Special Report

Instrumentation and Practice Standards for Electrocardiographic Monitoring in Special Care Units

A Report for Health Professionals by a Task Force of the Council on Clinical Cardiology, American Heart Association

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The proposed recommendations for continuous electrocardiographic monitoring systems represent goals for future development. Description of a technique in the report does not constitute an endorsement of its clinical use. Lead systems for ECG monitoring must adequately sense the cardiac electrical field and the leads should be standardized. Future monitors should be capable of simultaneously displaying and analyzing multiple leads. Recommendations for electrode placement and position of patient are made. Important parameters in each category of standards for instrumentation published in 1983 in the American National Standard for Cardiac Monitors, Heart Rate Meters, and Alarms are listed. Selected procedures proposed by the Association for the Advancement of Medical Instrumentation to inform users of minimally acceptable accuracy of computerized systems in a standardized manner are presented. Emphasis is placed on the importance of nursing and medical staff capabilities. Personnel qualifications and training as well as systems to assure and maintain quality of immediate ECG diagnosis are highlighted. (Circulation 1989;79:464–471)

Continuous electrocardiographic monitoring is a cornerstone of care in special care units.* The significant reduction in mortality after acute myocardial infarction that has resulted from widespread development of coronary care units is, in large measure, a consequence of prevention, early detection, and treatment of life-threatening arrhythmias.

The goals of ECG monitoring have become more ambitious in recent years. Computerized systems that detect and diagnose arrhythmias have begun to augment or supplant continuous visual observation of the electrocardiogram. At the same time, clinical requirements have evolved from simple heart rate monitoring to arrhythmia detection and diagnosis, and, most recently, detection of ST segment changes that suggest myocardial ischemia. Monitors performing these expanded functions rely on hardware and software designs that differ significantly from earlier systems. Increased reliance on these new systems makes it imperative to verify the high accuracy expected of them.

Specific guidelines for ECG monitors are required, even though much of the technology is similar to other forms of ECG measurement. The clinical environment, including severity and acuteness of illness and immediacy of treatment, places added demands on the monitoring systems. Limited time for overreading and editing, and initiation of urgent therapy by nonphysicians mandate more critical evaluation of automated arrhythmia detection and diagnostic systems than that needed for less urgent, chronic conditions. In addition, their use in patients who may have intravascular catheters and who may

*Throughout this report, “special care units” refers to coronary care units, intensive care units, telemetry units, surgical suites, emergency rooms, and all other areas in which ECG monitoring functions are performed.

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be dependent on other electrical devices increases concerns about safety and noise suppression.

Thus, it is appropriate that the American Heart Association (AHA) proposes recommendations for continuous ECG monitoring systems. As in previous cases of routine electrocardiography and ambulatory ECG monitoring, the proposed guidelines are considered both clinically important and technologically feasible. In many cases, they are goals for future development rather than rules governing current equipment use or manufacture. The components considered in this report may not all be necessary or appropriate in all monitoring environments. It is not the report’s intent to require that all systems include all components and all features discussed; for example, selected monitoring units may neither wish nor need computerized waveform analysis. The report does, however, define minimal requirements for systems that include such elements and that purport to provide such functions.

This report does not endorse the clinical value of any technique described. The value of any device or procedure must be determined by research, followed by evaluation of each clinical situation.

**Lead Systems**

Lead systems for ECG monitoring must adequately sense the cardiac electrical field for accurate rhythm and waveform analyses. In addition, the leads should be standardized to permit comparisons of recorded waveforms from one time to another, from one patient to another, and from one monitoring facility to another.

Current practice generally relies on one ECG lead for continuous monitoring and rhythm analysis. Although the clinician may choose among several leads, only one is usually displayed and processed. This is most commonly an anterior chest lead, approximating lead V1.

