Clinical Usefulness of the EASI 12-Lead Continuous Electrocardiographic Monitoring System

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The 12-lead electrocardiogram (ECG) is the diagnostic reference standard for evaluating cardiac rhythm and myocardial ischemia. The traditional 12-lead ECG system requires 10 electrodes that are strategically placed on the chest and the extremities (Figure 1). This lead configuration, however, is not practical for ambulatory patients in the telemetry setting. Subsequently, over the years, we have used a tool that captures limited and partial ECG data with just 1 or 2 views of the heart. This tool consists of a portable monitor (commonly referred to as a telemetry box), and 3 or 5 leads (depending on the type of telemetry that the institution has installed). Typically, 4 leads are attached to the patient's torso (modified extremity leads), and the last lead acts as the precordial or "V" lead (Figure 2). This method has been used successfully for continuous cardiac monitoring.[1]

Telemetry monitoring was not designed, however, to obtain 12 views of the heart, but rather to derive continuous monitoring information from the 1 or 2 most commonly used ECG leads. Recent research and national guidelines on monitoring for myocardial ischemia[2-6] recommended continuous 12-lead ST-segment monitoring for at-risk patients because silent ischemia (without chest pain) is common and may not always be detected with the same leads. The busy environment of areas devoted to patients' care, coupled with the need for frequent 12-lead ECG analysis, makes using a conventional, diagnostic 12-lead ECG device an impractical approach for continuous interpretation of cardiac rhythms and myocardial ischemia. What is most needed in the clinical monitoring environment is a continuous 12-lead ECG monitoring system to replace the traditional 3- to 5-lead telemetry monitoring system now used in most hospitals for continuous ECG monitoring.

In this article, we describe the clinical outcomes that occurred after

CE Continuing Education

* This article has been designated for CE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. Identify the differences between standard and continuous 12-lead systems
2. Identify 3 clinical conditions that are appropriate for continuous 12-lead monitoring
3. Describe the benefits of examining 12-lead electrocardiograms in the clinical setting

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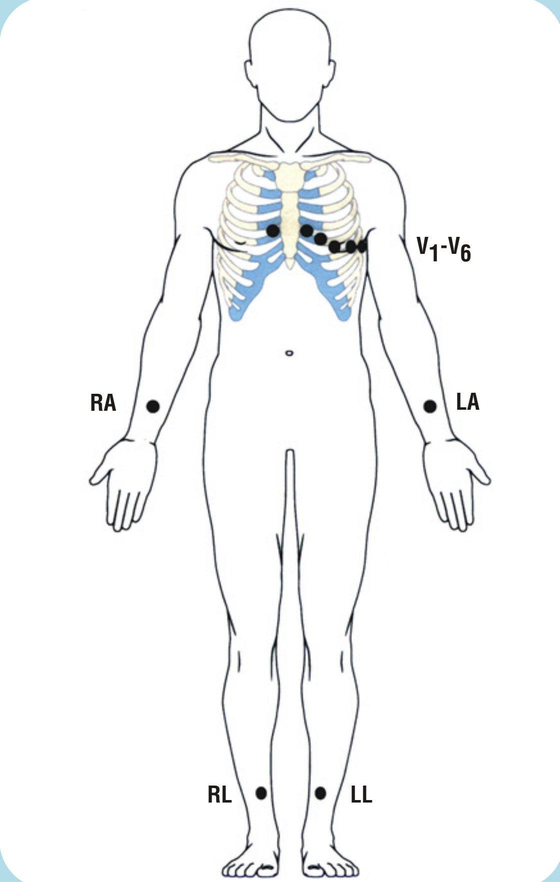

Figure 1 Placement of leads for standard 12-lead electrocardiography.

Abbreviations: LA, left arm; LL, left leg; RA, right arm; RL, right leg.

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ECG configuration and the standard 12-lead ECG configuration is that all 12 views of the heart are available on a continuous basis with the derived configuration, rather than the periodic basis available with the traditional 12-lead ECG system.

