Training and Competency Evaluation for Interpretation of 12-Lead Electrocardiograms: Recommendations from the American College of Physicians*

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This paper is part 1 of a 2-part series on interpretation of 12-lead resting electrocardiograms (ECGs). Part 1 is a position paper that presents recommendations for initial competency, competency assessment, and maintenance of competency on ECG interpretation, as well as recommendations for the role of computer-assisted ECG interpretation. Part 2 is a systematic review of detailed supporting evidence for the recommendations.

Despite several earlier consensus-based recommendations on ECG interpretation, substantive evidence on the training needed to obtain and maintain ECG interpretation skills is not available. Some studies show that noncardiologist physicians have more ECG interpretation errors than do cardiologists, but the rate of adverse patient outcomes from ECG interpretation errors is low. Computers may decrease the time needed to interpret ECGs and can reduce ECG interpretation errors. However, they have shown less accuracy than physician interpreters and must be relied on only as an adjunct interpretation tool for a trained provider.

Interpretation of ECGs varies greatly, even among expert electrocardiographers. Noncardiologists seem to be more influenced by patient history in interpreting ECGs than are cardiologists. Cardiologists also perform better than other specialists on standardized ECG examinations when minimal patient history is provided. Pending more definitive research, residency training in internal medicine with Advanced Cardiac Life Support instruction should continue to be sufficient for bedside interpretation of resting 12-lead ECGs in routine and emergency situations. Additional experience or training in ECG interpretation when the patient's clinical condition is unknown may be useful but requires further study.

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This guideline from the American College of Physicians presents supporting evidence and makes specific recommendations on training, initial competency evaluation, and maintenance of competency for interpretation of the 12-lead resting electrocardiogram (ECG). The scope of the guideline does not include intermittent or continuous ambulatory ECG interpretation or a comprehensive discussion of the indications for 12-lead electrocardiography. The accompanying systematic review in this issue, titled "Competency in Interpretation of 12-Lead Electrocardiograms: A Summary and Appraisal of Published Evidence," provides supporting evidence for the recommendations contained in this summary (1).

Other organizations have provided consensus-based guidance on ECG interpretation. The Accreditation Council for Graduate Medical Education Residency Review Committee for Internal Medicine issued guidelines stating that residents should be given an opportunity to develop competency in interpretation of ECGs but did not specify how to achieve this goal (2). The American Board of Internal Medicine does not require a minimum number of supervised ECG interpretations to take the internal medicine board certification examination (3). The American College of Cardiology (ACC) and American Heart Association (AHA) published consensus-based guidelines for attaining, testing, and maintaining competency in ECG interpretation. A 2001 statement by the ACC/AHA recommended interpretation of 500 ECGs under supervision to attain initial competency (4). A 1995 edition of the same guideline recommended 800 interpretations (5). The 2001 ACC/AHA statement also recommended confirming a physician's knowledge in ECG interpretation by using a valid and reliable certification examination dedicated exclusively to this subject. To maintain competency in ECG interpretation, the ACC/AHA statement advised the reading of 100 ECGs yearly.

Like many diagnostic tests, proficiency in ECG interpretation requires a combination of knowledge, skill, and practical clinical experience. Knowledge of the pathophysiology of electrocardiographic abnormalities, skill in recognizing common abnormal ECG patterns, and experience in relating the result of the ECG to a patient's clinical situation are all components of successful interpretation. We provide a practical outline, anchored in evidence-based literature when possible, for obtaining and maintaining ECG interpretation skills.

Physician Skill and Medical Errors in 12-Lead ECG Interpretation

Recommendation 1: Studies that incorporate clinical outcomes, interobserver variability measures, and sensitivity and specificity data for separate, clinically important ECG diag-

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noses are needed to identify differences in interpretation skill between primary care physicians, specialists, and trainees.

Several features of the current literature on ECG interpretation make valid conclusions difficult. Typically, noncardiologists or trainees are compared to an expert electrocardiographer "gold standard." The proportion of abnormal diagnoses correctly identified is then reported. The clinical significance of the differences between cardiologists and noncardiologists is uncertain because intra-interpreter reliability varies, even among cardiologists (6, 7). As many trials test comprehensive detection of ECG abnormalities, the sensitivity of physicians' detection of any given disorder is often uncertain. Specificity and the implications of false-positive interpretations are infrequently reported.