This task force recommends that future monitors should be capable of simultaneously displaying and analyzing at least two and preferably three or more leads. When used for rhythm analysis, multilead monitoring will permit evaluation of the same PQRS cycle in multiple projections, facilitating detection of P waves, assessment of QRS changes resulting from body position shifts, detection of QT axis shifts due to conduction defects, distinction between ventricular tachycardia and supraventricular aberrant complexes, and identification of episodes of ventricular tachycardia with clinically important differing ECG features, such as polymorphous or torsade de pointes types. Multiple leads may also permit more precise detection and localization of ST segment shifts due to ischemia or injury by viewing the ST segment along multiple lead axes. Recording from multiple leads also provides redundancy, reducing data loss from single-channel malfunction.

The task force is aware that this recommendation for simultaneous, multilead monitoring is a departure from current practice, although certain manufacturers have begun to market such multilead systems. The task force suggests, however, that ongoing efforts to develop these systems are clinically warranted and technologically feasible, although an added expense. As stated previously, this recommendation, like others in this report, should not be considered a rule for current operations but a goal for future implementation. In all cases, the number and configuration of monitoring leads should be determined by clinical need.

Further investigations are needed to answer questions about multiple lead monitoring. For example, the advantage of any one lead set for analysis of arrhythmias and detection of ST segment shifts has not been shown. Simultaneous monitoring of three leads in roughly orthogonal planes might provide comprehensive surveillance and permit vector analysis of waveforms to improve diagnostic accuracy. Such a system might include lead V1 or V2 in the anterior–posterior axis, lead V3 in the right–left axis, and lead aVF in the inferior–superior axis as suggested by studies of ischemia and injury during coronary angioplasty and acute myocardial infarction. A posterior or right anterior unipolar lead, as suggested by body surface potential mapping studies, may also be prudent for more comprehensive waveform analysis.

Electrode lead positions should be standardized. A feasible approach is similar to that proposed by Mason and Likar for exercise electrocardiography. Four limb electrodes may be placed in third and seventh intercostal spaces at the right and left midclavicular lines to register modified unipolar and augmented bipolar limb leads and to derive a modified Wilson central terminal voltage. Precordial leads should be placed in the standard left precordial locations for registering modified precordial leads.

Two specific topics should also be addressed. First, patient electrodes should be selected for maximum adhesiveness and minimum discomfort, without electrical noise, skin-electrode impedance, or polarization. The technical standards for electrodes published by the American Association for the Advancement of Medical Instrumentation (AAMI) should be followed. The recommended steps for electrode placement are:

1. Remove hair from electrode sites with scissors and shaver. Skin irritation and bony irregularities should be avoided.
2. Clean the electrode sites with gauze soaked in alcohol to remove substances that increase impedance or decrease adhesiveness. To further reduce impedance, mildly abrade only the electrode contact sites with a 1-in. square of ultrafine sandpaper. Despite the purported mildness of commercial electrode gels, only mild superficial abrasion is suggested.
3. Apply electrodes and electrode wires. Impedance of each electrode pair should be quanti-
fied with an appropriate device* to assure adequacy of skin preparation and to verify functioning of the electrode/electrode wire sub-

system. Measured impedance should be less than 5,000 Ω, and preferably less than 3,500 Ω.

Second, attention must be given to the patient’s position during monitoring. In some patients, changing from a prone to a sitting or standing position can alter ECG waveforms significantly.9 The effects of any expected changes in position should be explicitly examined. It may be necessary in some patients to periodically return the patient to a standard position to record surveillance strips.

Instrumentation

In 1983, AAMI published the American National Standard for Cardiac Monitors, Heart Rate Meters, and Alarms.10 The objective was to provide minimum labeling, performance, and safety requirements to help assure a reasonable level of clinical efficacy and patient safety in use of cardiac monitors. With the few exceptions noted below, performance and disclosure requirements in that standard remain appropriate. In one section, the standard defines performance requirements, specifying a minimum, a maximum, or a range of values, as applicable, that must be met. A separate section lists several performance parameters without specifying actual values; the requirement is for disclosure of the achieved value to the consumer in a standardized manner. For example, a minimum heart rate meter accuracy with irregular rhythms is not specified, but accuracy for several types of defined ECG complexes must be disclosed. Designation of specifications as either performance requirements or disclosures is appropriate. Below is a partial listing of important parameters in each category. The reader is referred to the standard10 for further details, including test procedures and rationale.

