrophy (QRS abnormality only)
51. Left ventricular hypertrophy with secondary ST-T abnormality
52. Right ventricular hypertrophy with or without secondary ST-T abnormality

REPOLARIZATION (ST-T,U) ABNORMALITIES
53. Early repolarization (normal variant)
54. Juvenile T waves (normal variant)
55. Nonspecific abnormality, ST segment and/or T wave
56. ST and/or T wave suggests ischemia
57. ST suggests injury
58. ST suggests ventricular aneurysm
59. Q-T interval prolonged
60. Prominent U waves

MYOCARDIAL INFARCTION
61. Inferior MI (acute or recent)
62. Inferior MI (old or age indeterminate)
63. Posterior MI (acute or recent)
64. Posterior MI (old or age indeterminate)
65. Septal MI (acute or recent)
66. Anterior MI (acute or recent)
67. Anterior MI (old or age indeterminate)
68. Lateral MI (acute or recent)
69. Lateral MI (old or age indeterminate)
70. Right ventricular infarction (acute)

CLINICAL DISORDERS
71. Chronic pulmonary disease pattern
72. Acute pericarditis
73. Suggests hypokalemia
74. Suggests hyperkalemia
75. Suggests hypocalcemia
76. Suggests hypercalcemia
77. Suggests CNS disease

PACEMAKER
78. Atrial-paced rhythm
79. Ventricular-paced rhythm
80. Atrial-sensed ventricular-paced rhythm
81. AV dual-paced rhythm
82. Failure of appropriate capture, atrial
83. Failure of appropriate capture, ventricular
84. Failure of appropriate inhibition, atrial
85. Failure of appropriate inhibition, ventricular
86. Failure of appropriate pacemaker firing
87. Retrograde atrial activation
88. Pacemaker mediated tachycardia

Modified from Mason, JW, Gettes LS, Griffin JC, et al. ACC ECGSAP III Program.
ECG indicates electrocardiogram; AV, atrioventricular; MI, myocardial infarction.

Table 2. Additional Clinical Disorder Diagnoses by Electrocardiography

1. CNS disease
2. Dextrocardia
3. Digitalis toxicity
4. End-stage renal disease
5. Endocardial cushion defect
6. Hypertrophic cardiomyopathy
7. Hypothermia
8. Hypothyroidism
9. Long QT syndrome
10. Mitral stenosis
11. Orthotopic heart transplant
12. Parkinsonian tremor
13. Pericardial effusion
14. Primary pulmonary hypertension or pulmonary stenosis
15. Pulmonary embolism
16. Secundum atrial septal defect
17. Sick sinus syndrome
18. Torsades de pointes
19. Tricyclic antidepressant (overdose)
20. Wolff-Parkinson-White syndrome
21. RV dysplasia
22. Brugada Syndrome

CNS indicates central nervous system.

C. Technical Aspects of ECG Recording and Interpretation

Accurate electrocardiographic interpretation assumes that technical standards are adhered to during the acquisition and recording of tracings. A number of technical factors may alter the quality of recorded ECGs. Some of these are patient-related, some are operator-dependent, and others relate to the equipment utilized for recording. Errors or variances in technical practice must be recognized by the physician if tracings are to be interpreted appropriately.

Patient-related technical factors include muscle tremors and movement that may impair the quality of recordings. Failure to minimize and recognize artifacts while recording, and failure to recognize artifacts during interpretation, may result in an incorrect diagnosis of arrhythmias and may lead to unnecessary interventions and treatment (12). Variations in body habitus (e.g., marked obesity, presence of chronic lung disease) may influence an ECG and should be noted at the time of recording.

Table 3. Examples of Diagnoses Aided by Review of Previous Electrocardiograms

1. Acute myocardial infarction
2. Old myocardial infarction
3. Acute myocardial ischemia
4. Early repolarization vs. injury
5. Ventricular aneurysm
6. Supraventricular tachycardia mechanism
7. Pulmonary embolism
8. Pericardial effusion
9. Hyperkalemia and other electrolyte disturbances
10. Distinction between VT and SVT
11. Leads misplaced

VT indicates ventricular tachycardia; SVT, supraventricular tachycardia.