On the basis of the clinical need for continuous 12-lead ECG monitoring and the impracticality of using a traditional 12-lead configuration for continuous monitoring, Dower and colleagues[7,8] developed in 1980 a 12-lead ECG based on the vector ECG principles described by Frank.[9] Instead of the traditional 10 electrodes, ECG signals are derived from 4 chest electrodes and 1 reference electrode (Figure 3). The electrodes are placed on the upper part of the sternum (S), the lower part of the sternum (E) at the level of the fifth intercostal space, and on the right and left midaxillary lines (I and A) at the same level as the electrode on the lower part of the sternum. A fifth ground electrode can be placed anywhere. This 5-lead configuration gives us a 3-dimensional portrayal of the electrical activity through the heart's conduction system, rather than independent channels of unipolar and bipolar energy. The result is 12 leads of information based on acquisition of simulatneous events in the frontal, horizontal, and sagittal cardiac planes. A mathematical calculation using standardized and fixed coefficients for each lead results in a linear transformation of the vectors, creating a derived 12-lead ECG.

implementation of a new 12-lead derived ECG system designed for continuous, bedside monitoring as a replacement for a traditional 3- to 5-lead system.

Derived 12-Lead ECG for Continuous Monitoring

Any time that the limb leads are moved away from the extremities and placed on a patient's torso and the precordial leads are modified down to a single lead that is calculated for the unipolar precordial V lead on the horizontal plane, the result is termed a *derived ECG*.[7] The main difference between a derived

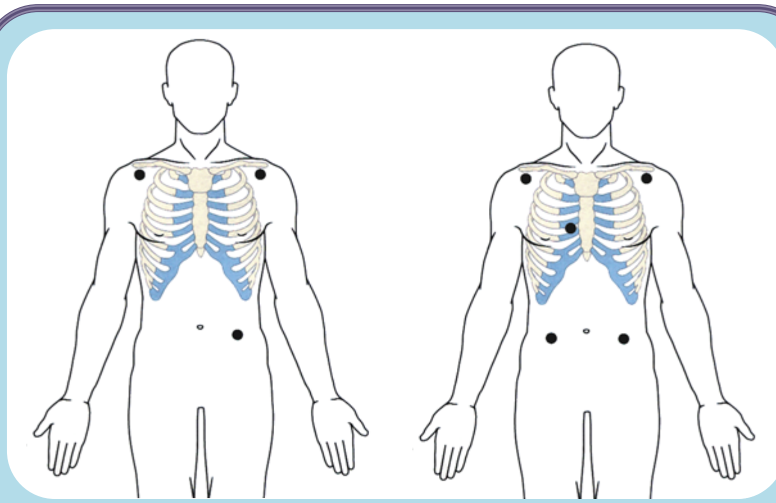

Figure 2 Typical placement of leads for 3-lead (left) or 5-lead (right) telemetry with the Mason-Likar format.

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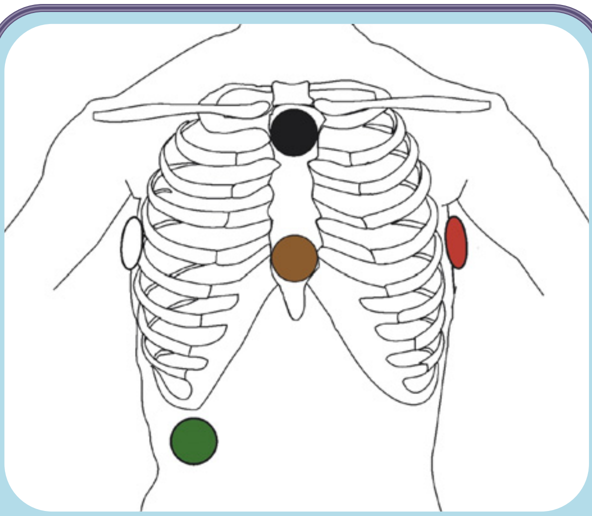

Figure 3 Placement of leads for derived 12-lead electrocardiography. EASI lead placement: E, electrode placed on the lower part of the sternum, level with the fifth intercostal space; A, electrode placed at the level of the fifth intercostal space, on the left midaxillary line; S, electrode placed on the upper part of the sternum; I, electrode placed at the fifth intercostal space, on the right midaxillary line. The fifth ground electrode can be placed anywhere.