Despite these limitations, the literature comparing cardiologists with noncardiologist physicians has several trends. Studies examining comprehensive ECG analysis show that, although major interpretation errors are common (4% to 33%), adverse patient outcomes resulting from these errors are rare, typically occurring in less than 1% of interpretations (1).

COMPUTER INTERPRETATION OF 12-LEAD ECG INTERPRETATION

Recommendation 2: Computer analyses of ECGs are useful adjuncts to ECG interpretation. As errors in computer interpretation are still common, computers should not replace a qualified physician in making patient management decisions.

Computer interpretation of ECGs is a common feature of many ECG acquisition devices. Automated ECG analysis may be a useful adjunct to physician interpretation by decreasing the time needed to interpret ECGs and modestly reducing medical errors (7–9). However, comparisons of the accuracy of computer ECG analysis with that of expert electrocardiographers show that only 0% to 94% of disorders are classified correctly; arrhythmias are the most problematic diagnosis (6, 7, 10, 11). Therefore, computer ECG analysis should be considered a helpful adjunct to, but not a substitute for, physician interpretation in clinical decision making.

ATTAINING COMPETENCY IN INTERPRETATION OF 12-LEAD ECGS

Recommendation 3: Training in ECG interpretation during residency should provide physicians with knowledge of the pathophysiology of electrocardiographic abnormalities; the skills to recognize common normal, abnormal, and technical artifact patterns; and the opportunity to apply this knowledge in bedside clinical decision making. Determination of initial competency in ECG interpretation at the end of residency training should be based on periodic objective assessment and documentation of resident interpretation skills in a clinical context rather than completion of a minimum number of interpretations.

Physicians must have sufficient knowledge to understand and accurately recognize the basic pathophysiology of electrocardiographic abnormalities. Electrocardiographers must also understand the process of ECG acquisition to determine whether an artifact is present and to judge whether the overall quality of the ECG is adequate for interpretation. The electrocardiographer must understand the sensitivity and specificity of the ECG for diagnosing common and high-risk clinical disorders. A list of electrocardiographic diagnoses has been prepared by the Institute for Clinical Evaluation (**Appendix Table**, available at www.annals.org). To maintain competency in ECG interpretation, the Institute recommends that a physician should have the ability to make these diagnoses and tests for this ability on a standardized examination (the ECGEXAM).

No evidence-based data are available and expert recommendations vary greatly on how many ECG interpretations, under the supervision of an expert electrocardiographer, are needed to obtain initial ECG competency (4, 5, 12). The Accreditation Council for Graduate Medical Education advises that the ideal results of a competency-based assessment should allow sound inferences about what learners know, believe, and can do in defined contexts. Given the lack of evidence-based literature, we believe that the number of ECGs required to achieve initial competency in ECG interpretation should be based on objective assessment and periodic documentation of resident ECG interpretation skills in a clinical context rather than completion of a minimum number of interpretations. Residents should obtain experience in ECG interpretation at the bedside in both ambulatory and inpatient settings. Specialty rotations incorporating ECG self-study texts and ECG interpretation under the supervision of an expert electrocardiographer may also prove useful for refining interpretation skills.

TESTING COMPETENCY IN INTERPRETATION OF 12-LEAD ECGS

Recommendation 4: Until further data are available on the relationship of standardized testing in ECG interpretation to clinical outcomes, internal medicine residency completion, Advanced Cardiac Life Support (ACLS) training, and board certification should demonstrate basic competency to interpret resting 12-lead ECGs at the bedside in routine and emergency situations.

Formal measurement of ECG interpretation may be obtained by several methods. Certifying boards of the American Board of Medical Specialties testing of residency-trained internists, family physicians, and emergency medicine physicians includes questions on ECG interpretation as part of the board certification process. Advanced Cardiac Life Support programs sponsored by the AHA also provide supplemental instruction and testing on abnormal cardiac

rhythm recognition in emergency settings. Successful completion of residency, board certification, and Advanced Cardiac Life Support training are one reasonable method of objective documentation that a physician is competent to interpret bedside ECGs in routine and emergency settings, pending additional outcomes-based research.