Operators recording ECGs should ensure that chest leads are placed in the proper position and electrodes make good skin contact to minimize artifacts. Incorrect placement of precordial leads may lead to a false diagnosis of infarction. The reversal of limb leads and the switching of precordial leads have been well-documented to cause alterations in ECGs (13). The presence of dextrocardia must be ascertained at the time of recording in order to correctly revise lead placement. Care must be taken to avoid using excess paste with electrode systems that require conductive skin paste. Excess paste may create "common" electrodes and contribute to errors in recording precordial leads.

Calibration marks or clear notations should be inscribed on each ECG tracing to enable interpreter to determine the paper speed and gain settings used in recording. Standard settings of 25 mm per s and 10 mm per mV should be used unless otherwise indicated on the tracing. Because of the possibility of electrical hazards resulting from current leakage in the recording apparatus, equipment must be checked at regular intervals to ensure that standards for current leakage are met (14–18).

The ultimate responsibility for making a correct interpretation of an ECG lies with the interpreting physician. Thus, it is incumbent upon the physician to be able to recognize aberrations and artifacts resulting from the above technical variations.

D. Computer Interpretation of ECGs

Several studies have examined the accuracy of computer ECG interpretation programs and have suggested that computer analysis cannot substitute for physician interpretation of ECGs (19–22). A systematic study of computerized ECG interpretation performed in 1991 demonstrated that computer programs were 6.6% less accurate, on average, than cardiologists at identifying ventricular hypertrophy and myocardial infarction (MI) (22). The best programs performed almost as well as experienced cardiologists in the interpretation of ECGs. However, disturbances in rhythm were not evaluated in that investigation, and anecdotal experience suggests that computer interpretation has a higher rate of error in analysis of rhythm than it does in the diagnosis of MI and hypertrophy. A more recent Japanese study (21) compared what has generally been the best-performing automated ECG interpretation program with readings by 25 physicians in their first two years of training and three cardiologists. Although the computer interpretation was usually accurate in diagnosing axis deviation and sinus tachycardia or bradycardia, it performed far less well than physicians-in-training in evaluating bundle branch block and QT interval. Overall, the false-positive and false-negative rate was 18 times higher for computer interpretations than for physicians-in-training in major ECG diagnoses. In addition to the lower accuracy of computer interpretation programs, comparison with prior ECG tracings, which is an important element in the interpretation of ECGs, is not a feature of current-generation computerized

Table 4. Training in Electrocardiographic Technology

1. Basic electricity
2. Lead placement: skin preparation and lead location
3. Signal filtration and its effect on waveforms
4. Technical artifacts
5. Basics of computer diagnosis algorithms
6. Safety

Table 5. Training in Cardiac Anatomy and Physiology Related to Electrocardiography

Basic electrocardiographic theory
Ionic currents generating the action potential
Action potential relationship to ECG waveforms
Potential gradients related to ECG waveforms
Anatomy of the cardiac chambers
    Orientation in the chest
    Electrical continuities and discontinuities between chambers
    Specialized conduction tissue of the atria and ventricles
Activation and repolarization characteristics of cardiac tissues
    SA node
    Atrial myocardium
    AV node
    His-Purkinje system
    Autonomic innervation of the heart
    Ventricular myocardium

ECG indicates electrocardiography.

interpretation systems. Thus, it is mandatory that all computer-interpreted ECGs be verified and appropriately corrected by an experienced electrocardiographer.

However, computerized interpretation of ECGs may be useful in the precise calculation of heart rate, conduction intervals, and axes, as long as manual over-reading occurs. Some computerized ECG interpretation programs may occasionally provide correct interpretations for ECGs that have been incorrectly read by physician readers (19). Newer processing techniques (e.g., neural networks) may improve the accuracy of computerized ECG interpretation, but these have not been well-validated (19). Thus, although computer interpretations of ECGs may have useful adjunctive value, they cannot substitute for interpretations by experienced electrocardiographers and should not be used in making clinical decisions.