Importance of Continuous Monitoring of Multiple ECG Leads

One of the strongest arguments for continuous monitoring of all 12 leads of the ECG is the situation in patients with suspected or confirmed myocardial damage. ECG monitoring is more sensitive than a patient's self-reporting of symptoms (eg, chest pain, chest discomfort) for detecting transient myocardial ischemia because 70% to 90% of the episodes of myocardial ischemia detected with ECG are clinically silent.[2-5] A consensus group of experts in ST-segment monitoring[6] have suggested a variety of clinical conditions and diagnoses other than myocardial ischemia that are appropriate for continuous 12-lead ECG monitoring (Table 1).

Implementation of a New 12-Lead Continuous Monitoring System

In March 2002, we implemented a research study for a newly installed telemetry system at North Shore University Hospital, one of the leading medical centers on Long Island in New York. The study was implemented in 3 separate intensive care telemetry step-down units, a total of 128 telemetry beds. Before the new system was installed, ECG monitoring were accomplished by using a traditional 3-lead ECG system, with periodic standard 12-lead ECGs obtained as needed to detect various dysrhythmias or myocardial damage. Nonlicensed personnel (monitoring technicians) specially trained for ECG monitoring do the continuous observation of ECG rhythms in the unit.

The new telemetry system installed at North Shore University Hospital is currently being marketed as the EASI 12-lead system (Philips Medical Systems, Andover, Mass). The EASI 12-lead monitoring system is integrated into patients' monitors, allowing display of up to 3 of the 12 continuously monitored derived leads. The EASI is the only system in the marketplace that does continuous 12-lead monitoring with only 5 electrodes. By using the stored data (referred to as the full-disclosure feature), data from all 12 leads of the ECG can be displayed and printed in either real time or retrospectively for any period in the preceding 24 to 96 hours. Automatic documentation of derived 12-lead ECGs can also be triggered by heart-rate alarms or ST-segment changes.[7,8]

All nursing and monitoring technical staff received extensive education and training on the new monitoring system before use of the system was implemented. The educational program consisted of information about the benefits of examining 12 leads of the ECG to improve diagnostic interpretation, how a 12-lead ECG is derived from the 5 leads of the 12-lead continuous monitoring system, and how and where to apply the 5 leads to the chest. Staff had ample time for

Table 1 Recommendations for clinical conditions for which continuous 12-lead electrocardiographic monitoring may be beneficial[6]

Clinical conditions	Recommended duration of monitoring
Unstable angina and ST-segment elevation	Minimum of 24-48 hours or until event-free for 12-24 hours
Acute myocardial infarction without ST elevation	Minimum of 24-48 hours or until event-free for 12-24 hours
Chest pain that prompts a visit to the emergency department	8-12 hours with determination of serum biochemical markers of injury
Catheter-based interventions	During procedure and for 6-12 hours after procedure in patients with unstable conditions
Cardiac surgery	24-48 hours postoperatively
Noncardiac surgery for patients at risk for myocardial ischemia	During and immediately after surgery

Table 2 Evaluation questionnaire completed by personnel monitoring electrocardiograms (ECGs) after implementation of a new continuous 12-lead ECG system

Questions	Ratings
1. How many times during the course of your shift did you go into full disclosure*?	❑ None ❑ 1-2 times ❑ 3-4 times ❑ 5-6 times ❑ 7-8 times ❑ 9-10 times ❑ >10 times
2. How many times during the course of your shift have you accessed EASI 12-lead?	❑ None ❑ 1-2 times ❑ 3-4 times ❑ 5-6 times ❑ 7-8 times ❑ 9-10 times ❑ >10 times
3. Did the physician request the EASI 12-lead?	❑ No ❑ Yes
4. Was there any change in the interpretation of a rhythm because of the retrospective ECG information found in full disclosure*?	❑ No ❑ Yes (if yes, describe):
5. Has the patient's treatment changed in any way because of the information found in full disclosure?	❑ No ❑ Yes (if yes, describe):

*Full disclosure is a decision support tool that provides clinicians with current and retrospective analysis of a patient's condition and past events. At the information center, beat-to-beat analysis, waveforms, trends, and alarms can be retrieved and reviewed wherever they are needed. It creates a continuous record of the patient's electrocardiographic data that can be accessed no matter where the patient is transferred.

