JACC Vol. 25, No. 1
January 1995:1–34

Task Force 2: Training in Electrocardiography, Ambulatory Electrocardiography and Exercise Testing

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Electrocardiography

Importance

Electrocardiography is the most commonly used diagnostic test in cardiology. Properly interpreted, it contributes significantly to the diagnosis and management of patients with cardiac disorders. Importantly, it is essential to the diagnosis of cardiac arrhythmias and the acute myocardial ischemic syndromes. These two conditions account for the majority of cardiac catastrophes. It is appropriately used as a screening test in many circumstances.

Goal of Training

Although every physician should have some basic knowledge of electrocardiography, and the general internist should have a more advanced knowledge, the subspecialist in cardiology should be familiar with nearly all clinically encountered patterns and arrhythmias. The trainee should understand their clinical implications and, equally important, their sensitivity and specificity. The trainee should easily identify normal variants. The trainee should have sufficient basic knowledge to understand the physiologic mechanisms for arrhythmias and electrocardiographic (ECG) waveforms rather than simply recognize patterns. Recognizing and understanding the basis for the items included in the Appendix of this task force report are minimal requirements for each trainee.

Training

An essential feature of training is to interpret a large number of ECGs and to review all interpretations with experienced faculty. A suggested minimal number of ECGs would encompass 3,500 over 24 to 36 months. This may be optimally accomplished by one or more training periods assigned specifically for interpretation of ECGs or may be an experience provided in a continuing manner. The experience should include clinical correlation in patients in intensive care units, emergency rooms and pacemaker clinics. The ECG should be integrated with the clinical problem. Formal courses and correlative conferences in electrocardiography are strongly desirable. In addition, the guidelines for the role of electrocardiography in clinical practice should be thoroughly understood, reviewed and followed (1).

In-Training Evaluation

Knowledge of electrocardiography and electrophysiologic studies should be reviewed so that the trainee becomes familiar with the indications for such studies. Similarly, the trainee should be familiar with the principles of intracardiac electrophysiologic studies, their indications, contraindications, sensitivity and specificity (see Task Force 6). The trainee should be evaluated on an ongoing basis by the responsible faculty. Because of variability in training in electrocardiography, to document the trainee's proficiency, an in-training examination in electrocardiography should be used and implemented by each training program. A standardized proficiency test in electrocardiography is currently available as the American College of Cardiology ECG Proficiency Test (ACCEPT) for individual assessment. In 1995, the American College of Cardiology Self-Assessment Program will contain a self-assessment examination in electrocardiography. Both examinations are being implemented on a national basis and should be quite useful in identifying knowledge areas of specific weakness as well as levels of proficiency.

Ambulatory ECG Monitoring

Importance

Observation and documentation of cardiac rhythm during daily activities and the relation of the rhythm disturbances to patient symptoms may be important factors for clinical decision making. Major indications for ambulatory ECG monitoring include the following: detection of or ruling out rhythm disturbances as a cause of symptoms; detection and assessment of arrhythmias believed to be associated with an increased risk for cardiovascular events; the accurate interpretation of ambulatory ST-T wave changes occurring throughout a diurnal time period; assessment of efficacy of antiarrhythmic and anti-ischemic therapy; and investigation of the effects of new therapeutic modalities (e.g., implantable cardioverter-defibrillator devices).

Goal of the Training

The technology is not perfect, and multiple methods of recording and analysis are currently in use. The trainee should understand the differences between continuous and intermittent recordings and the advantages and disadvantages of each. He or she should have a basic knowledge of the various methods utilized for arrhythmia and ST segment detection, classification and analysis. The trainee should understand the potential pitfalls inherent in each method. In addition, the trainee should have current knowledge about what may represent a "normal" finding for various age groups during sleeping and waking hours and what should be considered "abnormal," realizing that the clinical significance of some findings on ambulatory monitoring is still unresolved.