Performance Requirements

Performance requirements include but are not necessarily limited to:

- Protection from overload: Protection should be adequate (no damage) for 1 V (peak to peak), 60 Hz, applied for 10 seconds to any electrode connection. The device should recover within 8 seconds after a defibrillation shock of at least 5,000 V, with a delivered energy of at least 360 J.

- Isolated patient connection: The system should include isolated patient connections to meet standards defined in American National Standard for Safe Current Limits for Electromedical Apparatus.11

- QRS detection: Monitors should detect QRS complexes with amplitudes of 0.5–5.0 mV, slopes of 6–300 mV/sec, and durations of 70–140 msec* for adult use or 40–120 msec for pediatric use. The system should not respond to signals with an amplitude of 0.15 mV or less, or a duration of 10 msec or less.

- Accuracy of heart rate meter: The rate meter should be accurate to within the lesser of ±10% or ±5 beats/min over the range of 30–200 beats/min for adult use or 30–250 beats/min for pediatric use.

- Alarm range and accuracy: Alarm rates should be accurate to within the lesser of ±10% or ±5 beats/min over the range 30–100 beats/min for the lower limit range and 100–200 beats/min (adult), or 100–250 beats/min (pediatric) for the upper limit range. Time to alarm after exceeding rate limits should not exceed 10 seconds.

- Noise tolerance: Heart rate meters should remain accurate during application of a 60 Hz signal, 100 μV peak to peak, minimum; accuracy should not be affected when a triangular wave of 4 mV at 0.1 Hz is superimposed on a train of QRS signals of 0.5 mV amplitude and 100 msec duration.

All ECG monitors must provide visual display of waveforms. Displays with a minimum of two and preferably three simultaneously recorded ECG leads should be developed. Performance standards include:

- Input dynamic range: The device should display, without saturation, differential voltages of ±5 mV at rates up to 320 mV/sec; the output signal amplitude shall not change more than ±10% over the range of DC offsets of ±300 mV applied to any lead.

- Input impedance: Single-ended input impedance should be 2.5 MΩ, minimum, at 10 Hz.

- System noise: Noise due to all sources, including manufacturer-recommended patient cables, should be less than 40 μV peak to peak.

- Overall system error: Input signals with an amplitude limited to ±5 mV and varying at a rate up to 125 mV/sec should be reproduced with an error of less than ±20% or ±100 μV, whichever is greater.

- Upper cutoff frequency: High frequency cutoff should be at least 40 Hz (−3 dB).

- Common mode rejection (CMR): To test CMR, a 60 Hz signal, with a 200 pF source capacitance and a 10 V open circuit voltage, is applied from power ground to all patient electrode connections attached to a common node and with a parallel combination of a 51 kΩ resistor and 47 nF capacitor imbalance impedance in series with each patient lead (including RL, if

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*The testing device should calculate impedance to an alternating current no greater than 10 μA at a frequency of 10 Hz and display results on a meter with a qualitative indication of adequacy or inadequacy.

*The published AAMI standard calls for an upper limit of 120 msec.
supplied). Such a signal shall not produce an output signal exceeding 1 mV (peak to peak) referred to the input over a 60-second period.

- Gain selections and accuracy: Gains of 5 and 10 mm/mV should be provided, with a total allowable gain drift of ±0.66%/min and ±10% in 1 hour.
- Pacemaker pulse indication: Unit shall visually indicate on the output display the presence of a pacemaker pulse of 0.2 mV, minimum, referred to input.
- Display during other monitoring function: At least one ECG channel should be displayed continuously at all times, including entry and editing of data and procedures such as thermidolubation cardiac output calculations.