Table 3 Primary reasons for continuous electrocardiographic monitoring for 64 patients included in the evaluation

Reason for monitoring	% of patients*
Bradycardia	2
Hyperkalemia	2
Sinus arrhythmia	2
Supraventricular tachycardia	4
Congestive heart failure	5
Myocardial infarction	7
Ventricular tachycardia	7
Atrial fibrillation	16
Rule out myocardial infarction	21
Chest pain	30
Missing information	11

*Percentages do not total 100 because some patients had more than 1 reason for monitoring.

hands-on experience with the new system, and each staff member completed a competency checklist before the new system was implemented.

Four months after implementation of the new monitoring system, data were collected for 4 months to evaluate the system's performance. Members of the clinical staff were asked to complete a voluntary questionnaire whenever they were assigned to monitor ECG rhythms for the unit (Table 2).

Clinical Performance Outcomes

During the 4 months of data collection (May through August 2002) to evaluate the new 12-lead system, a total of 64 surveys were completed by staff members. Survey responses were based on patients who were being monitored for a variety of reasons; the most common problems were actual or potential myocardial damage (myocardial infarction, chest pain, rule out myocardial infarction, 58%), atrial fibrillation (16%), and ventricular tachycardia (7%; Table 3).

In response to the questions about the use of the new 12-lead system, most surveys indicated use of the full-disclosure function of the system more than 10 times per shift, similar to the frequency of accessing the EASI 12-lead ECG (Table 4). Most of the time (75%), the decision to use the 12-lead components of the system was independently made by the monitoring technician, as opposed to deciding to use it because a physician requested it.

Table 4 Summary of results from the questionnaires completed by monitor technicians on 64 patients

Question	Rating	% of responses*
1. How many times during the course of your shift did you go into full disclosure?	None	0
	1-2 times	3
	3-4 times	3
	5-6 times	3
	7-8 times	9
	9-10 times	0
	>10 times	81
2. How many times during the course of your shift have you accessed EASI 12-lead?	None	0
	1-2 times	5
	3-4 times	8
	5-6 times	8
	7-8 times	5
	9-10 times	0
	>10 times	75
3. Did the physician request the EASI 12-lead?	No	75
	Yes	25
4. Was there any change in the interpretation of a rhythm because of the retrospective ECG information found in full disclosure?	No	31
	Yes	69
5. Has the patient's treatment changed in any way because of the information found in full disclosure?	No	50
	Yes	50

*Because of rounding, percentages may not all total 100.

Of the surveys completed, 69% of the staff said that they changed their interpretation of ECG rhythms because of information obtained after examining the 12-lead stored information in the system (Table 4, Figures 4-7). Survey results indicated that these changes in ECG interpretation led to a different therapeutic regimen 50% of the time.

Staff described 49 anecdotes of differences in rhythms observed on the continuous 2-lead display and when the full-disclosure 12-lead system was accessed (Table 5). Of the 49 anecdotes, 15 described situations involving ventricular tachycardias or wide complex tachycardias for which interpretations of rhythms were changed after review of the full-disclosure function of the 12-lead EASI.

Figure 4 Change in interpretation of cardiac rhythm and patient's treatment after stored 12-lead information is examined. A, monitor layout; B, traditional layout. Patient is monitored in leads I and V_1 (A). Monitor technician, nurse, and physician all agree that rhythm is "V-Tach" (A, B). By using full-disclosure tools, EASI 12-lead electrocardiogram is pulled up to the screen (A). The rhythm shows torsades de pointes. Leads 1 and V_1 are the only leads in which torsades de pointes is not evident on the electrocardiogram (A). The patient's treatment was changed.