E. Minimum Training Necessary for Competence in Interpreting 12-Lead ECGs

Training of electrocardiography varies greatly, especially among medical specialties. Likewise, the electrocardiographic knowledge required for board-certification varies greatly among the medical specialties. Nevertheless, electrocardiographic interpretation requires a basic knowledge of electrocardiographic technology, cardiac anatomy, and cardiac physiology as well as the ability to recognize diagnostic patterns on a 12-lead tracing. The training necessary for electrocardiographic technology is summarized in Table 4. The required education in cardiac anatomy and physiology is listed in Table 5. Pattern recognition, which is an essential component of ECG interpretation, is learned only through repeated exposure to the patterns. Repeated exposure is especially important because of the need to visually recognize the many diagnostic variations. Although there is no scientific study to rely on, we estimate that most physicians can obtain competence only after reading at least 500 tracings under the supervision of an expert electrocardiographer. These tracings must include examples of the diagnoses listed in Tables 1 and 2 (these may be provided by a teaching set of ECGs). Completion of a residency or fellowship does not guarantee adequate training in electrocardiography (23); therefore, documentation of the number of ECGs interpreted under supervision is recommended. We would recommend prospective data that would correlate competence with the number of tracings read and whether the number or frequency varies significantly among learners or among learning environments.

As with other diagnostic tests, knowledge of clinical data may aid in the interpretation of ECGs and, in turn, enhance their ability to provide clinically useful information. The interpretation of ECGs should not be taught solely by over-reading of tracings with students on the ECG reading service, but it should also be taught at the bedside and in the clinic. In addition, acquisition of the skill required to interpret an ECG as an over-reader having no knowledge of a patient's clinical condition may require a higher level of training and expertise.

F. Measurement of Competence in 12-Lead Electrocardiography

Several vehicles are available for demonstrating competence in ECG reading. Training in the use of ECGs, including supervised reading of ECGs, is an essential requirement of a cardiology fellowship program, as described in the COCATS requirements (3). Board certification in cardiology requires passing a separate portion of the board certification examination in cardiology that deals only with ECG interpretation. Thus, those individuals that are board-certified in cardiology have demonstrated their competence in a standardized examination. Some physicians who are not board-certified in cardiology are experienced electrocardiographers and are appropriately credentialed to read ECGs. Documentation of having interpreted 500 ECGs during or after training under the supervision of an expert electrocardiographer may be an alternate way to demonstrate competence. However, as valid, reliable, and widely available standardized ECG exams (such as the ABIM ICE ECG exam) become more widely accepted, we recommend that by 2005 they become the primary pathway, apart from cardiology board-certification, to demonstrate competence when granting initial ECG over-reading privileges to physicians not previously credentialed. This is especially true if a physician is serving as the interpreter of inhospital ECGs of patients whose clinical status is unfamiliar to that physician.

G. Maintaining Competence in the Interpretation of 12-Lead ECGs

Maintaining competence in the interpretation of 12-lead ECGs also requires ongoing practice. If interpretations are made only occasionally, arrhythmia may be missed or inappropriately diagnosed, particularly when there is a change in the recording system, analysis system, or technical personnel in the laboratory performing the ECG. This Task Force recommends a minimum of 100 interpretations a year to maintain competence. A study validating this would be welcome.

In addition, electrocardiographers should periodically assess their reading skills. Though electrocardiography is the most static of the cardiological technologies, knowledge of the significance, sensitivity, specificity, and frequency of both old and newly recognized electrocardiographic patterns is continuously evolving. Examples from the past decade include Brugada Syndrome, the use of right chest leads to diagnose right ventricular infarction, recognition of new infarct patterns, particularly those indicative of proximal left anterior descending occlusion, and of infarction in the presence of left bundle branch block, and the realization that Q-waves do not necessarily indicate irreversible MI. Because electrocardiographic interpretation is often done without knowledge of the patient's clinical status or subsequent follow-up, electrocardiographers do not often receive feedback that enables them to correct errors and improve. Thus, periodic self-assessment and retraining in electrocardiography are necessary. Numerous resources are available for self-assessment and continuing education in electrocardiography. These may include ACC electrocardiography self-assessment programs, electrocardiography workshops at the ACP–ASIM annual session, sessions provided by other national and international organizations, and other seminars and case conferences approved for continuing medical education credit. Clinicians credentialed to interpret ECGs should routinely participate in quality improvement activities such as having a number of ECGs over-read by colleagues and participating in periodic discussions of systemic issues involving ECG acquisition and interpretation. Ideally, these activities should result in procedural changes and improvements in skills, patient care, and patient outcomes.