Disclosure Requirements

Disclosure requirements include but are not necessarily limited to the following:

- Electrosurgery and diathermy protection, including disclosure if electrosurgery overload will cause damage;
- Respiration, leads-off sensing, and active noise suppression methods, including disclosure of waveform type applied directly to the patient for detection;
- T-wave rejection capability, including disclosure of maximum T-wave amplitude for which heart rate indication is within error limits specified above;
- Heart rate averaging algorithm, including disclosure of type of algorithm used and frequency of display update;
- Heart rate meter accuracy and response to irregular rhythm for specified waveforms, including disclosure of meter time to indicate a ±40 beats/min change from an initial indication of 80 beats/min;
- Time to alarm for tachycardia of specified waveforms;
- Pacemaker pulse rejection capability for specified pacemaker pulses with and without overshoots/undershoots; and
- Service procedures and facilities, including name and location of acceptable repair facilities, recommendations for test methods to verify adequate performance, and frequency of recommended preventive maintenance.

The task force notes that certain important performance parameters omitted from the standard must be addressed; others addressed in the standard are judged inadequate. These include requirements for cardioversion, detection of ST segment abnormalities, time base accuracy and stability, pacemaker pulse rejection, and strip chart recorders.

Cardioversion is typically performed with a timing pulse derived from the ECG signal. A synchronization signal should be available from the monitor to allow cardioversion during an appropriate time interval. A national standard for defibrillators now exists and in a soon-to-be-released revised version, maximum time delay from synchronization pulse input to defibrillator pulse output will be specified as 25 msec. The monitor must be capable of providing a synchronization pulse appropriate for use as an input to a cardioverter so that time interval from R wave peak to synchronization pulse output is no more than 35 msec. This will assure that time interval from R wave peak to delivery of cardioversion signal is no greater than 60 msec. Efforts to produce an industry-standard hardware and software connection for monitors and cardioverters are also encouraged to facilitate emergency care.

Monitoring of transient ST segment shifts is, as noted above, an integral component of ECG monitoring, particularly, but not exclusively, in coronary care units. Such shifts, with or without chest pain, often reflect transient myocardial ischemia that may have therapeutic and prognostic significance, although other factors may also cause transient ST shifts. The need to accurately detect such events makes the 0.5 Hz low frequency response now specified in the monitor standard inadequate as a substantial error in measurement of ST-T potentials may result. It now seems more appropriate to require the same fidelity for low frequency performance for a monitor as for a diagnostic electrocardiograph. In 1975, the AHA recommended a 0.05 Hz low frequency response. Although this response should allow accurate ST-T recording, the potential for baseline wandering exists and may become troublesome, making the monitor useless in many instances. A system with an amplitude response flat down to a few tenths of 1 Hz may, however, be adequate if linearity between phase shift and frequency is preserved. Fortunately, advances in digital signal handling now make it practical to construct amplifier systems with linear phase shift over a broad frequency range.

The following recommendations do not specifically refer to phase linearity because a system meeting recommended amplitude and impulse response criteria will be appropriate for accurate ECG reproduction regardless of phase characteristics. However, a system with these amplitude response characteristics (see below), whose phase linearity equals that of a linear 0.05 Hz single-pole system, is likely to meet impulse response recommendations.

Specific recommendations include:

- Amplitude response should be flat to within ±6% (0.5 dB) over a range of 1.0–30 Hz; the −3 dB point should be less than 0.33 Hz.
- A 1 mV/sec impulse input should not produce displacement greater than 0.3 mV after the impulse.*

*This criterion is met by the 0.05 Hz, single-pole filter.
For a 1 mV/sec impulse input, slope of response outside the region of the impulse should nowhere exceed 1 mV/sec.

Time base accuracy and stability is clinically important for monitors with displays. It seems reasonable to require that instrument-induced errors be kept below 5% for critical time interval measurements within a single cardiac cycle such as QRS width. Errors greater than this may lead to false clinical interpretations such as presence of a conduction defect or long QRS duration. On the other hand, longer time intervals such as RR or QT intervals may not require this accuracy. Specifically, it is recommended that time base accuracy allow time measurements with an error no greater than ±5% or 20 msec, whichever is less, for time intervals below 0.5 seconds, and no greater than ±5% for time intervals of 0.5 seconds or more.