Implications of Clinical Performance Outcomes

Monitoring of Cardiac Rhythm

In previous surveys[10] of critical care clinicians, researchers found that the most common ECG lead used for continuous ECG monitoring in a single-channel monitor was lead II (74%); the second most commonly used was lead MCL_1 (18%). Half of the survey respondents used a single-channel monitor, 48% used a dual-channel monitor, and the remaining 2% used systems that allowed 3 or 4 leads to be displayed simultaneously. The clinical reality that most clinicians use lead II for continuous monitoring is in stark contrast to a growing body of ECG monitoring research[10-24] that monitoring and diagnostic capability are better when multiple leads and ST-segment monitoring are used.

As indicated in several studies by Drew and colleagues,[11-13] ventricular tachycardia and supraventricular tachycardia with aberrant conduction clearly cannot be correctly differentiated with lead II. Only a third of these tachycardias were correctly identified when lead II of the ECG was examined; the best leads for correct diagnosis were leads V_1 and MCL_1. The visibility of the P wave and the diagnostic morphology of the QRS complex are both better in lead V_1 or lead MCL_1 than in lead II; thus leads V_1 and MCL_1 are better than lead II for differentiating supraventricular tachycardia with aberrant conduction from ventricular tachycardia. Because treatment of supraventricular tachycardia with aberrancy differs dramatically from treatment of ventricular tachycardia, misdiagnosis of these

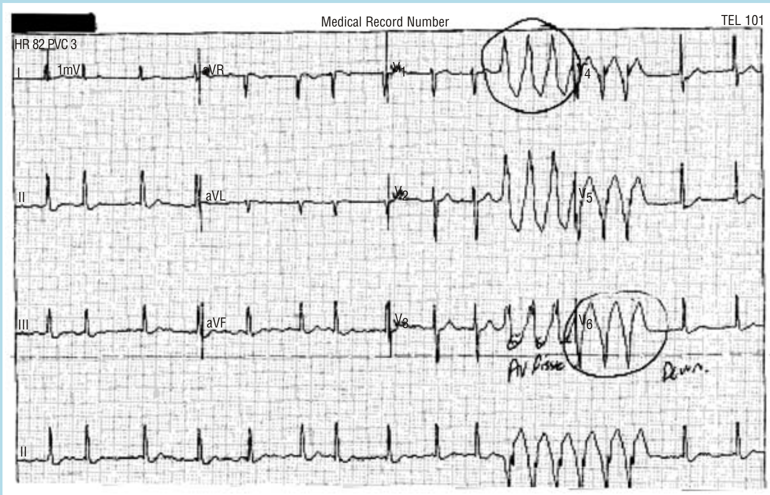

Figure 5 Change in interpretation of cardiac rhythm with no change in patient's treatment after stored 12-lead information is examined. Patient monitored in leads II and V_1. V_1 shows apparent 6-beat run of ventricular tachycardia. EASI 12-lead electrocardiogram is put on the screen. V_6 shows downward beats of atrioventricular dissociation. EASI 12-lead electrocardiogram provided critical information that would have otherwise been missed with the 2-lead monitoring system. Interpretation of the rhythm was changed, but the treatment remained the same.