IV. AECG MONITORING

A. Overview and Indications for the Procedure

Ambulatory electrocardiography is used in clinical practice to detect, document, and characterize occurrences of abnormal cardiac electrical behavior of the heart during ordinary daily activities. Because certain abnormalities may occur only during sleep or with mental, emotional, or exercise-induced changes in cardiac oxygenation or function, an ECG may need to be recorded over long periods of time. There are two categories of AECG examination: continu-

ous recordings (typically used for 24 to 48 h) and intermittent recordings that may be made over long periods of time to provide brief recordings (24–29). Some intermittent event recorders incorporate a memory loop that permits capture of very fleeting symptoms, tachycardia onset, and in some cases, syncope of infrequent occurrence (24).

Granting clinical staff privileges to physicians to interpret AECGs is one of the mechanisms used by hospitals to ensure quality of care. Ambulatory electrocardiography is frequently performed and interpreted in the setting of a physician's office. This section describes the minimum education, training, experience, and cognitive/technical skills necessary for competent ambulatory electrocardiographic interpretation. These criteria are applicable to any practice setting and provide a reference for physicians involved in either the granting of clinical privileges or peer review.

The indications for ambulatory electrocardiography are discussed in the ACC/AHA Guidelines for Ambulatory Electrocardiography (2). Current continuous ambulatory electrocardiography equipment is capable of providing analysis of the multiple parameters of cardiac electrical activity, including arrhythmia analysis, analysis of ST-segment shifts, and assessment of heart rate variability. There are no specific guidelines that distinguish patients for whom it is appropriate to perform continuous monitoring from those for whom intermittent ambulatory monitoring is adequate. However, when monitoring is performed to evaluate the cause of intermittent symptoms, the frequency of symptoms should dictate the type of recording. Continuous recordings are indicated for the assessment of frequent (at least one a day) symptoms that may be related to disturbances of heart rhythm, for the assessment of syncope or near syncope, and for patients with recurrent unexplained palpitations (30–39). (See the ACC/AHA Guidelines for Ambulatory Electrocardiography for additional Class IIb Indications.) By contrast, for patients with infrequent symptoms, intermittent event recorders may be more cost-effective in evaluating the cause of symptoms (40). In some clinical situations, a continuous monitor followed by intermittent event monitoring may be clinically appropriate. For patients receiving antiarrhythmic therapy, continuous monitoring is indicated to assess drug response, to monitor the rate of atrial fibrillation, and to exclude proarrhythmia (41–44). This is predicated on there being sufficient baseline ectopy to determine any changes caused by therapy. Continuous ambulatory monitoring is indicated for the analysis of patients with pacemakers or implantable cardioverter defibrillators (ICDs); for the evaluation of frequent palpitations, syncope, or near syncope; to assess the device for myopotential inhibition and pacemaker mediated tachycardia; and to assist in the optimization of physiologic programming (45–49). Continuous monitoring is also indicated for the evaluation of potential pacemaker or ICD failure and in the assessment of concomitant drug therapy. The assessment of silent ischemia may be facilitated by continuous ambulatory

monitoring (50,51). This may include screening for ischemia as well as assessment of anti-ischemic therapy.

Ambulatory monitoring by either continuous or intermittent recorders is safe. However, if the use of ambulatory monitoring results in a delay in hospitalization or treatment, the procedure is contraindicated. This could include those cases in which the patients' symptoms of altered consciousness or palpitations have an etiology identified by history, physical examination, or laboratory tests. Use of ambulatory monitoring for the assessment of patients with potential ischemia as the initial screening tool is not ideal for those who are able to undergo exercise testing or for the screening of asymptomatic patients. Use in these circumstances could lead to the potentially serious consequences brought on by a delay in diagnosis (2).