Structure of the Training

The trainee should participate in interpretation sessions with a staff cardiologist knowledgeable in the indications for the test, the techniques of recording and the clinical significance and correlations of findings. Although it is difficult to define a definite number of ambulatory ECG tests to interpret at level 1, this should be a minimum of 75 recordings over 24 to 36 months. Ideally, the trainee should be exposed to both full disclosure (complete printout) as well as computer-assisted systems so that the advantages, disadvantages and cost of each may be understood. In addition, transtelephonic and event recorder devices are increasingly utilized adjunctly for prolonged ambulatory electrocardiography. Knowledge of their indications and limitations must also be provided. This latter knowledge is optimally gained from a minimum of 1 month of training in ambulatory electrocardiography that permits interaction of the trainee with an experienced cardiovascular technician and ambulatory ECG instrumentation and review of interpreted records with the attending cardiologist with specific expertise in ambulatory electrocardiography. Such training will provide knowledge to satisfy clinical competence in ambulatory electrocardiography as indicated by the ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology (2).

Level 2 trainees will interpret a minimum of an additional 75 recordings over 12 months (total 150 recordings/36 months). Such recordings should include all forms of artifact, pacemaker studies, implantable cardioverter-defibrillator devices, heart rate variability studies, repolarization abnormalities (e.g., QT, T wave alternans) and applications of the signal-averaged ECG. Such trainees will demonstrate knowledge of the operation and limitations of a variety of ambulatory ECG instrumentation. Additional ECG interpretation of in-hospital telemetry ECGs is required. This may range from 6 to 8 s of real-time printout strips to 72 h of full-disclosure data. Such ECG data often augments standard and ambulatory electrocardiography. Trainees will be experienced in the interpretation and limitations of telemetry data. Interpretive knowledge at this level supports the objectives of level 2 training in electrophysiology, pacing and arrhythmia management (see Task Force 6).

In-Training Evaluation

Because of the large number of different rhythm patterns seen during routine clinical ambulatory ECG recordings and the many technologic approaches, it may not be possible to assess adequately a trainee's expertise in ambulatory electrocardiography by a uniform, written examination. Thus, the trainee must be given the responsibility for initial interpretation of all phases of the ambulatory ECG study. The trainee provides a detailed interpretation and reviews it with the attending cardiologist responsible and experienced in ambulatory electrocardiography. This attending cardiologist is responsible for the evaluation and documentation of a trainee's progress and skills.

Evolving New Applications

Long-term ambulatory electrocardiography continues to evolve with regard to QT measurements, heart rate variability and the signal-averaged ECG. These measurements provide insight into ventricular repolarization changes, the autonomic nervous system (sympathetic and parasympathetic) and examination of the amplified high resolution ECG over extended periods of ambulatory electrocardiography. Trainees should be cognizant of these developments and follow their clinical application and evolution.

Exercise Testing

Importance

Exercise testing with ECG monitoring and recording is recognized as a valuable clinical procedure for assessing patients with various types of cardiac disease. The procedure is most often used in the diagnosis of patients with suspected coronary heart disease or in the evaluation of functional status and prognosis of patients with known disease. The exercise ECG also plays a role in the evaluation of selected patients with cardiac arrhythmias, cardiomyopathy and valvular heart disease.

Goal of the Training

The trainee should become proficient at performing both heart-rate limited and maximal or near-maximal treadmill exercise tests and should have the opportunity to learn alternative exercise testing techniques. The training program should provide the opportunity for the trainee to become knowledgeable in exercise physiology and pathophysiology. The trainee should also be taught the basic essentials of exercise testing, such as skin preparation, electrode selection and application, choice of exercise testing protocols, blood pressure monitoring during exercise and monitoring of the patient for adverse signs or symptoms. The trainee should become proficient in data interpretation, written reports and, importantly, in the diagnostic and prognostic importance or sensitivity and specificity of the procedure in different clinical settings. Such training will provide knowledge to satisfy clinical

competence in exercise testing, as indicated by the ACP/ACC/AHA Task Force on Clinical Privileges in Cardiology (3).