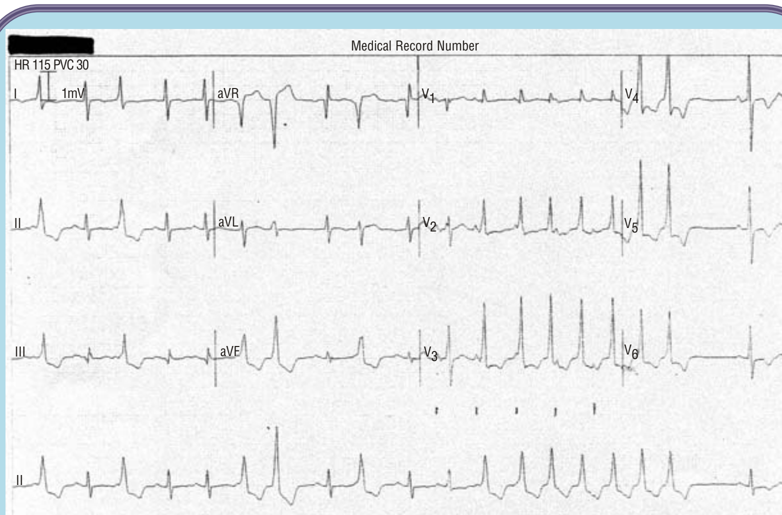

Figure 6 Change in evaluation of pacemaker function. Patient was monitored in leads II and V_1, with no evidence of pacemaker malfunction. EASI full-disclosure format was pulled up on the screen. The 12-lead electrocardiogram shows that the pacemaker was undersensing. The patient was sent to the electrophysiology laboratory for reprogramming of the pacemaker.

cardiac rhythms could result in deleterious clinical outcomes.[14,15] Correct identification of rhythm is critical and requires use of leads other than lead II.

Other arrhythmias that may not be easily identified in lead II, compared with other leads, include atrial flutter, bundle branch blocks, and heart blocks.[1,16] In addition, many abnormal cardiac rhythms are identified correctly more often when more than a single lead is used for evaluation.[1,11-13]

Our experience with the implementation of a continuous, derived 12-lead ECG monitoring system emphasizes the results of prior research on the best leads for monitoring. The ability to check multiple leads when evaluating a dysrhythmia resulted in numerous anecdotal notations of changes in diagnoses from initial interpretations, and many of those changes resulted in different therapies. Many of these changes in interpretation were related to differentiation of ventricular tachycardia from supraventricular tachycardia with aberrant conduction.

Monitoring of Myocardial Ischemia

The strongest case for the use of continuous 12-lead ECG monitoring comes from clinical studies of patients at risk for myocardial ischemia.[17-25] The value of continuous monitoring of ST segments in multiple leads of the ECG has been shown in a variety of patients. Continuous 12-lead ST-segment monitoring was highly sensitive and specific for identifying reperfusion and vessel patency after reperfusion therapy in patients with acute coronary syndromes[17-20] and in patients being treated with anti-ischemic drugs.[22]

Continuous ST-segment monitoring is particularly beneficial in predicting vessel patency in patients with extensive initial elevation of the ST segment, patients who are at highest risk for adverse cardiac events. Studies of patients with acute coronary syndrome and no persistent elevation of the ST segment have shown that ST-segment monitoring in all 12 leads significantly increases the detection of ischemic episodes compared with ST-segment monitoring in 3 leads.[21,23] Patients in the emergency department

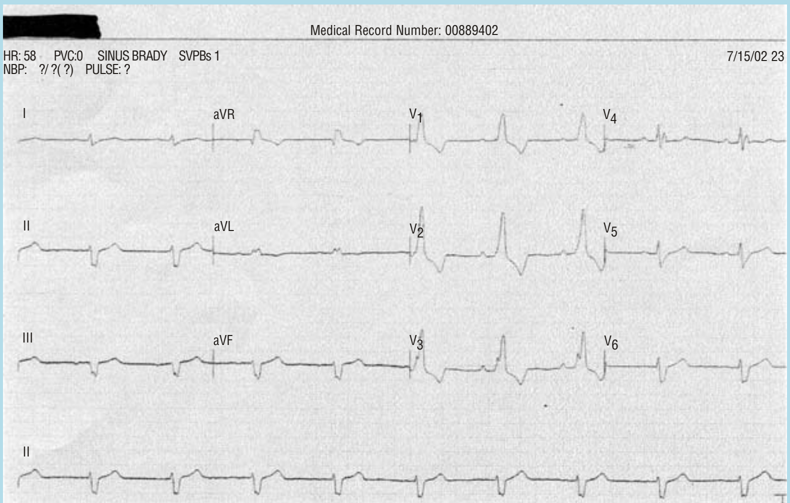

Figure 7 Early warning of myocardial infarction. Patient complains of chest pain. Monitor technician pulls up EASI 12-lead electrocardiogram (ECG) immediately, which shows an evolving myocardial infarction. Minutes pass before staff can get an order for and obtain a standard 12-lead ECG. Physician compares findings of the 2 methods and finds identical ECG patterns of an evolving myocardial infarction. Patient receives treatment for acute myocardial infarction.