Interpretation of 12-Lead ECGs when Clinical History Is Unknown

Recommendation 5: Evidence is lacking for competency in interpreting ECGs in situations where the physician is not familiar with the clinical status or context of the patient. Pending evidence from future research, clinical privileges in interpreting ECGs in these situations may reasonably be based on one or both of the following: 1) experience or 2) study/preparation for and passing a valid and reliable examination.

The skill of noncardiologist physicians in interpreting ECGs of patients not under their care remains uncertain. Research has suggested that noncardiologists are more affected by the context of the patient's clinical history and the automated computer interpretation than are cardiologists when interpreting an ECG (8, 13, 14). Cardiologists also demonstrate greater accuracy than noncardiologists in ECG interpretation during standardized examinations of ECG interpretation when minimal history is given (15). Most questions on board certification testing and Advanced Cardiac Life Support training use ECG tracings in combination with clinical vignettes. Therefore, to interpret ECGs when the clinical milieu of the patient is unknown, documentation of proficiency in addition to residency training, board certification, and Advanced Cardiac Life Support training may be desirable. This proficiency may be based on experience or standardized testing.

Maintenance of Competency in Interpretation of 12-Lead ECGs

Recommendation 6: Continuing medical education through seminars or self-assessment programs is encouraged to keep ECG interpretation skills current in settings where physicians read ECGs infrequently. There are insufficient data to recommend a yearly minimum number of ECG interpretations or continuing medical education hours to maintain competency.

No trials have measured how ECG interpretation skills change over time after initial residency or fellowship training. Therefore, the effect of continuing medical education and yearly volume of ECGs interpretations on competency or outcomes is uncertain. During internal medicine training, higher confidence levels were reported for procedures done more frequently, such as paracentesis, than for procedures done less often, such as graded electrocardiographic testing (16). Some literature on invasive procedures suggests improved patient outcomes with more procedures (17). Uncontrolled studies of medical student and resident instruction in ECG interpretation demonstrate improved short-term performance on nonvalidated ECG examinations (18–20). Until further data linking ECG interpretation volume with interpretation accuracy and patient outcomes are available, physicians who infrequently interpret ECGs should consider periodic self-study or continuing medical education to ensure that their skills remain current. Many academic commercial resources are available for self-assessment and continuing education in electrocardiography, including quality improvement programs with ECG overreading and feedback by expert electrocardiographers, self-paced interactive computer modules, workshops at the American College of Physicians Annual Session, ACC electrocardiography self-assessment programs, and seminars on ECG interpretation that have been approved for continuing medical education credit.

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Drs. Alguire and Salerno dedicate this article to Herbert Waxman, MD, a friend and colleague whose vision, leadership, and friendship will be missed. Dr. Waxman, who served as Senior Vice President for Medical Knowledge and Education at the American College of Physicians, died on 15 February 2003.

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Appendix Table. **Common Diagnoses for Which Electrocardiography May Be Useful***

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

Atrioventricular 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 (< 0.5 mV total QRS amplitude in each extremity lead and < 1.0 mV in each precordial lead)

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. Septal MI (old or age indeterminate)
67. Anterior MI (acute or recent)
68. Anterior MI (old or age indeterminate)
69. Lateral MI (acute or recent)
70. Lateral MI (old or age indeterminate)
71. Right ventricular infarction (acute)

Clinical Disorders
72. Chronic pulmonary disease pattern
73. Acute pericarditis
74. Suggests hypokalemia
75. Suggests hyperkalemia
76. Suggests hypocalcemia
77. Suggests hypercalcemia
78. Suggests CNS disease

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

* AV = atrioventricular; CNS = central nervous system; ECG = electrocardiogram; MI = myocardial ischemia. These diagnoses represent the 88-option electrocardiogram interpretation list from the Institute for Clinical Evaluations ECGEXAM. Reproduced with permission from the Institute for Clinical Evaluation.