Pacemaker pulse rejection guidelines currently described in the AAMI standard10 are limited to ventricular pacemakers. Changes are important to reflect characteristics of newer pacemakers and respond to use of dual chamber pacing systems. Disclosure of the rate indicator response to pacemaker pulses of ±2 to ±700 mV, and widths of 0.1–2.0 msec should be provided. Overshoot/undershoot should be within 2.5%–25% of pulse amplitude and less than 2 mV, with a time constant of 4–100 msec.

Dual chamber pacing conditions should be modeled with atrial pacing pulse preceding ventricular pulse by 150–250 msec. Amplitude and duration of atrial pulse should be the same as indicated for ventricular pulse.

Strip chart recorders connected to the ECG monitoring system must meet all standards for time base accuracy, frequency response, linearity, etc., previously proposed for other ECG recording systems.1,2 The overall monitoring system should include a sufficient number of recording devices to document simultaneous arrhythmias occurring in more than one patient. Such recorders should produce continuous output for the duration of alarm conditions.

Computer-Aided Analysis

Use of computer systems to detect, evaluate, and diagnose cardiac rhythms is now almost universally accepted in ECG monitoring systems. Therapy commonly must be initiated based on output without editing that is possible in the chronic care setting. Thus, algorithms must have a high sensitivity to detect all conditions with significant prognostic or therapeutic import and high specificity to avoid exposing patients to risks of unneeded interventions.

No standards currently define the minimally acceptable accuracy of computerized systems. It is vital, however, that users be informed of systems performance levels in a standardized manner. This permits meaningful understanding of a system's values and limitations and allows reasonable comparisons between systems.

Specific procedures to provide these data have been proposed by AAMI.14 The task force concurs with these recommendations. Selected parameters of widespread interest are presented in the discussion below. The interested reader is referred to Reference 15 for a more detailed discussion.

First, the same ECG data base must be used to test all algorithms. Comprehensively, fully documented collections of cardiac rhythms are available as standardized test material. The AHA's collection consists of 80 tapes stratified by type and density of ventricular arrhythmia; the last 30-minute period of each tape is annotated on a beat-to-beat basis.15 Another widely used collection provided by the Massachusetts Institute of Technology/Beth Israel Hospital16 consists of 48 30-minute tapes, which deliberately include noisy data and selected supraventricular arrhythmias. Other collections developed by individual, academic, or industrial concerns are neither publicly documented nor freely shared; such data bases do not fulfill open testing requirements and are not recommended.

The tape collection selected for testing must be specified. The test must also be complete, using all tapes.

There are problems, however, with these data bases, as all ECG patterns are not included. Specifically, the AHA data base includes ventricular arrhythmias only and excludes abnormalities such as supraventricular arrhythmias and atrioventricular block that are clinically important in the acute myocardial infarction setting. In addition, there is no data base for testing algorithms for detection of ST segment and other waveform abnormalities. This task force considers addition of other arrhythmias and waveform abnormalities to the data bases an important effort. Specific requirements for such data bases are presented in discussions below. Data bases for testing arrhythmia systems should not be used to evaluate ST segment analysis products. The remainder of this section focuses on currently available material, although the principles are applicable to other areas when test data become available.

These data bases are also collections of rhythms recorded primarily for evaluation of diagnostic algorithms of ambulatory ECG systems under environmental conditions and with methods that differ significantly from those used, for example, in the coronary care unit. Errors may be significant.17

Second, tests must be reproducible to permit verification of results. Results without adjustments of gain, bandwidth, or lead selection by the operator during the test must be reported and hardware specifications, including processor speed and precision, must be disclosed.