Structure of Training and In-Training Evaluation

The training of a fellow in cardiology should include at least 1 or 2 months, or the equivalent, of active participation in a fully equipped exercise testing laboratory during which time he or she should perform a minimum of 50 exercise tests reviewed by faculty over 24 to 36 months. Level 1 trainees will gain proficiency in the standard exercise test and interpretation (minimal experience 100 tests) to include pharmacologic testing (dipyridamole, adenosine, dobutamine), whereas level 2 trainees (additional 50 tests) will become experienced in advanced forms of exercise testing, which includes arrhythmia management, pulmonary function testing, echocardiographic techniques and nuclear cardiology (see Task Forces 4 and 5).

The laboratory should be performing, on a regular basis, exercise tests involving a broad spectrum of both inpatients and outpatients with a variety of cardiac disorders. The training program should be structured so that the trainee is guided in the laboratory by a specially trained exercise professional until the trainee has become proficient at conducting and monitoring exercise tests under a variety of clinical circumstances. Thus, the trainee must be given the responsibility for initial interpretation of all phases of the exercise study, providing a detailed interpretation and review of it with the attending cardiologist responsible and experienced in exercise testing. The faculty physician should assess and document on a regular basis the trainee's progress, including technical performance and ability to interpret the results.

Appendix

Electrocardiographic Items

Anatomy and Electrophysiology

1. Anatomy of the specialized conducting system (sinoatrial node, atrioventricular [AV] node, His bundle, bundle branches)
2. Spread of excitation in the ventricles
3. Difference between unipolar and bipolar leads
4. Einthoven triangle; frontal and horizontal lead reference system
5. Vectorial concepts
6. Significance of a positive and negative deflection in relation to lead axis
7. Relation between electrical and mechanical activity

Technique and the Normal ECG

8. Effect of improper electrode placement (limb and precordial)
9. Effect of muscle tremor
10. Effect of poor frequency response of the equipment
11. Effect of uneven paper transport
12. Measurement of PR, QRS, QT, normal values
13. Normal ranges of axis in the frontal plane
14. Effect of age, weight and body build on the axis in the frontal plane
15. Normal QRS/T angle
16. Differential diagnosis of normal ST-T, T wave variants (e.g., "juvenile" pattern and early repolarization syndrome)

Arrhythmias: General Concepts

17. Reentry, automaticity, triggered activity
18. Aberration (various mechanisms)
19. Capture and fusion complexes
20. Escape (passive, accelerated) complexes or rhythms: atrial, junctional and ventricular
21. Interpolated premature beat
22. Parasystole (atrial, junctional, ventricular), modulated parasystole
23. Vulnerability
24. Exit block
25. Reciprocation
26. Concealed conduction
27. Supernormality

Arrhythmias: Recognition

Sinoatrial Rhythm

28. Sinus tachycardia
29. Sinus bradycardia
30. Sinus arrhythmia
31. Sinoatrial arrest
32. Sinoatrial block

Atrial Rhythms

33. Atrial premature complexes (conducted, nonconducted)
34. Atrial tachycardia (ectopic)
35. Atrial tachycardia with AV block
36. Atrial fibrillation
37. Atrial flutter
38. Multifocal atrial tachycardia
39. Wandering atrial pacemaker—multifocal atrial rhythm

Atrioventricular Node (Junctional)

40. Premature junctional complexes
41. Atrioventricular node reentrant tachycardia (common and uncommon type)
42. Nonparoxysmal junctional tachycardia—accelerated junctional rhythm
43. Atrioventricular reentrant or circus movement tachycardia with an accessory pathway (fast and slow)
44. Escape complex or escape rhythm

Ventricular

45. Ventricular ectopic complexes
46. Accelerated idioventricular rhythm
47. Ventricular tachycardia: uniform (monomorphic), multiform (pleomorphic or polymorphic), sustained, nonsustained, bidirectional and torsade de pointes
48. Ventricular flutter, ventricular fibrillation
49. Ventriculoatrial conduction
50. Ventricular escape or idioventricular rhythm

Atrioventricular Dissociation Due to

51. Slowing of dominant pacemaker
52. Acceleration of subsidiary pacemaker
53. Above with depression of AV conduction
54. Third-degree AV block
55. Isorhythmic AV dissociation