B. Minimum Knowledge Necessary for Competence in Interpreting AECGs

Ambulatory electrocardiography is a subdivision of clinical electrocardiography, and for this reason, the criteria for competence are frequently the same as those for classic electrocardiography. The electrocardiographic diagnoses listed in Table 1, that can be diagnosed using AECGs, include items 4 through 39, 41 through 44, 47 through 49, 51 through 60, and 79 through 88. There are, however, technical and cognitive aspects peculiar to AECGs that require additional knowledge (Table 6).

Because of the many differences in recording, analysis, and reporting systems, this document can address only the features common to all ambulatory electrocardiographic systems. However, it is important that physicians who make interpretations understand the equipment and techniques used to perform AECGs and are familiar with the specific system used in their own laboratories. Physicians are rarely involved in the data collection and processing phases of AECGs. However, physician over-reading is essential. Regardless of the processing method, physicians should be aware of the potential for false-positive or false-negative findings in arrhythmia detection and classification (Table 7) and in the diagnosis of myocardial ischemia (Table 8).

C. Technical Aspects of Interpreting AECGs

Ambulatory electrocardiography has the potential for producing a substantial amount of invalid data because of technical problems inherent in the recording and analytic processes. The ambulatory state is not stable in most cases. Noise interference from numerous sources that may occur over a 24-h recording period is a major cause for computer inaccuracies in both arrhythmia and ST-segment shift recognition and analysis. Many of the potential sources of error in the computer analysis systems are quite complex, and expertise in the technical aspects of AECGs requires an understanding not only of computer algorithms for the detection of QRS complexes and their classification but also of the problems associated with editing the computer analysis results. Physicians who interpret AECGs should

Table 6. Cognitive Skills Needed to Interpret AECGs Competently

1. Knowledge of the appropriate indications for ambulatory electrocardiography (1)
2. Knowledge of cardiac arrhythmias, their diagnosis and significance in normal subjects and in patients with heart disease
3. Appreciation of the wide range of variability in arrhythmia occurrence in the ambulatory patient throughout a diurnal cycle, and the influence of the autonomic nervous system on the rhythm of the heart
4. Knowledge of changes in the ECG that may result from exercise, hyperventilation, conduction disorders, electrolyte shifts, drugs, meals, temperature, Valsalva maneuvers, ischemia and transient repolarization phenomena related to a variety of cardiac disease
5. Knowledge of cardiac drugs and how they may affect conduction and repolarization on the ECG, particularly for suspected proarrhythmic phenomena
6. Knowledge of the sensitivity, specificity and diagnostic accuracy of ambulatory electrocardiography in various age groups and populations, particularly with respect to ST-segment changes and the application of Bayes' theorem
7. Knowledge of the most widely accepted criteria for ischemic ST-segment changes
8. Knowledge of ambulatory electrocardiographic evidence of failure to capture, failure to sense, or failure to pace for cardiac pacemakers and ICDs
9. Knowledge of ambulatory electrocardiographic evidence of appropriate and inappropriate antitachycardia pacing or defibrillation in the ICD patient
10. A basic understanding of the advantages and disadvantages of the instrumentation used in continuous and intermittent ambulatory electrocardiography from recorder, and the possible causes for false-positive or false-negative test results that are due to inherent instrumentation or signal processing limitations
11. Knowledge of the particular characteristics of the AECG instrumentation used to process the recordings for which the electrocardiographer is responsible
12. Appreciation of the skills required by the technologist to interact with the AECG instrumentation in editing the computer output, and the need to be assured of the competence of the technologist

AECG indicates ambulatory electrocardiogram; ICD, implantable cardioverter defibrillators.

have the knowledge base to assess all potential technical failings. Consequently, systems with full disclosure capabilities are preferred by many clinicians because they can "read" the tracing much as they read a 12-lead ECG. The standard 12-lead ECG has also proved to have adjunctive value in the interpretation of AECGs (52).