*Available through Emergency Care Research Institute, 5200 Butler Pike, Plymouth Meeting, PA 19462.
Third, test conditions must approximate clinical conditions under which the system is to operate. To do so, the following elements must be disclosed and criteria met:

- Lead systems must be disclosed. If multiple leads are used in analysis, only one set of results can be reported for all channels of the data base. If only one lead is used, it must be specified.
- The test should be performed on hardware identical to that used clinically to maximize the predictive value of the reported information. Any differences must be disclosed. Although specification of the hardware to be used is beyond the scope of this report, performance of any algorithm is dependent on factors such as processor speed. Hence, the equipment used must be described.
- If the system is designed to monitor more than one patient simultaneously, testing must use all patient inputs simultaneously. Similarly, reports must include data for each patient channel used.
- Noise levels during acquisition of test data, such as amplitudes, durations, and frequency components should be disclosed. Because noise levels in special care units will probably differ from the ambulatory ECG setting in which test data were acquired, an estimate of the effect of defined types and levels of interference (specific frequencies and amplitudes) would be helpful.18

Fourth, measurements should be relevant to the intended application. Parameters that permit assessment of probable clinical usefulness include sensitivity (i.e., the fraction of real events correctly detected) and positive predictive accuracy (i.e., the fraction of detections that are real events). Such data should be tabulated separately for total QRS complexes, total ventricular premature beats (VPBs), and each grade of consecutive VPBs (couplets, short runs [<6 consecutive VPBs], and long runs [≥6 VPBs in length]). In addition, the period in which the algorithm is not functional, that is, shutdown time, must also be specified along with the fraction of each grade of arrhythmia missed during that period.

Finally, results must be presented in a standardized, meaningful format with sufficient detail. Results of all tapes must be presented, with separately tabulated results for each tape, each grade of ectopy (normal, single ectopy, couplets, and runs), and aggregate results for all tapes. Sensitivity, positive predictive accuracy, and the number of events detected must be included for each. Acceptable single-line and more complex formats for each tape are detailed in Reference 14.

Ventricular fibrillation (VF), ST segment shift diagnosis, and trend analysis require specific and expanded attention. A monitor’s ability to alarm in the presence of VF is critically important. A wide variation in VF waveforms and antecedent ECG changes exists. While no hard data are available, 50–100 VF waveforms should be adequate to challenge the monitor’s capabilities. No amount of testing can provide 100% assurance that a monitor will respond properly to any and all VF waveforms, but the monitor’s response to this future data base will provide extremely valuable information for the user. It is equally important that the data base of VF waveforms be well documented by expert electrocardiographers and available to designers and monitor users. Collection and assembly of these records from several sources should be feasible. The following recommendations are made:

- A monitor must be capable of responding with an alarm to VF.
- A monitor’s capabilities must be challenged with a data base of 50–100 VF waveforms from different individuals in customary clinical, hospital, or ambulatory environments.
- The data base must be documented for true VF incidents by expert electrocardiographers using an agreed-upon protocol.
- The data base should preferably be recorded in digital format to be transferable with little or no loss in fidelity.
- Disclosure of the monitor’s performance shall, as a minimum, reveal time to alarm from onset of VF for each documented VF event and list all VF alarms whether associated with a documented VF event or not.
- To challenge a monitor’s rate of false-positives, the data base should ideally include ECGs with superimposed noise from the power line, electrode/skin movements, myoelectric potentials, and short-duration, high-amplitude transients that resemble fibrillatory patterns.

Computerized assessment of ST segment shifts also requires new program development. Elements to be considered include user definition or verification of automated selection of baseline, end of the QRS complex, and time during ST segment shift for offset measurement. It is also important to report ST shifts only for normal beats, not ectopic or aberrant complexes. Reporting formats and alarm schema based on longer time frames than arrhythmia analysis must also be developed; abnormalities of the ST segment evolve over tens of seconds or minutes rather than individual cardiac cycles. Finally, all elements in verifying the accuracy of algorithms detailed for arrhythmias, including collection of an annotated data base, should be applied to ST analysis systems.

Finally, the ability to display past ECG activity as trends also deserves specific comment. Two issues are relevant. First, ability to recall from memory and display segments of the ECG record corresponding to past alarms should be provided. This permits retrospective review of significant patient events as...
an aid to patient care and staff education. Information should be stored before onset and continuing for duration of an alarm and afterward. Users should also be able and encouraged to correct errors and amend trended data. Second, the time frame in which information and associated records are stored should be at least 24 hours to permit convenient review. Longer storage periods extending to or beyond the period of hospitalization and permanent archival storage of selected data are additional, although optional, aids in patient care, teaching, and research functions.