Table 5 Categorization of 49 anecdotal notations made by monitoring technicians on the questionnaires

Categories of anecdotal notes	No. of notes
Ventricular tachycardia missed on the 2-lead continuous monitoring system	2
Ventricular tachycardia misinterpreted on the 2-lead continuous monitoring system	5
Ventricular tachycardia confirmed with EASI 12-lead system when conflicting interpretations obtained in each lead of the continuous monitoring system	1
Wide complex tachycardia of undetermined etiology with the 2-lead continuous monitoring system but interpretation confirmed on EASI 12-lead electrocardiogram (ECG)	9
Nonventricular tachycardia or wide-complex tachycardia rhythm interpretation changed after review of EASI 12-lead ECG	15
Capture of short-duration dysrhythmias with EASI 12-lead when unable to obtain with standard 12-lead ECG	3
Findings with standard 12-lead ECG equivalent to findings with EASI 12-lead ECG	8
Miscellaneous comments	6

with suspected acute coronary syndrome who have transient ischemic episodes also benefit from continuous 12-lead ECG monitoring.[24,25]

Recent studies[5,26,27] of patients at high risk for myocardial ischemia after elective surgery indicated a 6% to 11% incidence of myocardial ischemia after vascular surgery. Of interest in these studies is the inability to detect these episodes of ischemia with traditional single- or dual-lead monitoring. Even 2-lead ST-segment monitoring had a low sensitivity (<5%) for detecting myocardial ischemia postoperatively, because the leads selected for standard monitoring (II and V_5) rarely were involved in the ischemia patterns (V_2 to V_4).[5]

An interesting finding of ST-segment research is that monitoring the ECG leads that have the greatest ST-segment deviation during acute myocardial infarction or balloon inflation during cardiac catheterization, also called the “fingerprint” leads, is not sufficient to detect future episodes of ischemia.[10,21,22] On the basis of those studies, it is recommended that monitoring of patients with the potential for ischemia include all 12 leads rather than just the fingerprint leads.[6]

Conventional 12-Lead ECG Versus Derived 12-Lead Monitoring Systems

One aspect of the new monitoring system that initially concerned clinicians was how well the EASI derived 12-lead monitoring system approximated the standard 12-lead ECG. Although research has shown that use of the EASI 12-lead system for continuous monitoring results in the clinical detection of more ischemic episodes and the capture of more arrhythmias (because data are collected continuously rather than as a snapshot in time),[12,28-36] the conventional 12-lead ECG remains the reference standard as a “diagnostic” tool.

Having a continuous ECG system with all 12 leads stored in the computer memory was also better than standard 12-lead ECGs for verifying changes in cardiac rhythm or myocardial oxygenation. Cardiac rhythms or ischemic episodes that were of short duration could always be recalled by using the full-disclosure system of the EASI system. Such recall not only allowed accurate documentation of the changes in rhythm or myocardial oxygenation but also allowed the staff to treat the rhythm or perfusion problem more quickly because the clinical information was readily available.

Summary

Although the conventional 12-lead ECG is routinely used for diagnostic purposes, it is not practical for continuous monitoring. However, the standard telemetry placement produces only some of the ECG information that is needed, highlighting only 1 or 2 views of the heart. Technological advancements now enable us to obtain all 12 views of the heart on a continuous basis by using just 5 electrodes. By shifting the axis in which the 5-lead ECG is obtained, we can have important 12-lead information at our fingertips on a continuous basis. The clinical advantages of knowing that valuable 12-lead information can be obtained at any given time or at a designated time during any shift is important for correct diagnosis and treatment of ECG abnormalities.

In this study, the ability to generate both real-time and retrospective 12-lead ECGs resulted in important differences in clinical management. These results suggest that use of continuous 12-lead monitoring of the ST segment in all patients in the cardiac step-down area would have a clinical benefit.