Table 7. Some Causes for Technical False-Positive or False-Negative Findings in Arrhythmia Detection and Classification by the AECG

1. Inadequate computer QRS detection and classification algorithms
2. Noise interference or lead-electrode baseline drift or artifact
3. Low-voltage recording
4. Recorder malfunction with variable tape drive or inaccurate storage
5. Physiologic variations in QRS form and voltage
6. Incomplete degaussing or erasure of data from previously used tapes or memory storage
7. Inadequate or incorrect technician interpretation during analysis
8. Incorrect time stamping of AECG tracings

AECG indicates ambulatory electrocardiogram.

Table 8. Some Causes for False-Positive or False-Negative Findings in Detection and Interpretation of Myocardial Ischemia from the Ambulatory Electrocardiogram

1. Positional changes on the ST-segment
2. Hyperventilation
3. Sudden excessive exercise-induced ST segment changes
4. Vasoregulatory or Valsalva-induced ST segment changes
5. Intraventricular conduction disorders
6. Undiagnosed or unappreciated left ventricular hypertrophy
7. ST segment changes secondary to tachyarrhythmias
8. False ST segment changes from atrial fibrillation or atrial flutter
9. ST segment changes secondary to electrolyte disturbance or drugs
10. Inadequate lead system employed
11. Incorrect or lack of lead calibration
12. Inadequate recording fidelity
13. Recording signal processing that compresses or filters the data, altering the ST-segment characteristics

D. Minimum Training Necessary for Competence in Interpreting AECGs

Prerequisite to minimal competence in ambulatory electrocardiography is competence in interpreting standard 12-lead ECGs. These recommendations address the special educational and cognitive skills needed to assess heart rate variability, cardiac pacemakers, and ICDs by ambulatory electrocardiography. Training should result in the cognitive skills needed to interpret AECGs, as listed in Table 6. In addition, depending on the AECG instrumentation utilized, a variety of factors can result in false-positive or false-negative findings in assessing cardiac arrhythmias (Table 7) or myocardial ischemia (Table 8). Knowledge of these artifactual or transient physiological changes is incumbent upon physicians rendering interpretations of AECGs.

There may be several ways to achieve these skills. It is essential that the number of AECG interpretations made under the review and guidance of experienced faculty be sufficient to expose the trainee to most of the technical and physiological phenomena that tend to confound accurate interpretation. Many physicians acquire the knowledge required for AECG interpretation in a training program during a residency or fellowship and supervised interpretation of 150 AECGs in the norm (3). This Task Force recommends that supervised interpretation of a minimum of 150 AECGs be considered necessary for minimum competence. At the discretion of the program director, this experience may be gained, in part, from a teaching set of AECGs. Educational teaching should include a wide range of typical and atypical AECG records that exemplify common and uncommon problems. First-hand interaction with an operator of Holter instrumentation would enable a trainee to appreciate the recording and analysis of artifacts and errors. This experience in AECG interpretation under the guidance of an authoritative faculty reviewer should be documented in a permanent logbook of the training program within that institution.

A physician may become competent in interpreting AECGs by attending well-designed courses conducted by an expert in ambulatory electrocardiography, coupled with studies of teaching sets comprising representative recordings and subsequent interpretations of these recordings. All the requirements listed in the previous paragraph must be met.

E. Maintaining Competence in the Interpretation of AECGs

Maintaining competence in ambulatory electrocardiography requires a continual updating of technological knowledge and an ongoing accrual of experience in the interpretation of AECGs. If interpretations are made only occasionally, arrhythmia may be missed or inappropriately diagnosed, particularly when there is a change in the recording system, analysis system, or technical personnel in the laboratory performing the AECG. This Task Force recommends a minimum of 25 interpretations a year to maintain competence.

Currently, there are no formal data to document a correlation between the frequency of AECG interpretation and practitioner competence. Continuing competence as a part of quality assurance programs may be assessed by reviewing a random sample of AECG interpretations performed by the physician requesting continuing privileges. This sample should be examined by an acknowledged expert in ambulatory electrocardiography or one who is currently training physicians in the interpretation of AECGs. If no one within an individual institution is qualified to review a candidate's experience and cognitive skills, a qualified outside expert should be consulted.

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