**Integrated System Use**

In the final analysis, clinical effectiveness of the ECG monitoring system, regardless of technical sophistication, rests on the capabilities of the nursing and medical staff. Although it is beyond the scope of this report to provide detailed recommendations for training, systems operations, etc., certain topics merit restatement.

**Personnel Qualifications and Training**

It is assumed that the special care unit is organized along guidelines provided by the Joint Commission on Accreditation of Healthcare Organizations. In such units, there may be different hierarchies of responsibilities for monitoring personnel because of different organizational models and complexities of monitoring equipment. For example, cardiovascular technicians or registered nurses may be responsible for monitoring, and nurses may or may not be authorized to independently initiate therapy. Because multiple models for unit operation are possible, it is important that each unit explicitly define its operational construct. In ECG monitoring, each team member’s exact responsibilities and the member or members responsible for each function should be defined.

All personnel involved in ECG monitoring should receive formal training. The training program should be reviewed by appropriate medical, nursing, and hospital supervisory staff to determine its ability to meet the needs of the hospital’s ECG monitoring personnel. Practical, hands-on training should be combined with instruction on basic principles of electrophysiology and electrocardiography, and initial training should be followed by a regular program of continuing education. Each facility should develop a formal certification method to document completion of required training.

Regardless of the system used, all personnel responsible for monitoring should possess basic skills that minimally include ability to 1) identify ECG waveform components; 2) recognize abnormalities of cardiac rate; 3) recognize changes in waveforms or rates to identify, for example, conduction delay, premature complexes, pauses, brady-cardia, wide or narrow QRS complex tachycardias, and transient ST-T wave abnormalities; 4) detect common artifacts of ECG monitoring; 5) operate ECG monitoring equipment; 6) avoid common electrical hazards; and 7) deploy the different lead systems used in ECG monitoring. Training needs beyond these will vary among facilities.

**Systems to Assure and Maintain Quality of Immediate ECG Diagnosis**

Prompt and accurate ECG diagnosis is an essential ingredient in quality of care. It is the ultimate responsibility of the unit director to assure that quality of care is maintained, although this burden is shared by all medical, nursing, technical, and administrative personnel.

Monitor alarms and computer interpretation of ECG rhythms are a first step in assuring quality and accuracy of ECG recordings. Staff should be able to respond immediately to monitor alarms and verify if the alarm indicates a potentially dangerous condition. All users must also be familiar with limitations of current computer software so that unwarranted reliance on the computerized diagnostic systems can be avoided. Concepts of sensitivity and predictive accuracy should be understood. Most importantly, availability of automated systems should not replace development and maintenance of skills in ECG interpretation of abnormal rhythms and patterns.

Personnel with documented skills in ECG interpretation should be on hand at all times to immediately interpret abnormalities. These individuals will have completed a detailed training program as outlined previously and optimally have extensive experience in rhythm monitoring. A physician should also be readily available to review ECG monitoring records and assist in rhythm and pattern interpretation. The supervising physician should be fully cognizant of the limitations of computerized ECG diagnostic systems in general and those of the specific system used.

**ECG Rhythm Interpretation**

Each unit should develop a method to review and document ECG records. As a minimum, any ECG record that shows a significant change or results in a change in therapy should be documented by a printed tracing that demonstrates the abnormality. These tracings can then be analyzed to confirm accuracy of a diagnosis. Entering the tracings directly in the patient’s permanent medical record is a matter of individual hospital policy. A regular schedule for review of ECG recordings is desirable. More sophisticated monitoring outputs such as trend analyses or event records may also be recorded at regular intervals according to individual capabilities and needs. Individual rhythm tracings should not require a formal interpretation if these procedures for ECG rhythm interpretation, documentation, and quality control are followed.

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