Atrioventricular block

56. First degree

57. Second degree; 2:1, Mobitz type I (Wenckebach), Mobitz type II, high degree AV block
58. Third-degree AV block (complete)
59. Significance of wide versus normal QRS complex

Waveform Abnormality

Abnormalities of Repolarization (concept of primary and secondary ST-T wave change); Abnormalities of U Wave; Ventricular Hypertrophy

60. Left ventricular hypertrophy: criteria for left ventricular hypertrophy; specificity and sensitivity of criteria
61. Right ventricular hypertrophy: criteria for right ventricular hypertrophy; sensitivity and specificity of the criteria
62. Biventricular hypertrophy
63. Electrical alternans

Atrial Abnormalities

64. Criteria for left atrial abnormality
65. Criteria for right atrial abnormality
66. Biatrial abnormality
67. Clinical significance of atrial abnormalities

Intraventricular Conduction Disturbances

68. Anatomic and electrophysiologic basis for intraventricular conduction defects
69. Criteria for incomplete and complete left bundle branch block
70. Criteria for the diagnosis of incomplete and complete right bundle branch block
71. Criteria for left anterior and posterior fascicular blocks
72. Concept of combined bundle and fascicular blocks
73. Indeterminate intraventricular conduction defects
74. Diagnosis and classification of pre-excitation syndromes (e.g., Wolff-Parkinson-White syndrome)

Myocardial Ischemia and Infarction

75. Transient ischemia and injury
76. Normal and abnormal Q waves
77. Noninfarction Q waves
78. Differential diagnosis of tall R wave in right precordial leads
79. Theoretic basis of the ECG changes in acute myocardial infarction (Q, ST-T waves)
80. Time course of ST segment changes in acute myocardial infarction
81. Diagnosis of myocardial infarction (without Q waves)
82. ST segment changes in conditions other than myocardial infarction
83. Localization of myocardial infarction
84. QRS residuals of old myocardial infarction
85. Reliability of QRS and ST segment changes of myocardial infarction in previously abnormal ECG: intraventricular conduction defects; ventricular hypertrophy
86. Overall assessment of serial ECGs as to the probability of acute myocardial infarction

Pacemaker

87. Fixed-rate pacemaker
88. Atrial pacing
89. Ventricular demand pacing
90. Atrial triggered ventricular paced
91. Atrioventricular dual pacing
92. Malfunctioning: demand acting as fixed rate; failure to sense; slowing of rate; acceleration of rate; failure to capture; failure to pace (inappropriate inhibition)

Exercise ECG Test

93. Criteria for a positive response
94. Significance of an abnormal baseline ECG
95. Significance of heart rate and blood pressure response (normal and abnormal)
96. Sensitivity: false negative (incidence and principal causes)
97. Specificity: false positive (incidence and principal causes)
98. Significance of magnitude of ST segment changes

Clinical Diagnoses (selected)

99. Hyperkalemia
100. Hypokalemia
101. Hypercalcemia
102. Hypocalcemia
103. Long QT syndromes (congenital and acquired)
104. Atrial septal defect, secundum
105. Atrial septal defect, primum
106. Dextrocardia
107. Mitral stenosis
108. Chronic obstructive pulmonary disease
109. Acute cor pulmonale
110. Pericardial effusion
111. Acute pericarditis
112. Hypertrophic cardiomyopathy
113. Central nervous system disorder
114. Myxedema
115. Hypothermia
116. Sick sinus syndrome
117. Digitalis effect or toxicity
118. Effects of other drugs (e.g., tricyclic, antiarrhythmic agents)
119. Possible proarrhythmic effects

References

1. ACC/AHA Task Force Report. Guidelines for electrocardiography. J Am Coll Cardiol 1992;19:473–81.
2. ACP/ACC/AHA Task Force Statement. Clinical competence in ambulatory electrocardiography. J Am Coll Cardiol 1993;22:331–5.
3. ACP/ACC/AHA Task Force Statement. Clinical competence in exercise testing. J Am Coll Cardiol 1990;16:1061–5.