Acknowledgments
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CE Test Test ID C0552: Clinical Usefulness of the EASI 12-Lead Continuous ECG Monitoring System

Learning objectives: 1. Identify the differences between standard and continuous 12-lead systems 2. Identify 3 clinical conditions that are appropriate for continuous 12-lead monitoring 3. Describe the benefits of examining 12-lead electrocardiograms in the clinical setting

1. Which of the following best describes the standard 12-lead electrocardiogram (ECG) system?
a. A system that requires 12 electrodes placed in various locations of the chest and extremities
b. A system that requires 10 electrodes that are strategically placed on the chest and extremities
c. A system that requires only 8 electrodes with 2 grounding electrodes placed on the chest and extremities
d. A system that requires 10 electrodes that are strategically placed on the extremities alone for a true 12-lead tracing

2. Which of the following best describes the 5-lead telemetry monitoring setup?
a. Four leads are attached to the patient's torso, and the last lead acts as the precordial V lead.
b. Three leads are attached to the patient's torso, and the last 2 leads are the V and MCL_2 leads.
c. All 5 leads are attached to the patient's torso, and the telemetry box is programmed for which axis is wanted to be viewed.
d. Leads I, II, and III are attached to the patient's torso and the last 2 leads are attached to the upper extremities.

3. Which of the following best identifies recent research and national guidelines on monitoring for myocardial ischemia?
a. Use the diagnostic 12-lead ECG monitoring devices to help detect ischemia in patients with chest pain.
b. Focus on the emergency department as the primary area to help identify and interpret cardiac dysrhythmias.
c. Use standard 12-lead ECG monitoring in all busy critical care areas for the indemnification and interpretation of cardiac rhythms.
d. Use continuous 12-lead ST-segment monitoring for at-risk patients, because silent ischemia is common and may not always be detected in the same leads.

4. Which of the following best describes the difference between standard and derived ECG monitoring?
a. Only 8 views are available with standard ECG monitoring, and 10 continuous views are available with derived ECG monitoring.
b. Only 10 views are available continuously with standard ECG monitoring, and all 12 views are available with derived ECG monitoring.
c. All 12 views are available periodically with standard ECG monitoring, and all 12 views are available continuously with derived ECG monitoring.
d. All 12 views of the heart are available continuously with standard ECG monitoring, and only 10 views are available with derived ECG monitoring.

5. What is the percentage of clinically silent myocardial ischemia detected with ECG monitoring?
a. 70% to 90%
b. 60% to 95%
c. 50% to 80%
d. 50% to 70%

6. The EASI 12-lead system can display how many continuous derived leads?
a. 12 of 12 leads
b. 6 of 12 leads
c. 3 of 12 leads
d. 5 of 12 leads

7. According to the studies by Drew and colleagues, how many tachycardias were correctly identified using lead II?
a. One half
b. One third
c. Three quarters
d. Two thirds

8. Which are the 2 best leads for differentiating supraventricular tachycardia with aberrant conduction from ventricular tachycardia?
a. V_1 and MCL_2
b. V_1 and MCL_1
c. V_2 and MCL_6
d. V_3 and V_4

9. Which 2 arrhythmias may not be easily identified in lead II?
a. Atrial fibrillation and fascicular blocks
b. Atrial tachycardia and atrial flutter
c. Junctional tachycardia and heart blocks
d. Bundle branch blocks and heart blocks

10. Which of the following best describes the benefit of continuous ST-segment monitoring?
a. Predicting where ischemic changes will occur in the heart with elevation of the T wave
b. Identifying vessel occlusion in acute myocardial infarction
c. Predicting vessel patency in patients with extensive initial elevation of the ST segment
d. Predicting mortality of patients with significant ST-segment and T-wave abnormalities

11. What is the incidence of myocardial infarction after vascular surgery?
a. 6% to 11%
b. 10% 20%
c. 5% to 12%
d. 6% to 15%

12. Which of the following recommendations may be beneficial for continuous 12-lead ECG monitoring?
a. Unstable angina and no ST-segment elevation
b. Acute myocardial infarction without ST-segment elevation and cardiac surgery
c. Acute myocardial infarction with ST-segment elevation and noncardiac surgery
d. Chest pain that prompts a visit to an urgent care center and cardiac catheterization

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

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